ABE 307

MOMENTUM TRANSFER IN FOOD AND BIOLOGICAL SYSTEMS

Lecture 1 : August 21st 2017

Transport Phenomenon

- In Engineering three types of transport phenomena are encountered :
  - Transport of Momentum : Fluid Dynamics
  - Transport of Heat : Heat Transfer
  - Transport of Mass : Mass Transfer
- Any real engineering design such as Food processing or biological systems or reaction system will involve one or all flows depending on the conditions.
- Focus of this course : Momentum Transport which is basically how forces are acting on system to move the system.

Fundamental Mechanisms Behind Transport Phenomenon

- For each transport phenomenon there is a driving force.
- On a fundamental level, each flow has a molecular origin which is the molecular interaction defining the properties of
  - Viscosity : Important for Momentum Transport
    - We will learn about molecular and bulk transport of momentum
  - Thermal Conductivity : Important for Heat Transfer
  - Diffusion/Diffusivity : Important for Mass Transfer

Scales of Study

- When you study a system or you want to design a system for a particular purpose : such as moving fluid from one place to another you can think about different scales to be able to design the right system.
- Choice of scale will depend on your purpose.
- In this course, we will see how analysis at different scales are giving different information to be used.

Scales of Study contd…

- Macroscopic : High level, study inputs and outputs. This we will cover as Macroscopic Balance equations. Very useful in studying very complex geometries of instruments etc to analyze energy and mass for the system.
- Microscopic : Instead of studying whole system, interest is to study a small section to understand what is happening in that part. This is generally used to diagnose the impact of a part of system or enhance design to change flow in a small part. For this, we study "Equations of Change". Most important topic for understanding any transport phenomenon.

Scales of Study contd…

- Molecular : Developing more fundamental understanding of a particular transport phenomenon such as at molecular level. Specifically important to understand the role of complex molecules, extreme physical conditions where standard equations do not apply. First principle understanding. We will see this as "Newton's Law of Viscosity" which is the molecular theory for fluid flow properties applicable to certain kind of fluid.
- At each scale conservation laws are applied.

Relation Between Multiple Scales

- Molecular theories are used to develop equations at microscopic scale
- Equations from microscopic scale are used to write balances at macroscopic scale.

Types of Flows Encountered in Real Situations

- Pure fluids at constant Temperature
  - Emphasis on Viscous and Convective momentum transport.
- Pure fluids with Varying Temperature
  - Along with momentum, emphasis on conductive, convective and radiative energy transport.
- Flow of fluid mixtures with varying composition.
  - Emphasis on diffusive and convective mass transport.

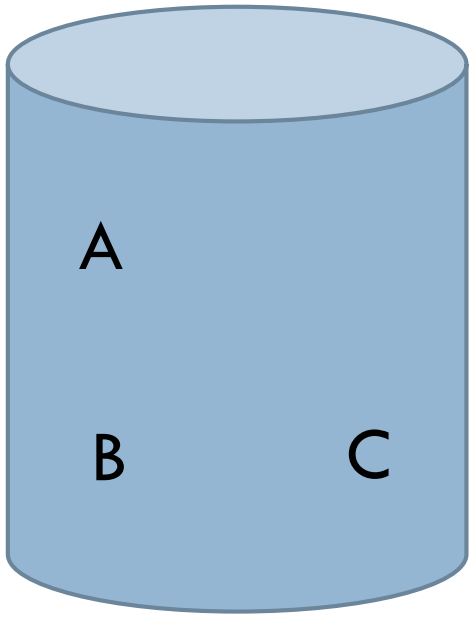
What you should be able to do after this course ?

- Be able to look at an engineering problem and choose appropriate theories to analyze the fluid flow problem for design of flow requirements.
- Be able to choose appropriate scale for analysis and apply relevant equations or method learnt in class.

Where will the pressure be higher ?

- A or B ?
  - B
- B or C ?
  - Same

In fluid statics, we will learn about pressure variation in static fluids, general equation derivation, proofs and calculation.



A Storage Tank for Fluid

Why is it useful as engineers ?

To design pressure measuring devices and appropriate systems to handle pressure for static fluids.

What is swimming ?

- Swimming in scientific term is moving a body through a “static” fluid (such as in pool, or lower depth in scuba diving) or turbulent fluid (such as in ocean).
- Front crawl – What happens in front crawl ?
  - Momentum gained by swimmer is transferred to fluid which provides force (by Newton’s third law) to move the swimmer forward.
  - Essentially a solid-liquid interaction for momentum transfer.
  - Forces – Buoyancy force , Drag force (or resistance of water) , force in forward direction exerted by swimmer
  - Drag force reduces the momentum build up

In Fluid Mechanics we will study all these mechanisms of momentum transfer (only in fluids), mechanisms of drag forces, effect on velocity profile, effect of solid object such as fluid flowing in closed pipes, channels etc.

http://www.explainthatstuff.com/swimming-science.html

Specific Course Learning Objectives

- Fluid Statics
  - Fluid at rest and associated forces.
  - Pressure Variation in static fluid.
  - Measurement Devices for Pressure and Specific gravity
- Fluid Dynamics : Momentum Transfer
  - Molecular theory for Fluid Flow
  - Velocity Profiles in Different Flow Conditions
  - Equations of Change : Microscopic Balances (Most Important topic for Transport Phenomenon)
  - Dimensional Analysis
  - Friction Factors
  - Macroscopic Balances

Logistics

EMERGENCY PREPAREDNESS – A MESSAGE FROM PURDUE

To report an emergency, call 911. To obtain updates regarding an ongoing emergency, sign up for Purdue Alert text messages, view www.purdue.edu/ea.

There are nearly 300 Emergency Telephones outdoors across campus and in parking garages that connect directly to the PUPD. If you feel threatened or need help, push the button and you will be connected immediately.

If we hear a fire alarm during class we will immediately suspend class, evacuate the building, and proceed outdoors. Do not use the elevator.

If we are notified during class of a Shelter in Place requirement for a tornado warning, we will suspend class and shelter in [the basement].

If we are notified during class of a Shelter in Place requirement for a hazardous materials release, or a civil disturbance, including a shooting or other use of weapons, we will suspend class and shelter in the classroom, shutting the door and turning off the lights.

Please review the Emergency Preparedness website for additional information.
http://www.purdue.edu/ehps/emergency_preparedness/index.html

Tips for Making Fluid Mechanics Easy

- Remember to relate all mathematical equations to a physical system.
- If the reason behind a step is not clear, stop the instructor and ASK !
- No substitute for Hand Writing ! When given handouts in class, always fill in the lecture in your own hand writing. Again, if not clear, ASK !
- Attempt HW problems on your own before working in group to match solutions (Collaborative learning helps when you have thought about the problem in advance)
- Occasionally problems will be given in class. Class Problems are also not graded, so solve it on your own or in group in Class.

Transport Phenomenon for Food and Biological Engineers

- https://www.youtube.com/watch?v=KjTJH5mC0_k