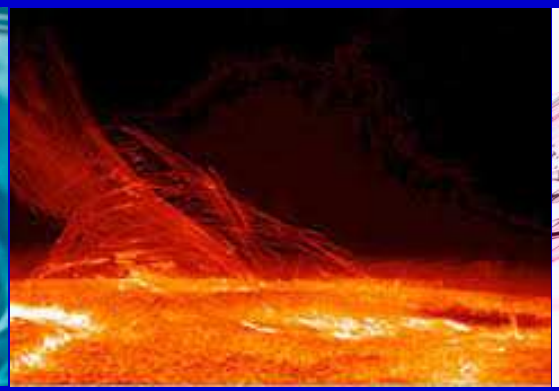
MAE309

General Principles of Transport Phenomena

输运现象原理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Preface

- Office Hour
  - Thursday 7-9 pm
- Venue
  - Room 505 Level 5, N15
- What can we discuss during office hour
  - Questions on lecture notes and references
  - Homework problems
  - Discussions on related transport topics (in your other projects, research ideas ...)

Preface

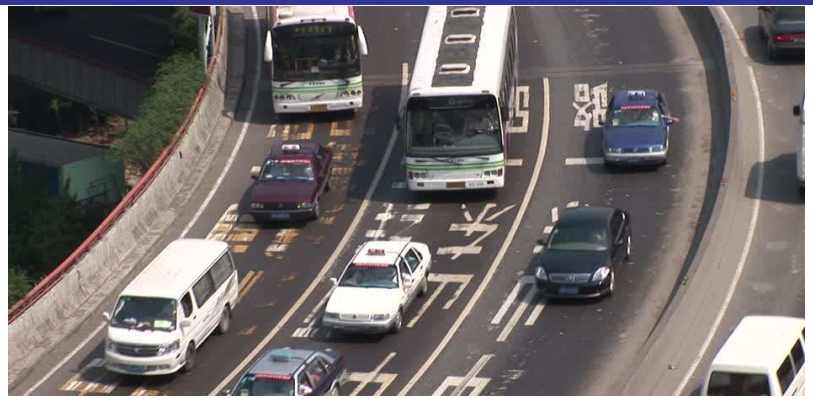
Transport Phenomena

Definition of 'transport' in dictionary

Transport (传输、输运):

To carry someone (people) or something (goods) from one place to another

Preface



Preface

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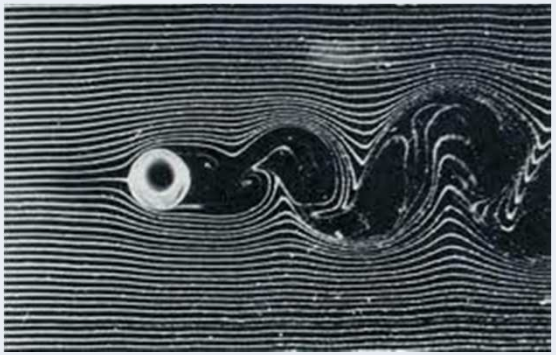
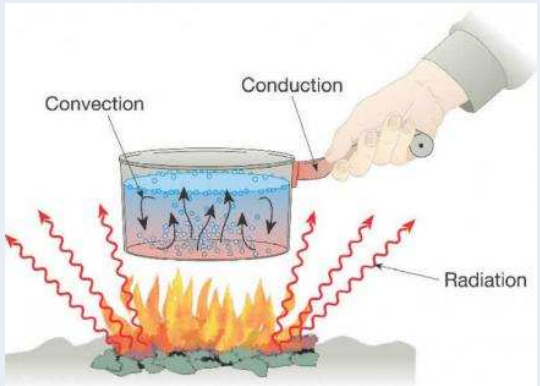
In this class, the ‘people or goods’ which we are going to move are : **momentum**, energy, and mass

