AME 516: Convective Processes:
(Thermal & Biological Transport Phenomena)
Units: 3
Spring 2021 – TuTh 02:00-3:20 pm

Location: OHE 132 & online

Instructor: Satwindar Singh Sadhal
Office: OHE 400G
Office Hours: TuTh 09:00-11:00 am
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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. The application is intended for heat/mass transfer industrial settings such as power plants as well as biological tissues. Specifically, the following topics will be included:

1. **Fundamentals: Physics of heat and mass transfer.**
2. **Fourier law, Fick's law. Review of fluid dynamics, momentum conservation**
3. **Equations of energy conservation and mass transport. Bioheat equation.**
4. **Pennes equation for biotransport.**
5. **Darcy flow for bioporous media.**
6. **Laminar two-dimensional flow. Boundary layer theory for energy and mass transfer.**
7. **Flow through channels. Couette flow.**
8. **Flow through pipes with heat transfer. Graetz problem.**
9. **Mass transfer through tubes; application to blood flow**
10. **Darcy flow through bioporous media with mass transfer.**
11. **Flow past cylinders with heat transfer.**
12. **Laminar to turbulent flow transition.**
13. **Turbulent heat transfer in parallel flow**
14. **Turbulent heat transfer in ducts.**
15. **Mass transfer with fluid flow biochemical reactions.**
16. **Application to drug delivery.**

Catalogue Description: Analytical techniques for solving convective heat and mass transfer problems in a variety of situations. The application is intended for heat/mass transfer industrial settings such as power plants as well as biological tissues.

Learning Objectives

At the end of the course, students will have acquired the skills to obtain analytical solutions to differential equations pertaining to convective heat and mass transfer. They will understand the modeling aspects of thermal and solute transport in fluid systems and biporous media.

Prerequisite: AME525, AME309, AME331 or equivalents.
Co-requisite: None
Concurrent Enrollment: None

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

Course Notes
Grading Type: Letter Grade.
The course will be available on DEN (Distance Education Network)

Technological Proficiency and Hardware/Software Required: Matlab proficiency.

Recommended Readings and Supplementary Materials
The class notes will be sufficient required reading. 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
3. "Transport Phenomena in Biological Systems," by Truskey, Yuan & Katz, Pearson Prentice Hall. ISBN-13: 978-0130422040, ISBN-10: 0130422045

Description and Assessment of Assignments
Weekly assignment of homework problems to be turned in for grading (20% of final grade)
Grading Breakdown

Grading Scheme:	Homework …….....	20%
	Mid-Term Examination (7th week, March 9, 2021) ……...	30%
	Final Examination (Thursday, May 6, 2:00-4:00pm) ……	50%
	TOTAL	100%

Assignment Submission Policy
Homeworks will be due one week after assignment at the end of the of the second lecture of the week. Submit assignment online every week by the posted due date. All 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

Week/Dates	TOPICS	Homework
1 Jan 19, 21	1. FUNDAMENTALS 1.1 Review of fluid mechanics. Conservation of mass and momentum 1.2 Scaling and nondimensionalization. 1.3 Boundary conditions	To be assigned. Due Jan 28
2 Jan 26, 28	2. ENERGY CONSERVATION 2.1 The energy equation. Diffusion, convection, dissipation. 2.2 Energy from chemical, biochemical and nuclear reactions	To be assigned. Due Feb 4.
3 Feb 2,4	3. MASS CONSERVATION (SOLUTES) 3.1 Convective and diffusive mass transfer	To be assigned. Due Feb 11
4 Feb 9, 11	4. TWO-DIMENSIONAL PROBLEMS 4.1 Thermal and momentum boundary layers on flat plates 4.2 Karman-Pohlhausen boundary layer theory	To be assigned. Due Feb 18
5 Feb 16, 18	4.3 Couette flow in channels. 4.2 Thermal entrance length in two-dimensional channels. Graetz Problem.	To be assigned Due Feb 25
6 Feb 23, 25	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.	To be assigned. Due Mar 4
7 Mar 2, 4	5.3 Flow around tubes and tube bundles.	No HW. Prep for Mid-term
Mar 9	Mid-Term Examination (during class period)	
8 Mar 11	6. BUOYANCY-DRIVEN CONVECTION 6.1 Density variation as a driving force.	To be assigned. Due Mar 18
9 Mar 16, 18	6.2 Dimensionless scaling, Grashof and Rayleigh numbers 6.3 Buoyant convection from a vertical flat plate	To be assigned. Due Mar 25
10 Mar 23, 25	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.	To be assigned. Due Apr 1
11 Mar 30 Apr 1	8. TURBULENT HEAT AND MASS TRANFER 8.1 Laminar to turbulent transition 8.2 Turbulent boundary layers k-ε models 8.3 Application to flat plates and tubes	To be assigned. Due Apr 8
12 Apr 6, 8	7. PROBLEMS IN SPHERICAL GEOMETRY 7.1 Classical problems with drops, bubbles and particles. 7.2 Evaporation of aerosols. Spherically symmetric problems. 7.3 Evaporation with translation of drops.	To be assigned. Due Apr 15
13 Apr 13, 15	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.	To be assigned. Due Apr 22
14 Apr 20, 22	10. POROUS AND BIOPOROUS MEDIA 10.1 Darcy equation for momentum conservation. 10.2 Convective heat and mass transfer in porous media 10.3 Application to targeted drug delivery.	To be assigned. Due Apr 29
15 Apr 27, 29	11. SPECIAL TOPICS 11.1 Topics of current interest 11.3 Biotransport issues relevant to Covid-19 transmission 11.4 Fluid dynamics and transport phenomena with aerosols	No homework
	FINAL EXAMINATION (Thursday, May 6, 2:00- 4:00 pm)	

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