

Chemical and Biomolecular Engineering 150A
Transport Processes
Spring Semester 2018

Objective: To introduce the basic concepts of fluid mechanics and heat transfer necessary for solution of engineering/science problems.

Text: Required:
Welty, Rorrer, and Foster, "Fundamentals of Heat, Mass, and Momentum Transfer," 6th ed., John Wiley (2015).

Recommended:

1. Bird, Stewart, and Lightfoot, "Transport Phenomena," 2nd ed. John Wiley, NY (2002).
2. Denn, "Process Fluid Mechanics," Prentice-Hall, NJ (1980).
3. White, "Fluid Mechanics," 2nd ed. McGraw-Hill, NY (1986).
4. Middleman, "An Introduction to Fluid Dynamics," Wiley, NY (1998).

Description: CBE 150A discusses fluid mechanics and introduces heat transfer: two processes which together with mass transfer (CBE 150B) comprise the field of transport phenomena. Since the transport or movement of momentum, heat and mass is indigenous to all chemical processing, this course is basic to what follows in the curriculum. In other words, this is really a base course of the curriculum. Text coverage is Chapters 1 – 22, excluding Chapter 10. However, lecture material will not necessarily follow the text. Students are expected to have a working knowledge of simple ordinary differential equations and calculus.

COURSE SCHEDULE

Total Lectures: 40

Week 1:

January 17 Concept of Continuum Mechanics,
Shell Balance for Statics

January 19 Barometric Equation,
Manometer Behavior,
Archimedes Principle

Week 2:

January 22 Plane Couette Flow,
Streamlines,
Stress and Strain,
Newtonian fluids, Viscosity

Fluxes and driving forces in transport process,
Characteristic Time of start up

January 24 Molecular origin of Shear stress and viscosity,
Introduction to Non-Newtonian fluids,
Control Volumes and Macroscopic Balances,
Conservation of Mass

January 26 Spatial Averaging,
Mass Conservation for Steady Flow in a Sudden Constriction,
Transient Emptying of a Liquid from a Tank,
Transient Filling of a Gas Cylinder

Week 3:

January 29 Microscopic Conservation of Mass, Continuity Equation,
Divergence Operator,
Concept of Flow Momentum,
Conservation of Linear Momentum, Collinear Flow

January 31 Steady Flow Through a Contracting Bend (Fluid Control Volumes),
Atmospheric Pressure on a Control Volume
Steady Flow Through a Contracting Bend (Pipe Control Volume)

February 2 Thrust on Nozzle Bolts, Microscopic Conservation of Momentum

Week 4:

February 5 Cauchy Momentum Equation,
Meaning of Gradient Operator,
Conservation of Energy

February 7 Classification and Solution of First Order ODEs
Conservation of Energy

February 9 First Law in Closed and Open Forms: Energy versus Enthalpy Balances
Viscous Heating in a Journal Bearing

Week 5:

February 12 Viscous Heating in a Journal Bearing (Continuation)
Importance of Viscous Dissipation
Adiabatic Filling of a Gas Cylinder

February 14 Adiabatic Filling of a Gas Cylinder (Continuation)

Safety in Pressurized Gas Vessels
The Entropy Balance
Engineering Bernoulli Equation

February 16 Engineering Bernoulli Equation (Continuation)
Bernoulli Equation Along a Stream line
Macroscopic Mass, Momentum and Mechanical Energy Balances to Calculate
Viscous Losses

Week 6:

February 19 Holiday

February 21 Viscous Losses in Fittings and Valves
Dimensional Analysis and Scaling
Power-Product Method

MIDTERM: Mid term 6:00-7:00 p

February 23 Mixing Power to a Stirred Tank,
Geometric and Dynamic Scaling,
Flow in Pipes,
Definition of Friction Factor

Week 7:

February 26 Dimensional Analysis by Buckingham Pi Theorem,
Fanning Friction Charts,
Reynold's Experiment on Turbulence,
Analytic Forms for Friction Factors in Laminar and Turbulent Flow,
Pipe Roughness, Standard Pipe and Tubing Sizes

