University of Waterloo
Department of Chemical Engineering
ChE 313 - Applications of Heat and Mass Transfer, Winter 2024, Jan 8 – Apr 8
Course Outline and Information

INSTRUCTOR: Prof. Boxin Zhao, Ext. 38666; Email: zhaob@uwaterloo.ca;
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LECTURES: Tuesdays, 10:30am – 12:20pm, AL-208, starting on Jan 9
Thursdays, 10:30am – 11:20am, MC -4060

TUTORIALS: Thursdays, 11:30am – 12:20pm, MC -4060, starting in the 2nd week
Note that we will have a lecture in the tutorial section in the first week.

OFFICE HOURS: Tuesdays, 9:30am – 10:20am starting in the 2nd week

TEXT: 1) Fundamentals of Momentum, Heat and Mass Transfer, Welty, Rorrer, and Foster, Sixth Edition, Wiley. **(Primary Textbook)**

2) Fundamentals of Heat and Mass Transfer, Incropera, DeWitt, Bergman, and Lavine, Sixth Edition (2007), Wiley. (Optional)

Exams/quizzes/assignments

Tests are open book in that you may consult your textbook, course notes, and materials posted in the course LEARN site. Use of any other resource (including file-sharing services such as chegg.com, coursehero.com, stackexchange.com, ...) is prohibited. You may not communicate directly or indirectly with any person except the course instructor.

Bonus case studies:

Voluntary case studies of Heat and Mass Transfer (e.g. daily life experience, particular industrial scenarios). To encourage students to think critically and energize the learning/teaching environment, each student can make a voluntary in-class presentation of their case studies (1-2min), starting after the mid-term exam (email two ppt slides to Instructor one day ahead)

A bonus of 2 marks for the in-class presentations

MARKING SCHEME:

Item	% Total Mark	Comments
Assignments	10	About 6 assignments*
Quizzes/Tutorials	10	About 4 quizzes**
Midterm	25	
Final	55	
In-class presentation	2	Bonus mark***

Note:
* Equal marks for each assignment
** Equal marks for each quiz
***The total mark is capped at 100 even though your mark might be above 100 due to the bonus.

Assignment due date:

Jan 23, Feb 6, Feb 13, Mar 7, Mar 19, Apr 4 (will be posted on Learn in a week before the due date, **submit in the class**): otherwise, it will be announced in the class

Quizzes:

Jan 25, Feb 8, Mar 14, Mar 28; otherwise, it will be announced in the class.

Reading week: Feb 17, 2024 to Feb 25, 2024

Midterm Exam Date: Feb 29, 2024

Final Exam Date: Scheduled by the Registrar's Office

PLAGIRISM/ACADEMIC OFFENCES:

Though you are encouraged to work in groups, you must present your own work in assignments and quizzes.

There will be a **zero tolerance** approach taken to cases of plagiarism and other offences. For more information, please refer to policy 71:

http://www.adm.uwaterloo.ca/infosec/Policies/policy71.htm

For a list of what type of offences happened and the consequences:

http://www.adm.uwaterloo.ca/infosec/students/UCSA_2004-05.pdf

COURSE OUTLINE:

Convective heat transfer. Analysis of convective heat transfer in external flows using boundary layer approach. Analysis of convective heat transfer in internal flows. Empirical correlations for convective heat transfer. Heat exchanger design. **Convective mass transfer.** Empirical correlations for convective mass transfer. Mass transfer at fluid-fluid interfaces. Analogy between heat-transfer, mass transfer and momentum. Dimensional analysis. Simultaneous heat and mass transfer operations.

Prereq: 3B Chemical Engineering

1. Introduction to Heat Transfer and Review of Conductive Heat Transfer

   Modes of heat transfer: conductive, convective and radiative
   Fourier's law of heat conduction
   Heat diffusion equation
   Conductive thermal resistance

2. Convective Heat Transfer (Text Ch.19)
   Fundamental considerations - thermal boundary layer
   Dimensional analysis of convective heat transfer
   Boundary layer equation for laminar flow
   Energy and momentum transfer analogies
   Turbulent flow considerations

3. Convective Heat-Transfer Correlations (Text Ch.20-21)
   Forced convection for external flow
   Forced convection for internal flow
   Natural or free convection
   Boiling and condensation

4. Heat Exchangers (Text Ch.22)
   Single-pass heat-exchangers analysis: the log-mean temperature difference
   Shell-tube heat exchanger analysis and design
   The NTU method of heat-exchanger analysis and design

5. Introduction to Mass Transfer and Review of Molecular Diffusion
   Modes of mass transfer: diffusion and convection
   Fick's law of diffusion
   Fick's second law of diffusion

6. Convective Mass Transfer (Text Ch. 28-29)
   Fundamental considerations - film theory, penetration theory, and boundary layer model
   The mass-transfer Nusselt number
   Dimensional analysis of convective mass transfer

Boundary layer equation for laminar flow
Concentration and momentum transfer analogies
Turbulent flow considerations
Interphase mass transfer

7. Convective Mass-Transfer Correlations (Text Ch. 30)
   Forced convection for external flow (plates, spheres and cylinders)
   Mass transfer involving flow through pipes
   Mass transfer in packed towers and fluidized beds
   Mass transfer operation in well mixed tanks

8. Mass Exchangers (Text Ch.31)
   Types of mass-transfer equipment
   Analysis and design of gas-liquid mass transfer operation in well mixed tanks
   Analysis and design of continuous-contact tower

Course Learning Outcomes

After successful completion of this course, students will be able to:

- Identify and solve heat and mass transfer problems relevant to technology ad society
- Analyze boundary layer flows, the relative thicknesses of the thermal and hydro- dynamic boundary layers and their effect on estimation of the convective heat transfer coefficients.
- Analyze and estimate convective heat transfer coefficients for internal and external flows
- Apply correlations for convective heat transfer coefficients in applications involving phase change such as boiling and condensation.
- Analyze and design heat transfer equipment (e.g. double pipe heat exchangers, shell and tube heat exchangers) used in process plants.
- Evaluate mass transfer problems by analogy to heat transfer.
- Analyze and design mass transfer equipment such as packed columns