AME 515: Advanced Heat and Mass Diffusion
New Proposed Title: Thermal and Biological Transport Phenomena I

Units: 4
Term: Fall 2023.
Lecture Time: MW 10:00-11:50 am

Location: OHE 120

Instructor: Satwindar Singh Sadhal
Office: OHE 412A
Office Hours: MW 08:30-09:30 am, 1:00=2:30 pm
Contact Info: sadha@usc.edu, 213-740-0492

Teaching Assistant: None

Course Description

The main theme of the course is for the students to learn the analytical techniques for solving heat and mass diffusion problems in various geometries. The application is intended for heat transfer in solids and mass diffusion in porous materials such as biological tissues. Specifically, the following topics will be included:

1. **Fundamentals: Physics of heat and mass transfer.**
2. **Fourier law, Fick's law, Darcy flow. Thermal and Biotransport problems.**
3. **One-dimensional problems.**
4. **Separation of variables.**
5. **Problems in cylindrical geometry.**
6. **Heat conduction and mass diffusion in spherical coordinates.**
7. **Laplace transform methods.**
8. **Green's functions and Duhamel's theorem.**
9. **Three-dimensional time-dependent problems in spherical and cylindrical coordinates.**
10. **Integral transform techniques: Mellin and Lebedev-Kontorovich transforms.**
11. **Special topics: thermal contact problems, porous membranes. Aerosols and Drug Delivery**

Catalogue Description: Analytical techniques for heat and mass diffusion problems in various geometries; application to heat/mass transfer in solids, liquids, porous media and bioporous materials.

Learning Objectives

At the end of the course, students will have acquired the skills to obtain analytical solutions to differential equations pertaining to heat and mass diffusion. They will understand the modeling aspects of transport through solid and biporous media.

Prerequisite: AME 525

Co-requisite:

Concurrent Enrollment: None

Recommended Preparation: Undergraduate degree in AE, ME, CE, ChE, AME 526, AME 331 or 431

Course Notes

Grading Type: Letter Grade.

The course will be available on DEN (Distance Education Network)

Technological Proficiency and Hardware/Software Required: Matlab proficiency.

Required Readings and Supplementary Materials

The class notes will be sufficient required reading. The following additional materials are recommended:

1. Recommended Textbook (not required): Heat Conduction
   by M.N. Ozisik
   John Wiley & Sons; ISBN: 0-471-05481-X
2. Other Recommended Reading
   Mathematics of Diffusion
   By J. Crank
   Oxford University Press; ISBN: 0198534116

Description and Assessment of Assignments

Weekly assignment of homework problems to be turned in for grading (15% of final grade)
One **term project** (15% of the final grade): See attachment for a sample of the term project.

Grading Breakdown

Grading Scheme:	Homework ……...	15%
	Mid-Term Examination (7^{th} week) ……..……	25%
	Term Project (due 14^{th} week) ……..	15%
	Final Examination (as per the schedule of classes) …….	45%
	TOTAL	100%

Project will carry 15% of the final grade.
Students are required to submit a project requiring a more complex analysis than regular homework problems and may require numerical work. The project will be assigned in week 11 and due on week 14. The solution will include all detailed derivations and all numerical work including programs. A sample project is attached at the end of the syllabus.

The sample project has 4 parts, each carrying 25% of the total project grade, i.e., 3.75% of the final total grade. All parts have to be submitted together on the due date.

Assignment Submission Policy

Hand in assignment in class every week on designated class periods. Homeworks will be due one week after assignment at the end of the of the second lecture of the week. For example, "Homework 1 will be due at the second lecture of week 2. DEN students will submit assignments through the DEN system.

Grading Timeline

Usually, one week after turning in.

Additional Policies

- Final grade will depend entirely on the performance on the above components, and will be independent of the financial support requirements (e.g., minimum grade requirement for tuition reimbursement).
- Work-related travel should be scheduled during time periods outside of the mid-term and final exams. Accommodation to take exams on different dates will be made only for family emergencies and documented illness or health-related emergencies. Other exceptions will be considered on a case-by-case basis.
- Homework will not be accepted after the due date. Exceptions due to documented medical or family emergencies will be considered on a case-by-case basis.

Course Schedule: Weekly Breakdown. While all topics are relevant to thermal and biotransport problems, the ones very specific to biotransport are marked in blue.