February 28 Use of Friction Factors for Pipe Flow,
Watering the Lawn,
Viscous Losses in Bernoulli Engineering Equation for Pipes and Fittings

March 2 Tank Loading,
Piping Networks,
Pump Characterization and Sizing

Week 8:

March 5 External Flow,
Stokes Flow around a Sphere,
Form and Friction Drag, Drag Coefficient Graphs for Various Shapes,
Flow Separation and Streamlining,

March 7	Terminal Velocities, Friction Factors in Packed Bed (also in Discussion Sections), Fluidized Beds
March 9	Microscopic Balances, Shell Balances of Mass and Momentum in Plane Couette Flow, Continuity Equation, Cauchy Momentum Equation, Velocity and Shear Stress Profile in Plane Couette Flow, Boundary Conditions
<u>Week 9:</u>	
March 12	General Continuity and Cauchy Momentum Equations General Relation between Shear Stress and Shear Rate for Newtonian Fluid Navier-Stokes Equations, Examples: Hagen-Poiseuille Flows
March 14	Substantial Derivative, Navier-Stokes equations: A Rotating Spindle Viscometer
March 16	A Rotating Spindle Viscometer and Cavitation, Non-Newtonian Power-Law Fluid Flow in a Pipe
<u>Week 10:</u>	
March 19	Boundary Layer on a Flat Plate, Scaling Behavior, Drag Coefficient
March 21	Adverse Pressure Gradients, Boundary Layer Separation and Streamlining, Turbulent Momentum Transfer Characteristics
March 23	Time Averaging Continuity and Cauchy Momentum, Reynolds Stresses, Eddy Viscosity, Turbulent Boundary Layer on a Flat Plate
<u>Week 11:</u>	
March 26	Spring Recess
March 28	Spring Recess
March 30	Spring Recess
<u>Week 12:</u>	
April 2	Heat Transfer Modes: Conduction, Convection, Radiation and Fourier's Law, Heat Transfer Coefficients: Newton's Law, Stefan-Boltzmann Radiation,

Boundary Conditions,
Microscopic Thermal Energy Balance

April 4 Steady Conduction Between Two Plates,
Boundary Conditions of the First, Second and Third Kinds,
Heat Conduction in a Composite Wall

MIDTERM: Mid term 6:00 – 7:00p

April 6 Heat Conduction in a Composite Wall,
Overall Heat Transfer Coefficient,
Concept of Thermal Resistance,
Analogy to Electrical Circuits

Week 13:

April 9 Conduction in a Rectangular Fin,
Biot Number,
2nd order ODEs with Constant Coefficients,
Fin Efficient and Enhancement Factors

April 11 Meaning of Biot Number,
An Annular Chemical Reactor

April 13 Transient Heating of a Plate,
Isothermal Boundary Conditions,
Separation of Variables, Fourier Series Expansions

Week 14:

April 16 Definition of Heat Transfer Coefficient,
Bulk or Adiabatic Mixing Cup Temperature,
Logarithmic Mean Temperature

April 18 Dimensional Analysis of Convective Heat Transfer,
Nusselt Numbers,
Heat Transfer Coefficient Correlations

April 20 Thermal Boundary Layer on a Flat Plate,
Role of Prandtl Number,
Local and Average Heat Transfer Coefficient

Week 15:

April 23 Power-Law Dependence of Nusselt Number on Reynolds and Prandtl Numbers
Double Pipe-Heat Exchangers: Co and Counter Current Flow,

Logarithm Mean Temperature Driving Force

April 25

Double-Pipe Heat Exchanger Design,
Overall Heat Transfer Coefficient from Individual Heat Transfer Coefficients,
Exchanger Sizing and Duty,
Actual Shell and Tube Heat-Exchangers

April 27

Shell and Tube Heat Exchanger Design
True-Mean Temperature Driving Force,
Extended-Area Heat Transfer

Week 16:

RRR Week

FINAL EXAMINATION:

May 7:

7-10 p