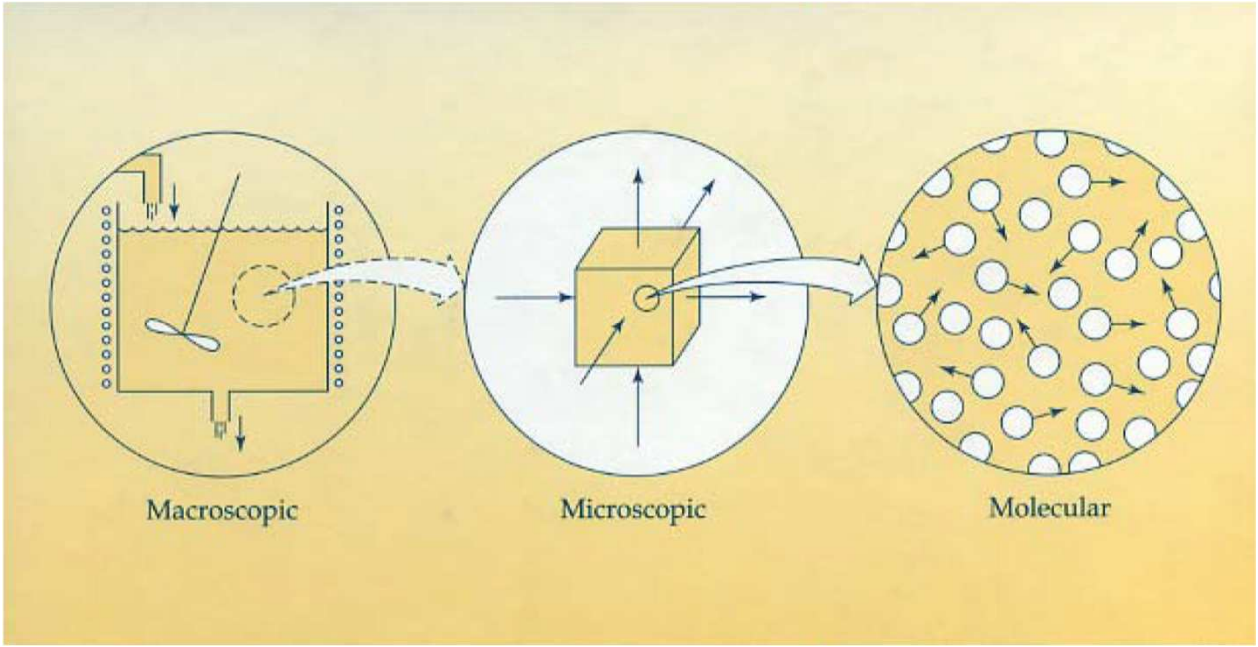
Preface

- What are the transport phenomena?
  - The subject of transport phenomena includes three closely related topics: fluid dynamics, heat transfer, and mass transfer.

Fluid Dynamics	Heat Transfer	Mass Transfer
transport of momentum	transport of energy	transport of mass of various species
		

Preface

- Three levels at which transport phenomena can be studied
  - Macroscopic level: length scales centimeter or meters
  - Microscopic level: length scales micron to centimeter
  - Molecular level: length scales 1 to 1000 nanometers

