# CHBE 6200

## Advanced Transport Phenomena

**Credit Hours:** 3

**Suggested Prerequisites**

Undergraduate Chemical Engineering Transport I and II
Ordinary Differential Equations
Undergraduate Physics

**Recommended Textbooks**

R.B. Bird, W.E. Stewart, E.N. Lightfoot, "Transport Phenomena", 2nd edition
John Wiley & Sons (2002)
W.E. Deen, "Analysis of Transport Phenomena", 2nd edition, Oxford University Press

**Course Objectives**

Many research and industrial problems in chemical engineering depend on a well-developed knowledge of fluid flow in complex geometries. This course provides an advanced overview of fluid transport phenomena fundamentals and their application to relevant applications. The course will review fundamentals of momentum and mass balances as well as vector and tensor analysis for these expressions. Then students will learn to apply these principles to steady and unsteady unidirectional flow, nearly-unidirectional flow, high Reynolds number flow (Boundary layer theory) and low Reynolds number flow (Stokes flow). The course will also address numerical solution techniques to real-world flow problems.

**Learning Outcomes**

By the end of the course, a student should be able to:

1. Apply momentum balances to a variety of fluid flow systems and problems.
2. Use boundary layer theory to obtain approximate analytical and numerical solutions to momentum balances at high Reynolds numbers.
3. Understand and apply Stokes theory to low Reynolds number flows.
4. Be able to solve steady-unsteady unidirectional flow problems and flow in nearly-unidirectional flow geometries.

**Representative Topics**

1. Review of basic fluid mechanics principles and math

Setting up balances (differential and macroscopic) and concepts of transport. Introduction to tensor and vector calculus; index notation. Fluid Statics.

2. General conservation equations

Kinematic time derivatives, spatial derivatives, transport theorem. Conservation laws in a continuous fluid. Constitutive relationships and boundary conditions.

3. Steady-unsteady parallel (unidirectional) transport

4. Nearly unidirectional transport

5. Boundary Layer (High Re) Theory

Scaling principles. Approximate solution for thermal and momentum B.L. Numerical solution of B.L. equations.

6. Stokes (Re << 1) Flow

Scaling of equations of motion; discussion of properties and physical meaning. Solution of Stokes equations using spherical harmonics; 3D and 2D examples.

7. Computational Methods for solving Transport Phenomena

The Finite Volume Method: application to solving heat transfer problems. Coupled heat-mass-momentum transfer problems using the Semi-Implicit-Method for Pressure-Linked Equations (SIMPLE).

8. Surface Phenomena

Contact angles, Laplace pressure. Motion of bubbles and drops. Surfactants and Marangoni flows. Capillary flows.

9. Non-Newtonian Fluids

Polymeric liquids. Dispersion and emulsion flow.