AME 404 – Computational Solutions to Engineering Problems, Fall 2022

Lecture: MW 9:30−10:50 am (class # 28755) OHE100C
MW 2:00−3:50 pm (class #28754) THH301
MW 9:30−10:50 am (class # 29005) DEN
Instructor: Takahiro Sakai PhD
Email: tsakai@usc.edu, **Office:** OHE430H
Office Hours: Mondays 12:40pm−1:40pm, 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 :
Yeo Jung Yoon (yeojungy@usc.edu): Office hour: TBA (start from the 2nd week)
Fares Maimani (maimani@usc.edu): Office hour: TBA (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 analysis of dynamical responses
   - Fourier series, Fourier spectral analysis, FFT, Frequency Power Spectrum, Nyquist frequency
   - Simulation of nonlinear, complex systems (Project)
2. Numerical Solutions to Two-point Boundary Value Problems (BVP)
   - Iterative method (ODE shooting method)
   - Direct method (Finite difference linear system)
   - Modal analysis (Eigenvalues and Eigenfunctions)
   - High order, complex 2pt BVP (Project)
3. Numerical Solutions to Partial Differential Equations (PDEs)
   - Finite differences, accuracy, convergence, consistency, and stability
   - Solution methods of linear system equations (direct vs. iterative methods)
   - 1D steady and unsteady heat conduction problems
   - Explicit scheme vs. Implicit scheme
   - Implementation of Dirichlet, Neumann and Convection boundary conditions
   - 2D steady state heat conduction problems (Direct vs. Iterative Jacobi, Gauss-Seidel and SOR)
   - Transport equations (advection and diffusion problems, predictor-corrector scheme)
   - Introductory computational fluid dynamics problems (Project)

Grading Weights: Homework 25% (drop one lowest score) and three projects, 25% each (no drop).

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/.

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. Any academic misconduct 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. All informal submissions will be ignored.
- Due date is fixed and will NOT be extended. Any post-due supplemental submission will NOT be accepted strictly. It is your responsibly 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. For the final project, the regrading request function in Gradescope will be turned off, because it is due during the final exam week and the grading will be double checked and we ensure consistency under established evaluation standard applied to everyone uniformly. Hence, there will be no regrading opportunity, no question on grading details, for you to gain any cent or nickel. Only the total score will be posted to D2L. If the student still wishes to see how the final project was graded, the student can visit the instructor's office in person during the following semester.
- 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 will not 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. The final project grade, after double-checked by the instructor team for consistent grading, will be never published.

Late Submission Policy:

- **Homework:** 50% of total score (2.5pt) will be deducted for penalty, if submitted within 24 hours past due. No acceptance after the 24-hour.
- **Project:** Late submission is never accepted, even a second. This is because the projects have a long lead time. If you anticipate you may not be able to complete the project, it is strongly encouraged to submit anything you have done to date for partial credit. It is your responsibility to plan ahead of time, start working on the assignment early enough.

Late submission may be considered only when you encounter family emergency and documented medical emergency which significantly affect your ability to perform the assignment tasks by the due. This applies to all assignments except the final project whose due date will be never extended in any circumstances. The lowest homework score will be dropped, which is provided for any type of unexpected happening that hampers your submission in time. Therefore when you ask us for extension of homework due for the first time, we will advise that you take advantage of this one-drop policy. Internet connection issue, which is difficult to prove, will not be granted as a valid excuse, and, therefore, it is advised that you turn in well before the due (even the work might be incomplete) to avoid the entire credit loss for unexpected internet failure in last minute.

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 and how the grader distributes points. Incorrect answer includes incomplete answer. Submission without computer program will be subject to deduction of one point.

Course Letter Grade Policy: The course final grade is determined automatically based on the U.S. college standard scaling 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 (73-77); C− (70-72); D+ (68-69); D (63-67); D− (60-62); F (59 and below) This scaling will be unchanged unless the class average falls below 80%,, in which case, the scaling will be curved so that the average is set to the lower cutoff of B-. Any plea and solicitation to give away a better grade for student's sake of maintaining or obtaining graduation status, scholarship, good GPA, award, prize, etc., will be adamantly resisted under the spirit of USC Integrity and Accountability Code. This rejection includes reevaluation and appeal of any past assignment.