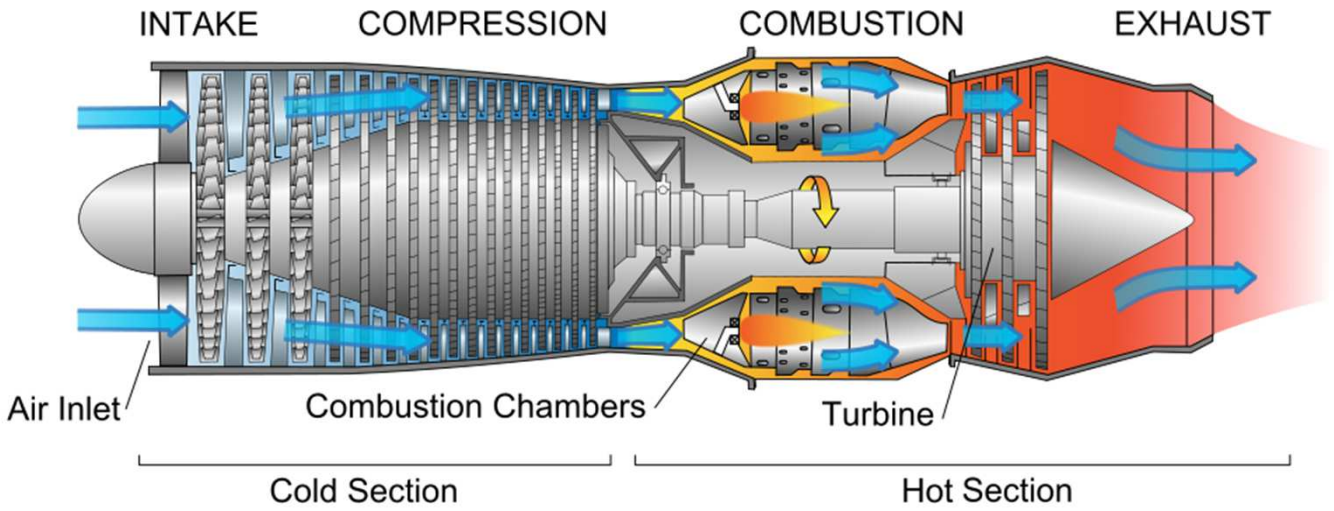


Preface

- Why should these three transports be studied together:
  - They frequently occur simultaneously.
  - The basic governing equations that describe the three transports are closely related.
  - The mathematical tools needed for describing these phenomena are very similar.
  - The molecular mechanisms underlying the various transport phenomena are very closely related.

Preface

- Mechanics and Aerospace Engineering
  - Turbine Combustion
    - ✓ Airflow intake (momentum transfer).
    - ✓ Mixing of air and fuel (mass transfer).
    - ✓ Combustion process (heat transfer).
    - ✓ Exhausting gases (momentum, heat, and mass transfers).
    - ✓ ……

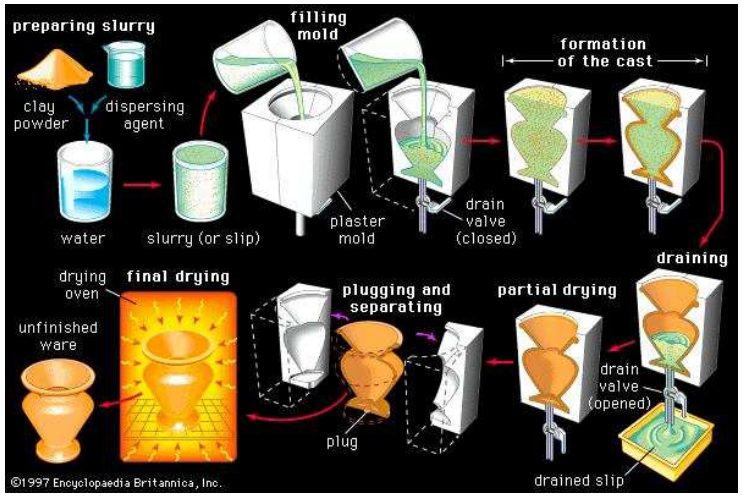


Preface

- Mechanics and Aerospace Engineering
  - In-flight aircraft icing
    - ✓ Airflow with supercooled droplets (momentum and mass transfer).
    - ✓ Formation of water ice on the surfaces of an aircraft (heat transfer).
    - ✓ ……

