Course CHE 325 – Chemical Reaction Engineering

**Semester Spring 2019**

**Course Format** 3 hr Lecture

**And Credit hours:** 3 hr Credit

**Co-requisites** CHE 312

**Instructor:** Dr. David J. Klinke II, ESB 517 Evansdale and BMRF 219 Health Sciences

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**Class Schedule:** Tuesday 11:00 – 12:15 pm

 Thursday 11:00 – 12:15 pm

**Location**  Room 135 Advanced Engineering Research (AER) Building

**Office Hours:** Monday 3:00-5:00 or by appointment

**Course Goal:**

In this course, students will learn to apply knowledge of mass and energy balances, chemical kinetics, and chemical reaction equilibrium to achieve the design objectives for isothermal and nonisothermal batch, plug flow, and continuous stirred tank reactors.

**Teaching Approach:**

Chemical reaction analysis and reactor design is unique to chemical engineering. There are relatively few concepts and design equations that are needed to describe most situations at the undergraduate level. However, there are many different reactors and reactor situations. This course starts with a rigorous mathematical development of the defining design equations and then this set of equations is used to solve problems in the different reactors and reactor situations. The course strives to show how simple and complex problems are solved with the same set of equations and how the concepts learned on one system are directly applicable to other systems. By completing the homework exercises, you will develop proficiency in applying the concepts presented in the lectures and the text. Problems that you will encounter in the future may be more time consuming to solve, but they will not be any more difficult conceptually.

**Knowledge, Abilities, and Skills Students Should Have Entering this Course**

1. A comprehensive knowledge of transport phenomena is essential. This course relies on shell balances and the constituent equations to develop the material and energy balances for the various reactors, and to develop the balances in heterogeneous catalysts that account for diffusion with reaction. Transport phenomena concepts are used to appreciate the consequences of turbulent flow on velocity, temperature and concentration profiles that form the basis of the one-dimensional models (CHE 310, CHE 311, and CHE 315).

2. Knowledge of heat transfer processes is needed for nonisothermal reactors (CHE 311 and CHE 315).

3. Understanding of reaction equilibria and heat of reaction is required (CHE 320 and CHE 326).

4. The ability to solve linear differential equations by hand (MATH 261).

5. The ability to solve ODEs using explicit numerical methods and to have a working knowledge of how these methods work (CHE 230).

6. The ability to solve sets of linear and nonlinear algebraic equations using numerical methods (CHE 230).

7. The students need an appreciation of numerical optimization techniques (CHE 230).

8. The students need to have a working knowledge of MATLAB and CHEMCAD numerical software that operates on the computers in the Departmental Computer Laboratory (CHE 230).

**Course Objectives (ABET Outcomes):**

1. Students will be able to apply material balances to model ideal reactors such as batch reactors (BR), plug flow reactors (PFR), and continuous stirred tank reactors (CSTR) (Outcome 1).

2. Students will be able to design ideal isothermal, isobaric BRs, PFRs, and CSTRs (Outcome 1).

3. Students will be able to design ideal isothermal, non-isobaric BRs, PFRs, and CSTRs (Outcome 1).

4. Students will be able to design ideal, multiple reactor schemes (Outcome 1).

5. Students will understand selectivity and yield for multiple reactions and how to choose reactor conditions and design reactors to maximize one or both of these parameters (Outcome 1).

6. Students will be able to design non-isothermal, BRs, PFRs, and CSTRs (Outcome 1).

7. Students will be able to design reactors under non-steady-state conditions (Outcome 1).

8. Students will understand the effects of diffusion on reactions and on reactor behavior (Outcome 1).

9. Students will be able to design heterogeneous, catalytic reactors (Outcome 1).

10. Students will use software and other numerical methods to study, understand, and explain the behavior of chemical reactors (Outcomes 1 and 7).

11. Students will gain an appreciation for the environmental and safety aspects of chemical engineering through solution of applicable reactor design problems (Outcome 2).

