AME 404 – Computational Solutions to Engineering Problems, Fall 2021

Lecture: MW 9:30–10:50 am (class # 28755D) OHE100C
MW 2:00–3:50 pm (class #28754R) SAL101
MW 9:30–10:50 am (class # 29005D) DEN
Instructor: Takahiro Sakai, Ph.D.
Email: tsakai@usc.edu, **Office:** OHE430H
Office Hours: Mondays 12:50pm–1:50pm, 4–5pm (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 :
TBA (TBA@usc.edu): (start from the 2nd week)
TBA (TBA@usc.edu): (start from the 2nd week)

Learning Management System: This course is managed by Brightspace (D2L). Google "usc den" and click the first hit or go to https://courses.uscden.net/d2l/login and login using your USC NetID.

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 Weights: 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. MATLAB is freely available from USC ITS at https://itservices.usc.edu/software/.

Slack: Slack (usc.slack.com) will be used as our online discussion/messaging platform (see https://keepteaching.usc.edu/students/student-toolkit/classroom/slack/ for quick start). Please use our common channel **fall21-ame-404-common** so that your message is shared over entire AME404 sections. Please refrain from posting your code and answer to avoid their improper use by others.

General Assignment Policy (read carefully):

- Students are required to write computer programs independently. Your work will be carefully examined 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. The best protection of your integrity is NEVER SHARE your work with anybody.

- 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. 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, full credit is not guaranteed even you obtained correct results.
- **All assignments must be submitted electronically to Gradescope.** Submitted document must be **a single PDF file**. Please DO NOT directly email your work to us. No exception. All informal submissions will be ignored.
- Due date will NOT be extended for any circumstance (see the late submission policy below). Any post-due supplemental submission will NOT be accepted strictly. You are responsible to make sure your online submission is successful.
- Regrading request will be accepted for one week (except the final project) counting from the day the homework is returned, and the grade will NOT be changed thereafter (even the answer is correct) and NO appeal or excuse will be accepted.
- Please do not email 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, 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.

Project Assignment Policy:

- Project is considered as a "take-home exam". Group work is NOT allowed. 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. Solution manual will be provided for midterm projects but NOT for the final project.

Late Submission Policy:

- **General:** Late submission may be considered only when you are diagnosed positive at COVID-19 test and the symptom has not yet alleviated. Otherwise the following policies may apply.
- **Homework:** In any circumstance 50% of total score (2.5pt) will be deducted for penalty, if submitted within 24 hours past due. No acceptance after the 24-hour. It is advised that you rather focus on a new assignment than consuming time for the past assignment unless it will be completed within an additional 24-hour.
- **Project:** Late submission is not accepted, even a second. If you anticipate you may not be able to complete the project in some circumstances, it is advised to submit anything you have done to date for partial credit. Extension will be never granted. It is your responsibility to plan ahead of time, start working on the assignment early enough and avoid submitting in last minutes (lest some internet issue might hamper the submission).

Homework Grade Scale: Homework grade is scaled into quintile based on the level of correctness. **5:** All answers are correct and supported well; **4:** 1 incorrect answer; **3:** 2 incorrect answers; **2:** 3 incorrect answers; **1:** submit something. This measure may vary depending on the size of problem set. Incorrect answer includes incomplete answer. Submission without computer program will be subject to deduction of one point.

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 will be truncated (e.g., 89.99 → 89 → B+). A (93-100); A− (90-92); B+ (88-89); B (83-87); B− (80-82); C+ (78-79); C− (70-72); D+ (68-69); D (63-67); D− (60-62); F (59 and below)

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.

Tentative Schedule and Assignments

Week	Day	Topics	Assignment	Due date
1	8/23	Intro to the 1st order models, Numerical solution of the 1st order ODE, Euler's method		
	8/25	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 9/03
2	8/30	Numerical simulation of the 2nd-order model (spring-mass-damper system)		
	9/01	Simple pendulum model; Matlab programming using output data	Hw 2	Fri 9/10
3	9/06	**Labor Day (Holiday)**		
	9/08	Numerical simulation of high order model - Heat exchanger system		
4	9/13	Simulation of Airplane longitudinal dynamics; system matrix, eigenvalue/vectors, stability	Hw 3	Fri 9/24
	9/15	Fourier series - Review: periodic functions, Fourier modes, convergence, Gibbs phenomenon		
5	9/20	Fourier spectral analysis - complex Fourier series, Discrete Fourier Transform (DFT), Inverse DFT, Nyquist frequency, Frequency Power spectrum	Project 1	**Wed 10/13**
	9/22	Fast Fourier Transform (FFT), numerical treatment of non-uniformly sampled signals & non-periodic signals, aliasing error	Hw 4	Fri 10/01
6	9/27	2pt Boundary Value Problem (BVP) - the shooting method, numerical solution to the laminar boundary layer (Blasius) equation		
	9/29	Modal solutions of 2pt BVP - Torsional vibration of a shaft: modal shapes, modal frequencies	Hw 5	Fri 10/08
7	10/04	Torsional vibration of a shaft (cont.) - Implementation of shooting method; Project 1 - review		
	10/06	Intro to PDE: classification, derivation of the heat conduction equation, boundary conditions		
8	10/11	1D steady heat equation: Dirichlet problem - Finite differences, tridiagonal system		
	10/13	1D steady heat equation: Neumann problem, consistency, numerical accuracy, convergence	Hw 6	Fri 10/22
9	10/18	Steady heat conduction in a circular rod submerged in water, numerical treatment of the pole	Project 2	**Fri 11/12**
	10/20	Steady heat conduction in a gas turbine blade, variable shape, convection boundary condition	Hw 7	Fri 10/29
10	10/25	Revisit modal solutions of 2pt BVP - direct solution by the finite difference method		
	10/27	2D steady heat conduction: Fourier series representation of solution, scalar/vector field plotting	Hw 8	Fri 11/05
11	11/01	Project 2 - review		
	11/03	2D steady heat conduction: numerical implementation of direct method		
12	11/08	2D steady heat conduction: iterative solution approach - Jacobi, Gauss-Seidel, SOR methods	Hw 9	Fri 11/19
	11/10	1D unsteady heat conduction: Fourier series representation of solutions, making computer animation of time-dependent solutions by using Matlab		
13	11/15	1D unsteady heat conduction: Explicit scheme (FTCS scheme), Numerical stability	Hw 10	Fri 12/03
	11/17	1D unsteady heat conduction: Implicit scheme (Fully-Implicit method), Neumann BC		
14	11/22	No class	Project 3	**Mon 12/13**
	11/24	**Thanks giving holiday (no class)**		
15	11/29	1D transport equation (linear advection-diffusion), upwind scheme, MacCormak's scheme		
	12/01	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.