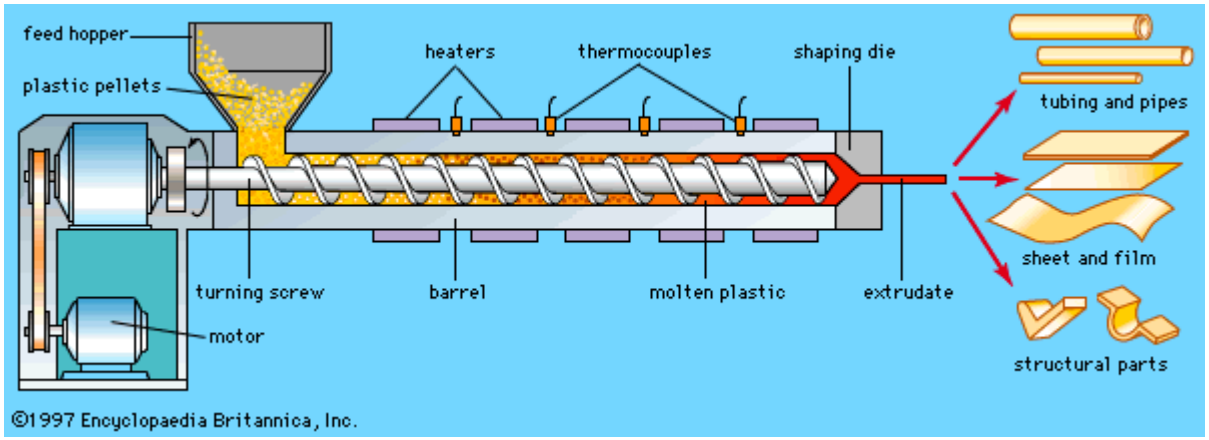
Preface

- Materiel Science and Engineering
  - Ceramic Processing
    - ✓ Mixing clay powder with dispersing agent (momentum and mass transfers).
    - ✓ Filling mold (momentum and mass transfers).
    - ✓ Drying: removing the water or binder from the formed material (momentum, heat, and mass transfers).
    - ✓ ……



Preface

- Materiel Science and Engineering
  - Plastic Processing
    - ✓ Heating plastic pellets until they are molten (momentum, heat, and mass transfers).
    - ✓ Flow of the molten plastic (momentum transfer).
    - ✓ Cooling of the products (heat transfer).
    - ✓ ……

