CHEN E 4110 X
MECHANISMS OF TRANSPORT IN FLUIDS
Fall 2020

PREREQUISITES: A working knowledge of vector calculus, linear algebra and ordinary differential equations is needed. An undergraduate course in transport, and some exposure to methods in partial differential equations, are also needed.

DESCRIPTION: The course develops and applies a continuum framework for modeling non-equilibrium phenomena in fluids with clear connections to the molecular/microscopic mechanisms for "conductive" transport. The first part of the course reviews and extends beyond undergraduate level the common continuum approach to transport analysis in fluids. Continuum balances of mass and momentum (linear and angular momentum) are developed. Closure through the continuum-level development of frame indifferent constitutive laws for the conductive momentum flux (stress tensor) is considered for simple fluids in the incompressible limit. Applications of this common framework to several classes of flow problems important in chemical engineering technologies are reviewed (lubrication flows, creeping flows). In the second part of the course, a microscopic development of the conductive fluxes for simple and/or complex fluids is developed along with select applications. Options for this part include (i) kinetic theory of gases by an ad-hoc mechanical treatment or via the Boltzman equation to predict transport coefficients, (ii) review of liquid state "free-volume" and activated state models for predicting transport coefficients in simple liquids (iii) development and application of Langevin/Fokker-Plank/Smoluchowski framework for modeling the conductive momentum flux in complex fluids and (iv) introduction to active matter.

INSTRUCTOR: INSTRUCTOR C.J. Durning, 811A Mudd, cjd2@columbia.edu, office hour Tue: 2:30-3:30 PM via Zoom invitation

CLASS MEETING: Tue/Th 11:40 AM - 12:55 via Zoom Invitation (on CANVAS).

REQUIREMENTS: Homeworks, Midterm (*tentatively* the week of October 19), Final (during finals week 12/17-23). Exam format TBD.

HOMEWORKS: Readings and problems assigned approximately biweekly; Homeworks checked for submission/completeness/integrity, but not graded in detail; HW solutions will be posted.

EXTRA CREDIT: Course notes

GRADES: Based on exams, homeworks.and extra credit.

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REFERENCES:

1. **Required Text:** D.C. Venerus, H.C. Ottinger, A Modern Course in Transport Phenomena, Cambridge University Press, NY (2018) (VO)
2. **Supplemental Texts:** W.M. Deen, *Analysis of Transport Phenomena, 2nd. (US) Ed.*, Oxford University Press, NY (2012) (De); R.B. Bird, W.E. Stewart, E.N. Lightfoot, *Transport Phenomena, 2nd Edition*, J. Wiley, NY (2002) (BSL).
3. **SELECTED READINGS:** To appear on CANVAS website.

CHEN E 4110 X - Fall 2020 COURSE OUTLINE

1. **OVERVIEW / PRIMER** (1 week)**:**
   a. Continuum description of matter
      - local averaging
      - frames of reference
      - kinematics; Eulerian and Lagrangian descriptions
2. **CONTINUUM FRAMEWORK FOR FLUIDS** (2 weeks)**:**
   a. Eulerian balance laws
      - mass, linear and angular momentum
      - assessment of closure

   b. Continuum level development of constitutive laws for the conductive momentum flux (stress tensor)
      - continuum definition of simple fluids
      - consequences of material frame-indifference
      - Euler, Newtonian and non-Newtonian models

   c. Incompressiblility
      - dynamic pressure
      - Navier-Stokes (NS) eqns
3. **APPLICATIONS OF CONTINUUM FRAMEWORK** (4 weeks):
   a. Incompressible Laminar Channel and Couette flows
      - steady/psuedo-steady lubrication flows for incompressible Newtonian fluids

   b. Creeping flows
      - Stokes equation; general features of creeping flow: psuedo-steady description, kinematic reversibility, superpostion
      - stream function and its use for select 2-d creeping flows
      - point source solutions and their applications
      - creeping flows of non-Newtonian fluids
4. **MICROSCOPIC FRAMEWORK AND APPLICATIONS** (6 weeks)
   a. Langevin/Smoluchowski model
      - modeling Brownian motion in "simple" suspensions
      - including complex particles, external fields, and particle interactions in suspensions

   b. Applications of Langevin/Smoluchowski framework
      - barrier crossing and first passage time problems
      - stress tensor in elastic dumbell suspensions
      - modeling active media

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Course Calender

WEEK	DATES	REMARKS
1	Sept. 8/10	Objectives/Continuum description
2	Sept. 15/17	Eulerian balance laws
3	Sept. 17/19	Constitutive laws for stress
4	Sept. 22/24	Constitutive laws/Lubricatiom flows
5	Sept. 29/Oct. 1	Lubrication flows
6	Oct. 6/8	Creeping flows
7	Oct. 13/15	Creeping flows
8	Oct. 20/22	Creeping flows/**Midterm**
9	Oct. 27/29	Brownian motion in "simple" suspensions
10	Nov. 5	**Election Day**/Langevin-Smoluchowski model
11	Nov. 10/12	BM: complex particles, external fields
12	Nov. 17/19	Dumbell suspensions
13	Nov. 24	Dumbell suspensions/**Thanksgiving**
14	Dec. 1/3	Dumbell suspensions/Active media
15	Dec. 8/10	Active media
16	Dec. 17-23	**Finals Week**