

## ChBE 3200 Transport Phenomena I (required course)

Credit 3-0-3

**Instructor:** Hang Lu

**Textbook:** *Fundamentals of Momentum, Heat and Mass Transfer*, 5th ed. J. R. Welty, C.E. Wicks, R. E. Wilson, G. Rorrer, John Wiley & Sons, Inc. (2008)

### Catalog Description

The basic principles of fluid mechanics and heat transfer are introduced and the analysis and design of equipment using these principles is practiced.

**Prerequisites:** Differential Equations (Math 2403), minimum grade of "C"  
Thermodynamics I (ChBE 2110 or 2130), minimum grade of "C"  
Numerical Methods (ChBE 2120), minimum grade of "C"

**Objectives:** This course introduces the fundamental concepts of momentum and heat transfer as well as their use in typical engineering applications. Special emphasis is put on analogies between the balance equations of fluid flow and heat flow, on dimensional analysis, and the prediction of friction losses. Applications include the analysis and design of flow models, piping networks, packed and fluidized beds as well as insulation and heat transfer devices.

**Learning Outcomes:** By the end of this course, a student will be able to:

1. Design/simulate the operation of process piping systems (estimate frictional losses, size pipes, size pumps, etc.) for the specific flow of liquids and gases. (Student Outcomes: a, c, e, k)
2. Design/simulate the operation of packed beds, fluidized beds, and filters for specified fluid flow rates. (Student Outcomes: a, b, e, k)
3. Design flow models and interpret experimental data using dimensional analysis (Student Outcomes: a, b, e, k)
4. Apply the macroscopic balances of mass, momentum, and energy, as well as the differential continuity equation and the equations of motion to simple systems using both Cartesian and polar coordinates. (Student Outcomes: a, e, k)
5. Apply the Fourier law of heat conduction to homogeneous and heterogeneous objects of various shapes. (Student Outcomes: a, k)
6. Estimate transient and steady state heat transfer rates from/to object such as tanks, pipes, buildings, etc. (Student Outcomes: a, c, e, k)
7. Apply principles of radiative heat transfer. (Student Outcomes: a, k)

## Topical outline

1. Fluid Statics
  - a. Concept of fluid stresses, pressure
  - b. Buoyancy
2. Macroscopic Balance Equations of Fluid Motion
  - a. Macroscopic mass balance
  - b. Macroscopic momentum balance
  - c. Macroscopic energy balance, Bernoulli's equation
3. Shear Stress in Laminar Flow
  - a. Shell momentum balance, velocity profile
  - b. Non-Newtonian fluids, pipe flow
4. Differential Balance Equations
  - a. Differential mass balance: continuity equation
  - b. Shell momentum balance, non-Newtonian Fluids
  - c. Differential momentum balance, Navier-Stokes equations
  - d. Analysis of flow profiles
5. Dimensional Analysis
  - a. Similarity
  - b. Buckingham Methods, Model Analysis
6. Theory and Applications of Viscous Flow
  - a. Boundary layer theory, form drag
  - b. Mechanical energy balance, frictional losses
  - c. Piping networks
  - d. Flow in packed and fluidized beds
  - e. Filtration
  - f. Pumps, developed head, lift, cavitation
7. Steady-state Heat transfer
  - a. Fourier's law of heat conduction, Newton's law of cooling (convection)
  - b. Differential energy balance, steady-state limit
  - c. One-dimensional heat conduction, heat transfer from extended surfaces
  - d. Multi-dimensional heat transfer
8. Transient Heat Transfer
  - a. Heat transfer in the regimes of high, flow and intermediate Biot number
  - b. Boundary layer approach to heat conduction
9. Radiation Heat Transfer
  - a. Black body radiation, Planck's law, Stefan-Boltzmann law
  - b. Kirchhoff's law, radiation heat exchange between real bodies

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