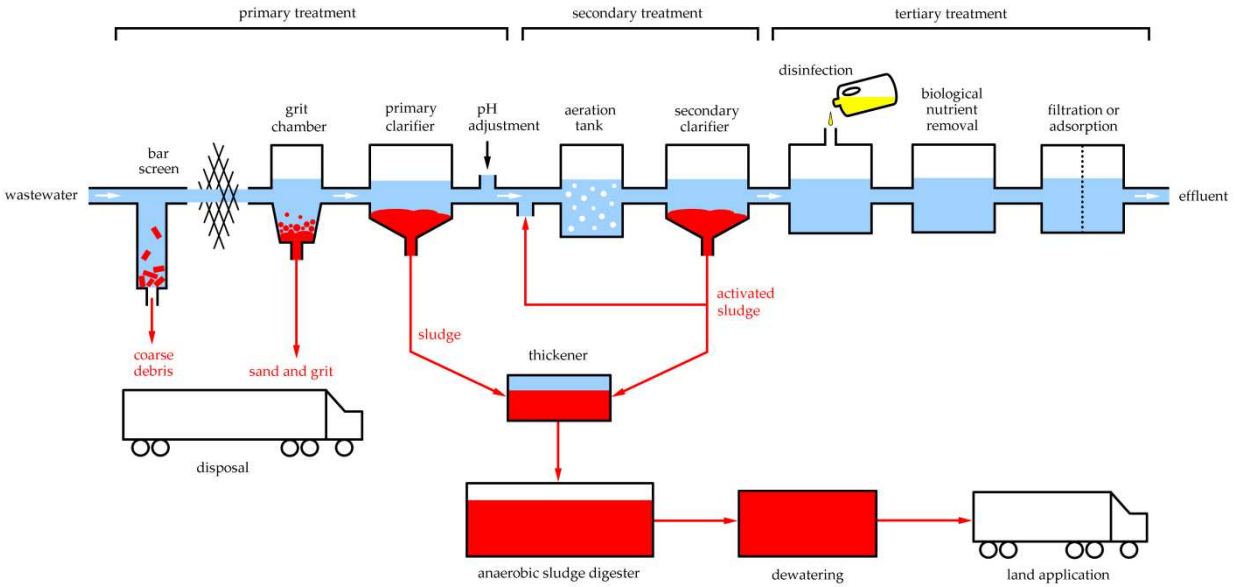


Preface

- Environmental Science and Engineering
  - Volcano Eruption
    - ✓ Flow of hot lava (momentum transfer)
    - ✓ Transport of volcano ash (mass transfer)
    - ✓ Heat transfer from hot lava (heat transfer)
    - ✓ Natural convection (momentum transfer and heat transfer)
    - ✓ …

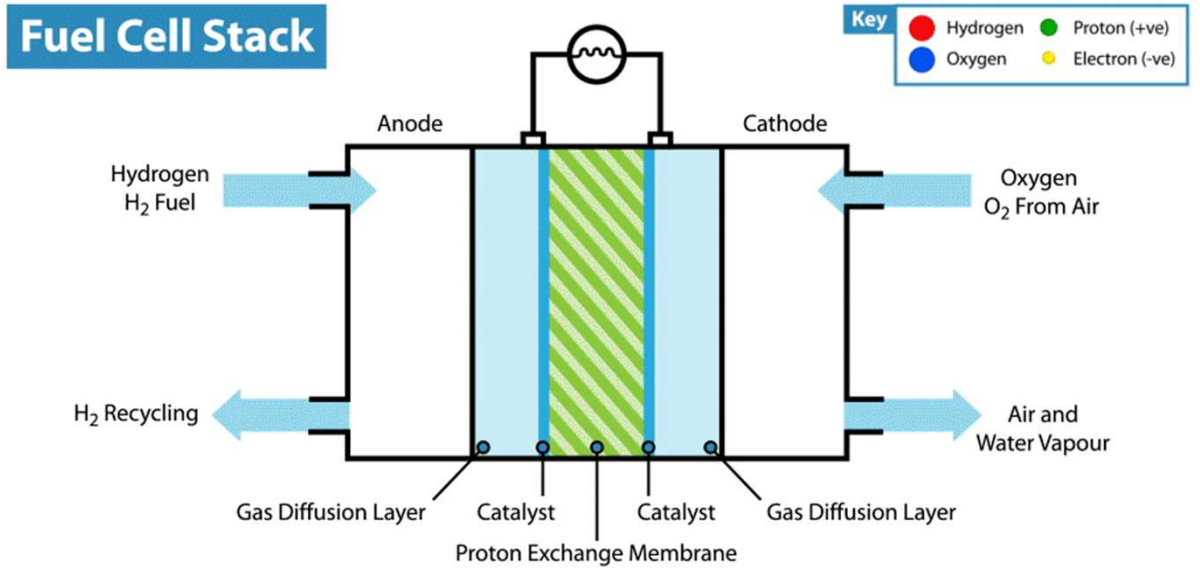
Preface

- Environmental Science and Engineering
  - Waste Water Treatment
    - ✓ Flow of waste water (momentum and mass transfer).
    - ✓ Chemical and biological treatments (heat, momentum, and mass transfer).
    - ✓ Sediment process (momentum and mass transfer).
    - ✓ …



Preface

- Mechanical and Energy Engineering
  - Fuel Cell
    - ✓ Hydrogen and oxygen flow (momentum transfer).
    - ✓ Heat generation due to reaction (heat transfer).
    - ✓ Air and water flow from outlet (momentum and mass transfer).
    - ✓ …



