



## **AME 515: Advanced Heat and Mass Diffusion**

**Units: 4**

**Fall 2019 – TuTh 09:00-10:50 am**

**Location: OHE 100C**

**Instructor: Satwindar Singh Sadhal**

**Office: OHE 400G**

**Office Hours: TuTh 1:00-3:30 pm**

**Contact Info: [sadhal@usc.edu](mailto:sadhal@usc.edu), 213-740-0492**

### **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.**
- 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.**

### **Recommended 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 (not required)  
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):

## Grading Breakdown

Grading Scheme:	Homework .....	15%
	Mid-Term Examination (7 <sup>th</sup> week, October 10, 2019) .....	25%
	Term Project (due November 21, 2019) .....	15%
	Final Examination (December 12, 2019; 11:00am-1:00pm) ....	45%
	TOTAL	100%

## 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

Week	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 concentration as a driving potential 1.3 Diffusion problems in solids, liquids, and 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 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.	To be assigned by instructor. Due the following week.
	Mid-Term Examination (October 10, 2019 during class period)	
8	GREEN'S FUNCTIONS AND DUHAMEL'S THEOREM. 6.1 Advanced analytical development of solutions to 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	COMPOSITE MEDIA AND CONTACT RESISTANCE PROBLEMS 8.1 Heat conduction in laminated composites.	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 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 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 (December 12, 2019; 11:00am-1:00pm)	

## 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>