

AME 515:
Thermal and Biological Transport Phenomena I
Units: 4
Term—Day—Time: Fall 2024 – TBA

Location: TBA

Instructor: Satwindar Singh Sadhal

Office: OHE 412A

Office Hours: MW 08:30-09:45 am, 1:00-2:00 pm

Contact Info: sadhal@usc.edu, 213-740-0492

Teaching Assistant: None

IT Help: N/A.

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 student audience is expected to be Master's and PhD level graduate students preparing for careers in Power and Sustainability as well as in the Medical Engineering profession. The application is intended for heat transfer in solids and mass diffusion in porous materials such as biological tissues.

The detailed week-by-week course description is given under **Course Schedule**

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.

Course Objectives: The goal of the course is to provide students the necessary mathematical skills to analyze problems in diffusive transport in industrial and biological systems and obtain quantitative solutions to real-life situations. It is expected that the students will learn techniques of tackling problems in these areas and also develop the skills needed to acquire the know-how in dealing with further developments beyond the classroom.

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 bioporous media. In addition, they need to

- apply mathematical modeling techniques to heat conduction and mass diffusion problems.
- obtain analytical solutions to various types of heat and mass diffusion problems in different geometries.
- show that they are able to formulate and quantify a physical situation in mathematical terms and follow up with an engineering solution;
- demonstrate that they have acquired the necessary mathematical and engineering skills in solving practical problems relevant to thermal and mass diffusion.

Prerequisite: AME 525

Co-requisite:

Concurrent Enrollment: None

Recommended Preparation: Undergraduate degree in AE, ME, CE, ChE, AME 526, Matlab proficiency to the level of ITP 168 or equivalent.

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 following additional materials are required besides the class notes:

Heat Conduction

by M.N. Ozisik, John Wiley & Sons; ISBN: 0-471-05481-X

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 every week as per assigned deadlines (usually one day after the last lecture every week). Assignments will be posted on D2L Brightspace and submissions will be made on that portal as well, as stated under **Assignment Submission Policy**.

Grading Breakdown

Grading Scheme:	Homework	20%
	Mid-Term Examination (7 th week)	30%
	Final Examination (as per the schedule of classes)	50%
	TOTAL	100%

Project: None.

Assignment Rubrics

Each assignment will be weighted in the basis of how long it is. Approximate distribution of the homework part of the grade is as follows:

HW1	HW2	HW3	HW4	HW5	HW6	HW7	HW8	HW9	HW10	HW11	HW12	TOT
7%	8%	6%	12%	7%	7%	17%	7%	9%	9%	7%	5%	100%

Assignment Submission Policy

Assignments will be due one week after the assignment date. The due date will be clearly stated on the D2L Brightspace portal. Submissions will be made on this portal as well. Assignments will be graded on the portal and available for viewing one week after submission.

Grading Timeline

Usually one week after the due date.

Course-Specific Policies

- 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.

Academic Integrity

Unless otherwise noted, this course will follow the expectations for academic integrity as stated in the USC Student Handbook. The general USC guidelines on Academic Integrity and Course Content Distribution are provided in the subsequent “Statement on Academic Conduct and Support Systems” section.

For this class, please note the following:

1. Collaboration: In this class, you are expected to submit work that demonstrates your individual mastery of the course concepts.
2. Group work: Unless specifically designated as a ‘group project,’ all assignments are expected to be completed individually. Learning from classmates through group discussion is not discouraged but dividing the workload is not allowed.
3. Computer programs: Plagiarism includes the submission of code written by, or otherwise obtained from someone else.

If any outside resources are used, please cite the source clearly.

Use of Generative AI in this Course

Generative AI permitted but limited as follows: In this course, students are permitted to use artificial intelligence (AI)-powered programs to help them, but only on assignments that explicitly indicate a permitted use of AI. However:

- Students should also be aware that AI text generation tools may present incorrect information, biased responses, and incomplete analyses; thus, their answers may not meet the standards of this course.
- To adhere to our university values, students must cite any AI-generated material (e.g., text, images, and other content) included or referenced in your work and provide the prompts used to generate the content. Using an AI tool to generate content without proper attribution will be treated as plagiarism and reported to the Office of Academic Integrity.

Students must review the instructions in each assignment for more details on how and when to use AI Generators for their submissions.