Preface

- Chemical Engineering
  - Refining of crude oil
    - ✓ Flow of crude oil (momentum transfer).
    - ✓ Distills the incoming crude oil into various fractions for further processing (heat and mass transfer).
    - ✓ Adds or removes chemicals from the various fractions (momentum and mass transfer).
    - ✓ …

Preface

- Summary of Important Examples
  - Aerospace engineering: turbine engine, in-flight icing, space shutter ...
  - Materials processing and production: metal, ceramic, polymer ...
  - Environment science and engineering: volcano, water treatment, underground water pollution ...
  - Chemical engineering: petroleum refinery ...
  - Energy engineering: fuel cell, chemical batteries ...
  - Bioengineering: artificial organ, blood system, drug delivery ...

Preface

- Technical Disciplines
  - Mechanics and Aerospace Engineering
  - Materials Science and Engineering
  - Environmental Science and Engineering
  - Mechanical and Energy Engineering
  - Biomedical Engineering
  - Marine Science and Ocean Engineering
  - Chemical Engineering
  - ……

Preface

- Similar Governing Equations
  - Conservation law can apply to three transports
    - ✓ A particular measurable property of an isolated physical system does not change as the system evolves over time.
    - ✓ Conservation of momentum: Navier-Stokes equation in fluid dynamics
    - ✓ Conservation of energy: heat transfer equation
    - ✓ Conservation of species: mass transfer equation

Preface

- Similar Molecular Mechanisms

Comparison of diffusion phenomena

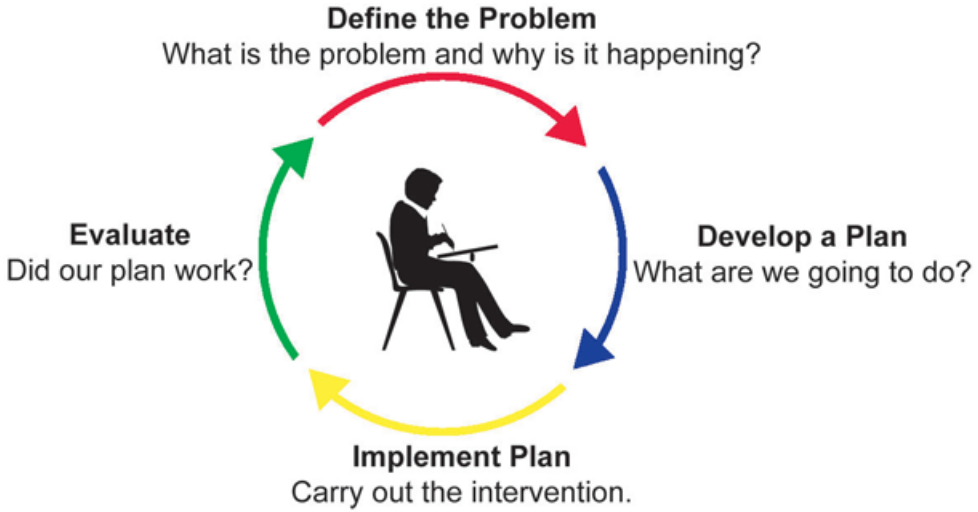
Transported quantity	Physical phenomenon	Equation
Momentum	Shear Stress (Newtonian fluid)	$\tau = \mu \frac{\partial u}{\partial x}$
Energy	Heat conduction (Fourier's law)	$q = k \frac{\partial T}{\partial x}$
Mass	Molecular diffusion (Fick's law)	$J = D \frac{\partial C}{\partial x}$

Preface

- Pre-requisites
  - Math such as vector, calculus, ordinary and partial differential equation.
    - ✓ GE101
    - ✓ GE102
  - Physics such as thermodynamics.
    - ✓ PHY101
    - ✓ PHY102

Preface

- Objectives
  - Provide students with basic principles of the three transfers encountered in engineering, momentum, heat and mass transfers.(Success in your exam)
  - Help students to develop critical thinking skills by solving transport phenomena problems taken from the fields of engineering, using analytical methods. (Success in your future career)



Preface

- Learning Outcomes
  - Students can understand the basic concepts on transport phenomena.
  - Students can identify the mechanism of an engineering transport phenomenon and construct the proper model for it.
  - Students can apply the knowledge from pre-requisite as a tool to solve the model defined above.