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	8/22	Intro to the 1st order models, Numerical solution of the 1st order ODE, Euler's method		
	8/24	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 9/02
2	8/29	Numerical simulation of the 2nd-order model (spring-mass-damper system)		
	8/31	Simple pendulum model; Matlab programming using output data	Hw 2	Fri 9/09
3	9/05	**Labor Day (Holiday)**		
	9/07	Numerical simulation of high order model - Heat exchanger system		
4	9/12	Simulation of Airplane longitudinal dynamics; system matrix, eigenvalue/vectors, stability	Hw 3	Fri 9/23
	9/14	Fourier series - Review: periodic functions, Fourier modes, convergence, Gibbs phenomenon		
5	9/19	Fourier spectral analysis - complex Fourier series, Discrete Fourier Transform (DFT), Inverse DFT, Nyquist frequency, Frequency Power spectrum	Project 1	**Wed 10/12**
	9/21	Fast Fourier Transform (FFT), numerical treatment of non-uniformly sampled signals & non-periodic signals, aliasing error	Hw 4	Fri 9/30
6	9/26	2pt Boundary Value Problem (BVP) - the shooting method, numerical solution to the laminar boundary layer (Blasius) equation		
	9/28	Modal solutions of 2pt BVP - Torsional vibration of a shaft: modal shapes, modal frequencies	Hw 5	Fri 10/07
7	10/03	Torsional vibration of a shaft (cont.) - Implementation of shooting method; Project 1 - review		
	10/05	Intro to PDE: classification, derivation of the heat conduction equation, boundary conditions		
8	10/10	1D steady heat equation: Dirichlet problem - Finite differences, tridiagonal system		
	10/12	1D steady heat equation: Neumann problem, consistency, numerical accuracy, convergence	Hw 6	Fri 10/21
9	10/17	Steady heat conduction in a circular rod submerged in water, numerical treatment of the pole	Project 2	**Thu 11/10**
	10/19	Steady heat conduction in a gas turbine blade, variable shape, convection boundary condition	Hw 7	Fri 10/28
10	10/24	Revisit modal solutions of 2pt BVP - direct solution by the finite difference method		
	10/26	2D steady heat conduction: Fourier series representation of solution, scalar/vector field plotting	Hw 8	Fri 11/04
11	10/31	Project 2 - review		
	11/02	2D steady heat conduction: numerical implementation of direct method		
12	11/07	2D steady heat conduction: iterative solution approach - Jacobi, Gauss-Seidel, SOR methods	Hw 9	Fri 11/18
	11/09	1D unsteady heat conduction: Fourier series representation of solutions, making computer animation of time-dependent solutions by using Matlab		
13	11/14	1D unsteady heat conduction: Explicit scheme (FTCS scheme), Numerical stability	Hw 10	Fri 12/02
	11/16	1D unsteady heat conduction: Implicit scheme (Fully-Implicit method), Neumann BC		
14	11/21	No class	Project 3	**Mon 12/12**
	11/23	**Thanks giving holiday (no class)**		
15	11/28	1D transport equation (linear advection-diffusion), upwind scheme, MacCormak's scheme		
	11/30	Project 3 - review		

Support Systems:

Counseling and Mental Health - (213) 740-9355 – 24/7 on call
studenthealth.usc.edu/counseling
Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

National Suicide Prevention Lifeline - 1 (800) 273-8255 – 24/7 on call
suicidepreventionlifeline.org
Free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week.

Relationship and Sexual Violence Prevention Services (RSVP) - (213) 740-9355(WELL), press "0" after hours – 24/7 on call
studenthealth.usc.edu/sexual-assault
Free and confidential therapy services, workshops, and training for situations related to gender-based harm.

Office for Equity, Equal Opportunity, and Title IX (EEO-TIX) - (213) 740-5086
eeotix.usc.edu
Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants.

Reporting Incidents of Bias or Harassment - (213) 740-5086 or (213) 821-8298
usc-advocate.symplicity.com/care_report
Avenue to report incidents of bias, hate crimes, and microaggressions to the Office for Equity, Equal Opportunity, and Title for appropriate investigation, supportive measures, and response.

The Office of Student Accessibility Services (OSAS) - (213) 740-0776
osas.usc.edu
OSAS ensures equal access for students with disabilities through providing academic accommodations and auxiliary aids in accordance with federal laws and university policy.
USC Campus Support and Intervention - (213) 821-4710
campussupport.usc.edu
Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

Diversity, Equity and Inclusion - (213) 740-2101
diversity.usc.edu
Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

USC Emergency - UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call
dps.usc.edu, emergency.usc.edu
Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

USC Department of Public Safety - UPC: (213) 740-6000, HSC: (323) 442-120 – 24/7 on call
dps.usc.edu
Non-emergency assistance or information.

Office of the Ombuds - (213) 821-9556 (UPC) / (323-442-0382 (HSC)
ombuds.usc.edu
A safe and confidential place to share your USC-related issues with a University Ombuds who will work with you to explore options or paths to manage your concern.

Occupational Therapy Faculty Practice - (323) 442-3340 or otfp@med.usc.edu
chan.usc.edu/otfp
Confidential Lifestyle Redesign services for USC students to support health promoting habits and routines that enhance quality of life and academic performance.

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