Wk	TOPICS	Homework
1	FUNDAMENTALS 1.1 Derivation of the heat equation and the mass diffusion equation 1.2 Fourier law and Fick's law; temperature and mass concentration as a driving potential 1.3 Diffusion problems in solids, liquids, and bio/porous media 1.4 Boundary conditions	To be assigned by instructor. Due the following week
2	ONE-DIMENSIONAL PROBLEMS 2.1 Infinite and finite media situations. Similarity solutions.	To be assigned. Due next week
3	SEPARATION OF VARIABLES 3.1 Product solutions of two- and three-dimensional problems	To be assigned. Due next week
4	3.2 Problems with heat generation and solute production 3.3 Eigenfunction expansions in the rectangular coordinate systems	To be assigned. Due next week
5	PROBLEMS IN CYLINDRICAL GEOMETRY 4.1 Fourier-Bessel series for temperature and concentration. 4.2 Problems with sources (heat and mass). 4.3 Product solutions. Application cylindrical geometries for homogeneous boundary conditions. 4.4 Non-homogeneous boundary conditions in cylindrical geometry. 4.4 Advanced integral transforms (Mellin, Lebedev-Kontorovich)	To be assigned by instructor. Due the following week
6	DIFFUSION IN REGIONS BOUNDED BY SPHERES 5.1 Legendre and spherical Bessel function series	To be assigned. Due next week
7	5.2 Fully-three dimensional steady problems for spheres and spherical cavities. 5.3 Legendre function analysis. 5.3 Application to drops, bubbles and particles: condensation, evaporation; dissolution of gas bubbles. Biotransport problems with aerosols.	To be assigned by instructor. Due the following week.
	Mid-Term Examination	
8	GREEN'S FUNCTIONS AND DUHAMEL'S THEOREM. 6.1 Advanced analytical development of solutions to mass diffusion problems.	To be assigned. Due next week
9	ADVANCED COORDINATE TRANSFORMATIONS 7.1 Elliptical, and prolate/oblate spheroidal systems.	To be assigned. Due next week
10	NUMERICAL EVALUATION OF SERIES SOLUTIONS 8.1 Fourier, Legendre and Bessel Series summation, error analysis. 8.2 Stability and convergence of solutions	To be assigned. Due next week
11	INTERFACE AND CONTACT RESISTANCE PROBLEMS 8.1 Heat conduction in laminated composites. Flow through porous membranes	To be assigned. Due next week
12	8.2 Averaged thermal properties for laminates and spherical dispersions.	No HW. Project assigned.
13	9.3 Thermal modeling of nominally flat partially contacting solid surfaces. 9.4 Modeling of fluid permeation through porous membranes in biological systems 9.5 Dual series techniques for mixed boundary value problems.	No HW. Project work.
14	MASS DIFFUSION IN POROUS AND BIOPOROUS MEDIA 10.1 Modeling of bio/porous media as diffusive transport (Darcy's law). Pressure as a driving potential.	To be assigned. Due next week
15	10.2 Percolation and diffusion of liquids and gases. 10.3 Targeted drug delivery 10.4 Sustained-release modeling of drug capsules.	No homework
	FINAL EXAMINATION (Date as per schedule of classes)	

Statement on Academic Conduct and Support Systems

Academic Conduct:
Plagiarism – presenting someone else's ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in *SCampus* in Part B, Section 11, "Behavior Violating University Standards" https://policy.usc.edu/scampus-part-b/. Other forms of academic dishonesty are equally unacceptable. See additional information in *SCampus* and university policies on scientific misconduct, http://policy.usc.edu/scientific-misconduct.

Support Systems:
Student Counseling Services (SCS) - (213) 740-7711 – 24/7 on call
Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention. https://engemannshc.usc.edu/counseling/

National Suicide Prevention Lifeline - 1-800-273-8255
Provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week. http://www.suicidepreventionlifeline.org

Relationship and Sexual Violence Prevention Services (RSVP) - (213) 740-4900 - 24/7 on call
Free and confidential therapy services, workshops, and training for situations related to gender-based harm.
https://engemannshc.usc.edu/rsvp/

Sexual Assault Resource Center
For more information about how to get help or help a survivor, rights, reporting options, and additional resources, visit the website: http://sarc.usc.edu/

Office of Equity and Diversity (OED)/Title IX Compliance – (213) 740-5086
Works with faculty, staff, visitors, applicants, and students around issues of protected class. https://equity.usc.edu/

Bias Assessment Response and Support
Incidents of bias, hate crimes and microaggressions need to be reported allowing for appropriate investigation and response. https://studentaffairs.usc.edu/bias-assessment-response-support/

The Office of Disability Services and Programs
Provides certification for students with disabilities and helps arrange relevant accommodations. http://dsp.usc.edu

Student Support and Advocacy – (213) 821-4710
Assists students and families in resolving complex issues adversely affecting their success as a student EX: personal, financial, and academic. https://studentaffairs.usc.edu/ssa/

Diversity at USC
Information on events, programs and training, the Diversity Task Force (including representatives for each school), chronology, participation, and various resources for students. https://diversity.usc.edu/

USC Emergency Information
Provides safety and other updates, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible, http://emergency.usc.edu

USC Department of Public Safety – 213-740-4321 (UPC) and 323-442-1000 (HSC) for 24-hour emergency assistance or to report a crime.
Provides overall safety to USC community. http://dps.usc.edu