Course Schedule: Weekly Breakdown.			
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	No homework	
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.	Mid-term prep. No homework	
	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.	To be assigned. Due next week	
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.	To be assigned. Due next week	
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 Integrity:

The University of Southern California is a learning community committed to developing successful scholars and researchers dedicated to the pursuit of knowledge and the dissemination of ideas. Academic misconduct, which includes any act of dishonesty in the production or submission of academic work, comprises the integrity of the person who commits the act and can impugn the perceived integrity of the entire university community. It stands in opposition to the university's mission to research, educate, and contribute productively to our community and the world.

All students are expected to submit assignments that represent their own original work, and that have been prepared specifically for the course or section for which they have been submitted. You may not submit work written by others or "recycle" work prepared for other courses without obtaining written permission from the instructor(s).

Other violations of academic integrity include, but are not limited to, cheating, plagiarism, fabrication (e.g., falsifying data), collusion, knowingly assisting others in acts of academic dishonesty, and any act that gains or is intended to gain an unfair academic advantage.

The impact of academic dishonesty is far-reaching and is considered a serious offense against the university. All incidences of academic misconduct will be reported to the Office of Academic Integrity and could result in outcomes such as failure on the assignment, failure in the course, suspension, or even expulsion from the university.

For more information about academic integrity see [the student handbook](#) or the [Office of Academic Integrity's website](#), and university policies on [Research and Scholarship Misconduct](#).

Please ask your instructor if you are unsure what constitutes unauthorized assistance on an exam or assignment, or what information requires citation and/or attribution.

Course Content Distribution and Synchronous Session Recordings Policies

USC has policies that prohibit recording and distribution of any synchronous and asynchronous course content outside of the learning environment.

Recording a university class without the express permission of the instructor and announcement to the class, or unless conducted pursuant to an Office of Student Accessibility Services (OSAS) accommodation. Recording can inhibit free discussion in the future, and thus infringe on the academic freedom of other students as well as the instructor. ([Living our Unifying Values: The USC Student Handbook](#), page 13).

Distribution or use of notes, recordings, exams, or other intellectual property, based on university classes or lectures without the express permission of the instructor for purposes other than individual or group study. This includes but is not limited to providing materials for distribution by services publishing course materials. This restriction on unauthorized use also applies to all information, which had been distributed to students or in any way had been displayed for use in relationship to the class, whether obtained in class, via email, on the internet, or via any other media. ([Living our Unifying Values: The USC Student Handbook](#), page 13).

Students and Disability Accommodations:

USC welcomes students with disabilities into all of the University's educational programs. [The Office of Student Accessibility Services](#) (OSAS) is responsible for the determination of appropriate accommodations for students who encounter disability-related barriers. Once a student has completed the OSAS process (registration, initial appointment, and submitted documentation) and accommodations are determined to be reasonable and appropriate, a Letter of Accommodation (LOA) will be available to generate for each course. The LOA must be given to each course instructor by the student and followed up with a discussion. This should be done as early in the semester as possible as accommodations are not retroactive. More information can be found at osas.usc.edu. You may contact OSAS at (213) 740-0776 or via email at osasfrontdesk@usc.edu.

Support Systems:

[Counseling and Mental Health](#) - (213) 740-9355 – 24/7 on call

Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

[988 Suicide and Crisis Lifeline](#) - 988 for both calls and text messages – 24/7 on call

The 988 Suicide and Crisis Lifeline (formerly known as the National Suicide Prevention Lifeline) provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week, across the United States. The Lifeline is comprised of a national network of over 200 local crisis centers, combining custom local care and resources with national standards and best practices. The new, shorter phone number makes it easier for people to remember and access mental health crisis services (though the previous 1 (800) 273-8255 number will continue to function indefinitely) and represents a continued commitment to those in crisis.

[Relationship and Sexual Violence Prevention Services \(RSVP\)](#) - (213) 740-9355(WELL) – 24/7 on call

Free and confidential therapy services, workshops, and training for situations related to gender- and power-based harm (including sexual assault, intimate partner violence, and stalking).

[Office for Equity, Equal Opportunity, and Title IX \(EEO-TIX\)](#) - (213) 740-5086

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

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 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) 740-0411

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

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

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) 442-1200 – 24/7 on call

Non-emergency assistance or information.

[Office of the Ombuds](#) - (213) 821-9556 (UPC) / (323-442-0382 (HSC)

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) 442-2850 or otfp@med.usc.edu

Confidential Lifestyle Redesign services for USC students to support health promoting habits and routines that enhance quality of life and academic performance.