

AME 516: Thermal and Biological Transport Phenomena.

Units: 4

Spring 2024 – Schedule: Tu Th 12:00-1:50 pm

Location: OHE 100D

Instructor: Satwindar Singh Sadhal

Office: OHE 412A

**Office Hours: Tu 09:00-11:30 am, 2:00-3:30 pm
Th 2:00-3:30 pm**

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Course Description

The main theme of the course is for the students to learn the analytical techniques for solving convective heat and mass transfer problems in a variety of practical situations. Problem-solving techniques in this course are applied to heat/mass transfer biological tissues. However, the transport phenomena in this course are also applicable to traditional industrial applications. 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. Specifically, the topics covered are given in the week-by-week breakdown:

Catalogue Description: Analytical techniques for solving convective heat and mass transfer problems; applications include heat/mass transfer in biological systems as well as traditional industrial settings.

Course Objectives: The goal of the course is to provide students the necessary mathematical skills to analyze problems in convective 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

It is expected that when exiting AME 516, students will be able to:

- apply mathematical modeling techniques to thermal and solute transport in fluid systems and biporous media;
- set up relevant heat and mass conservation differential equations;
- obtain analytical solutions to many varieties of convective heat and mass transfer problems in a wide array of important applications, including biotransport and industrial systems;
- translate and quantify mathematical formulations to physically meaningful results;
- apply the skills acquired to real-life situations such as, e.g., cardiovascular flow, drug delivery, power-plant heat transfer, pollutant dispersion in water and the atmosphere;
- demonstrate that they have acquired the necessary mathematical and engineering skills in solving practical problems relevant to thermal and solute transport in fluid systems and biporous media;
- show that they are able to formulate and quantify a physical situation in mathematical terms and follow up with an engineering solution.

Prerequisite: AME 525, AME 515

Recommended Preparation: Undergraduate courses on differential equations, fluid dynamics, thermodynamics and heat transfer; AME 526

Other Details

Grading Type: Letter Grade.

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

Technological Proficiency and Hardware/Software Required: MATLAB proficiency.

Textbook: “Transport Phenomena in Biological Systems,” by Truskey, Yuan & Katz, Pearson Prentice Hall. ISBN-13: 978-0130422040, ISBN-10: 0130422045

Recommended Readings and Supplementary Materials

For further insights, the following additional materials are recommended:

1. “Convective Heat Transfer,” by Louis C. Burmeister, Wiley Interscience, ISBN: 0-471-09141-3
2. “Transport Phenomena,” by Bird, Stewart & Lightfoot, Wiley. ISBN-13: 978-0470115398, ISBN-10: 0470115394

Description and Assessment of Assignments

There will be thirteen weekly homework problem assignments which will account for a percentage of the grade as indicated in the Grading Breakdown. The submissions are 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 and submissions will be made on that portal as well, as stated under **Assignment Submission Policy**. Students should expect that the reading and homework assignments will require roughly eight hours/week outside class.

Grading Breakdown

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

Assignment Submission Policy

Homework assignments will be due one week after assignment at the end of the of the Thursday lecture. Submit assignment online every week by the posted due date through D2L Brightspace.

Grading Timeline

Usually one week after the due date.

Course-Specific Policies

- Final grade will depend entirely on the performance on the above grading breakdown 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.

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 your submissions.

Course Schedule: Weekly Breakdown

Week	TOPICS	HW	Recommended Reading
1	1. FUNDAMENTALS 1.1 Review of fluid mechanics. Conservation of mass and momentum. Fick's law. 1.2 Scaling and nondimensionalization. 1.3 Boundary conditions	HW1	Chapters 1-3 Truskey
2	2. ENERGY CONSERVATION 2.1 The energy equation. Diffusion, convection, dissipation. 2.2 Energy from chemical, biochemical and nuclear reactions	HW2	Chapters 3, 6 Truskey
3	3. MASS CONSERVATION (SOLUTES) 3.1 Convective and diffusive mass transfer	HW3	Class Notes
4	4. TWO-DIMENSIONAL PROBLEMS 4.1 Thermal and momentum boundary layers on flat plates 4.2 Karman-Pohlhausen boundary layer theory	HW4	Chapters 2-4 Truskey + Class notes
5	4.3 Couette flow in channels. 4.2 Thermal entrance length in two-dimensional channels. Graetz Problem.	HW5	Chapter 5 Truskey
6	5. PROBLEMS IN CYLINDRICAL GEOMETRY 5.1 Heat transfer in pipes. Graetz problem for circular channels. 5.2 Pulsating flow in tubes. Application to blood flow.	HW6	Class Notes
7	5.3 Flow around tubes and tube bundles.	Prep for Mid-term	Class Notes
	Mid-Term Examination (during class period): February 22, 2024		
8	6. BUOYANCY-DRIVEN CONVECTION 6.1 Density variation as a driving force.	HW7	Class Notes
9	6.2 Dimensionless scaling, Grashof and Rayleigh numbers 6.3 Buoyant convection from a vertical flat plate	HW8	Class Notes
10	6.4 Buoyant convection between two parallel plates. Critical Rayleigh numbers for onset of convection. 6.5 Convective transport due to density stratification in isothermal systems.	HW9	Class Notes
11	7. TURBULENT HEAT AND MASS TRANFER 7.1 Laminar to turbulent transition 7.2 Turbulent boundary layers k - ϵ models 7.3 Application to flat plates and tubes	HW10	Class Notes
12	8. PROBLEMS IN SPHERICAL GEOMETRY 8.1 Classical problems with drops, bubbles and particles with convection. 8.2 Evaporation of aerosols with convective transport. Spherically symmetric problems. 8.3 Evaporation with translation of drops.	HW11	Class Notes
13	9. PENNES BIO-HEAT EQUATION 9.1 Blood perfusion as a heat-removal/addition mechanism. 9.2 Application to mammalian tissue. 9.3 Tumors, and radiation therapy. Thermal analysis.	HW12	Chapters 17 Truskey
14	10. POROUS AND BIOPOROUS MEDIA 10.1 Darcy equation for momentum conservation. 10.2 Convective heat and mass transfer in porous media. Darcy law. 10.3 Application to targeted drug delivery.	HW13	Chapters 8 Truskey
15	11. SPECIAL TOPICS 11.1 Topics of current interest 11.2 Advanced fluid dynamics and transport phenomena with aerosols	No HW	Class Notes
	FINAL EXAMINATION: TBA, Wednesday May 8, 2024. 2:00-4:00 pm		

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.