ENG ME/MS 527 Transport Phenomena (Spring 2021)

Catalog Data:
ENG ME/MS 527 Transport Phenomena Prereq: ENG ME 304 or equivalent. Introduction to momentum, heat and mass transport phenomena occurring in various processes. Whereas transport phenomena underlie many processes in engineering, agriculture, meteorology, physiology, biology, analytical chemistry, materials science, pharmacy and other areas, they are key to specific applications in diverse areas such as materials processing, green manufacturing of primary materials, biological membranes, fuel cell engineering, synthesis of clean fuels. This course covers three closely related transport phenomena: momentum transfer (fluid flow), energy transfer (heat flow) and mass transfer (diffusion). The mathematical underpinnings of all three transport phenomena are closely related and the differential equations governing them are frequently quite similar. Since in many situations the three transport phenomena occur together, they are presented and studied together in this course.

Course Schedule: 4 lecture hours/week

Status in the Curriculum: Elective

Class Location and Time: Photonics 202, Tue & Thu: 9 – 10.45 AM

Instructor: Srikanth Gopalan, Rm 144, 15 St.Mary's St., sgopalan@bu.edu

Office Hours: Wed 2:00-3:30 PM

COVID 19 Related Information: The class will be held in LfA mode. If you attend class in person you are expected to wear face coverings and maintain social-distancing in class to protect yourself and others in the class. If you arrive in class without a face covering you will be asked to leave and return with one. If you choose to attend in-person classes, you are also expected to adhere to the university regulations regarding Covid testing. The lectures will be recorded and links to the recorded lectures will be posted on Blackboard. Since it is a small class, we do not have a class moderator. You are highly encouraged to participate actively in class.

Zoom Link:
https://learn.bu.edu/webapps/blackboard/content/launchLink.jsp?course_id=_75117_1&content_id=_8864358_1&mode=cpview

Textbooks:

1) Transport Phenomena by Bird, Stewart, and Lightfoot, Revised Second Edition, Wiley, 2007
2) Convection Heat Transfer, by Bejan, Wiley, Fourth Edition, 2013

References:

3) S. Kou, Transport Phenomena in Materials Processing, John Wiley and Sons, New York (1996)

Coordinator: Prof. Srikanth Gopalan, Department of Mechanical Engineering

Prerequisites:
An understanding of engineering thermodynamics as taught in EK 304.

Goals:
This is designed to provide graduate students and senior undergraduates an introduction to transport phenomena and its applications in various fields such as materials science, electrochemistry, mechanical engineering, chemicals processing and bioengineering.

Computer Usage:
This course uses symbolic manipulation software such as MATHEMATCA or MATLAB in a few assignments. There may also be a few numerical computation assignments.

Course Learning Outcomes:

As an outcome of completing this course, students will:

i. Gain a fundamental understanding of the principles of momentum, heat and mass transport.

ii. Be able to formulate with boundary and initial conditions and solve differential equations pertaining to momentum, heat and mass transport in various situations encountered in materials science, electrochemistry, mechanical engineering, chemicals processing and bioengineering.

Topics: The list of topics is uploaded as a separate file on blackboard.

Grading: Problem sets will be posted in Blackboard about once every two weeks. There is no grade for solving problem sets, however, it is in your interest to solve them to prepare for quizzes and midterm exams. I plan to post solutions one week after I upload problem sets.

Three take-home midterm exams worth 80% of the grade. There will also be four short in-class quizzes totaling 20% of the grade. I will announce the quiz date one week prior to the quiz and they will be on blackboard. I will drop your lowest quiz grade. If you miss a quiz without telling me ahead of time, you will be given a zero for that quiz. The dates of the take-home midterms are already available on the list of topics. You will have twenty-four hours to return your exams from the time you download the exam. You are expected to adhere to BU's academic code: https://www.bu.edu/academics/policies/academic-conduct-code/

Violation of the BU academic code have severe consequences spelled out in the code.

MS/ME 527: Transport Phenomena (Spring 2021) – List of Topics

Introduction

Week 1

1) What is transport phenomena and why study it?
2) Motivating by a few real life examples
3) Introduction to dimensionless analysis – Convection and diffusion, Buckingham pi theorem and the emergence of dimensionless groups in transport phenomena, physical interpretation of dimensionless groups

Week 2

4) Origin and estimation of mass, thermal, and momentum diffusion (Chapters 1, 9, 17)

Purely diffusive transport with and without source terms

Week 3

5) Shell balance -- Unidirectional velocity, temperature, and concentration distributions in laminar flow (Steady flow problems from chapters 2, 10, and 18; a few non-steady problems using similarity solutions and separation of variables/ Fourier analysis from chapters 4 and 12)

Week 4 **(Take home exam 1: 2/23/2021)**

6) Balance laws in cylindrical coordinates – steady and unsteady heat conduction in a cylinder, Heat conduction from a wire (Chapter 10, chapter 12)
7) Effect of body force and pressure in momentum transfer -- falling film (steady and unsteady flow) and analysis of pipe flow and friction factor.

Transport with convection terms included

Week 5

8) A little vector and tensor analysis (Appendix A)
9) The combined momentum flux tensor (chapter 2 and 3)
10) Derivation of the equation of motion – Navier-Stokes equation (chapter 3)
11) Various forms of the equation of motion in Cartesian, cylindrical and spherical coordinates (chapter 3) ; inviscid flow and use of the velocity potential (chapter 4)

Week 6

12) Equations of change for non-isothermal systems—derivation of different forms of the energy equation (chapter 11)

13) Boundary layer theory (forced convection) – laminar boundary layer flow (Chapter 2 from Bejan's book)

Week 7

14) Laminar duct flow – forced convection (Chapter 3 from Bejan's book)
15) External and internal forced convection (Chapters 4 and 5 from Bejan's book)

Mass Transfer

Week 8 (**Take home exam 2: 3/23/2021**)

16) Equations of change for multicomponent systems (Chapter 19)
17) Unsteady state diffusion and two dimensional problems (Chapter 20)

Week 9

18) Forced convection mass transfer – boundary layer theory for mass transfer (Chapter 20)

Week 10-13

Study of Transport Phenomena in Materials Processing and Energy Conversion (Topics TBD)

Week 13 (**Take home midterm 3: TBD during finals week**)