1. Good marks in your exam (Level 1).
2. Apply the knowledge of transport phenomena to solve the related problems in your job (Level 2).
3. Apply the skills developed in this course to solve other challenge problems in your future career (Level 3).

Preface

- Syllabus
  - Introduction
  - Basic Concepts on Fluid Mechanics
  - Fluid Statics
  - Conservation Law
  - Laminar Flow
  - Turbulence Flow
  - Heat Conduction
  - Forced Convection
  - Natural Convection
  - Radiation
  - Heat Transfer with Phase Change
  - Diffusion
  - Mass Convection
  - Multiphase Flow

Preface

- Textbook and References
  - No Textbook.
  - A lot of references:
    - ✓ R. Byron Bird, Warren E. Stewart, Edwin N. Lightfoot, Daniel J. Klingenberg, Introductory Transport Phenomena, Wiley, 2014.
    - ✓ Pijush K. Kundu, Ira M. Cohen, David R Dowling, Fluid Mechanics, Elsevier, 2012
    - ✓ Joseph Katz, Introductory Fluid Mechanics, Cambridge University Press, 2013
    - ✓ Adrian Bejan, Heat Transfer, Wiley, 1993
    - ✓ Hans Dieter Baehr, Karl Stephan, Heat and Mass Transfer, Springer 2006
    - ✓ Many others ……
  - Many other materials online

Preface

- Tutorials
  - Fluid Mechanics
  - Heat Transfer
  - Mass Transfer

- Three groups
  - There are more than 100 students from three departments MAE, MSE, ESE.
  - Randomly divided into three groups.
  - Each TA will teach tutorials in one group.

Preface

MOOC Course: Basics of Transport Phenomena from Delft University of Technology

Course starts on October 21, 2016

https://www.edx.org/course/basics-transport-phenomena-delftx-tp101x

Preface

- Evaluation
  - Attendance 10%
  - Projects (term paper) 20%
  - Homework 10%
  - Midterm exam 20%
  - Final exam 40%
- You pass this course, if you attend all the classes, finish all project and homework.
- You fail this course, if you cheat in exam, plagiarize homework, directly copy materials online for your project.

Preface

- How to succeed in this course
  - Preview lecture notes before the class.
  - Come to all lectures and listen attentively in class – do not play your mobile please!
  - Review lecture notes and read reference books.
  - Work on all homework problems.
  - Discuss with peers and attend the office hours when have questions.
  - Connect what you have learned to the phenomena occur in the applications related to your own major and in everyday life.

Preface

- How to write a good term paper
  - Find a topic which you are interested in
    - ✓ Related to transport phenomena
    - ✓ Related to your discipline or everyday life
    - ✓ Make it as creative as possible
  - Do your research
    - ✓ Understand the background to the topic
    - ✓ Find out what future research is
    - ✓ Search what are the possible solution
  - Final Write-up
    - ✓ Develop an outline
    - ✓ Introduce your own opinion in the term paper
    - ✓ Prove your opinion
    - ✓ Strength your conclusion

Preface

- Term Paper
  - Discuss transport phenomena related to your discipline or your everyday life.
  - At least include one of the three transport phenomena (fluid dynamics, heat transfer or mass transfer).
  - Decide the title yourself.
  - 10-20 pages (A4 paper).
  - Please DO NOT Plagiarize!!!