12. Students will be able to apply the above knowledge to the solution of a design problem (Outcomes 1, 7).

13. Students will increase their proficiency in oral and written communication (Outcome 3).

14. Students will become more proficient at working in groups (Outcome 5).

15. Students will be able to use Matlab to solve the above problems (Outcome 7).

**Required Text:**

Fogler, H.S., *Elements of Chemical Reaction Engineering*, Prentice Hall PTR, 2016. [defined in class notes as HF]

**Related Texts and Recommended Reading:**

*Safety, Health, and Loss Prevention in Chemical Processes*, Center for Chemical Process Safety of the American Institute of Chemical Engineers, 1990. [SHLP]

**Grading :** 2 Exams (@ 25 % each) 50 %

Homework Problem Sets 10 %

Design Project 15 % due April 18, 2019

Final Exam 25 % May 2, 2019 (8:00 – 10:00 am)

100 %

**Grade Assignment :** 100 – 90 A

 89 – 80 B

 79 – 70 C

 69 – 60 D

 59 – 0 F

**Grading Policy :** No make-up exams except by prior arrangement with instructor

Late assignment = no assignment

Exam grading appeals must be submitted in writing on the week that the exam is returned. The appeal must include a cover letter explaining the reason for re-grading. If you miss that window or do not follow these guidelines, you lose the opportunity for re-grading. Note that some exams may be copied prior to returning to the student for accreditation purposes.

**HW Assignments**: Weekly homework assignments are an opportunity to develop intuition from new concepts by actively applying the new concepts to solve problems and answer questions. The process of actively struggling with the use of new ideas until you understand them is an effective and rewarding form of education. Homework assignments will be typically due one week after assignment and are due at the beginning of class or at the stated time. (Typically there will be 10 homeworks. Each will be worth the same amount resulting in the total worth equal to 10% of the final grade). Homework problems will be chosen for their educational value. **If you skip the process of personally struggling with the use of new concepts, you will have destroyed your most important educational experience.** Reading someone’s solution to a problem **or copying the solution available on the internet is not educationally equivalent to generating your own solution.** I encourage students to work together to understand the concepts in the homework. However, each student should work out his/her own solutions. Submitted homework should reflect your own work. Assignments that are obviously copied will receive no credit.

**HW Format**: Use a clean sheet of paper, one side of each page; begin each problem on a new page, and box the final answers. Staple the pages together and put your name, the problem set number, and the date on the top of the front page. Number and include your name on subsequent pages.

**Exams:** There will be two exams during the semester and a comprehensive final exam. All exams will be open-book, closed-notes. Besides a calculator, no electronic texts or devices will be allowed. While taking the exams, students will not be allowed to leave the classroom. Students deemed to have performed academic misconduct will be reported to the Office of Student Conduct.

**Design Project:** During this course, you are expected to work in a group of 3 or 4 students to solve a design problem covering material presented in this course. The problem statement will be given to you in approximately the 10th week of the semester. A written report will be due to the instructor on the Thursday of the week before dead week. You and your group members will also be required to present the results of your work in a formal oral presentation to the instructor a week before the project is due. If you do not participate in the design project as part of your assigned group, your grade for the entire course will automatically be an F, regardless of other grades earned in this class.

**Attendance Policy:** Consistent with WVU guidelines, students absent from regularly scheduled examinations because of authorized University activities will have the opportunity to take them at an alternate time. Make-up exams for absences due to any other reason will be at the discretion of the instructor.

**Academic Integrity**

**Statement :** “The integrity of the classes offered by any academic institution solidifies the foundation of its mission and cannot be sacrificed to expediency, ignorance, or blatant fraud. Therefore, I will enforce rigorous standards of academic integrity in all aspects and assignments of this course. For the detailed policy of West Virginia University regarding the definitions of acts considered to fall under academic dishonesty and possible ensuing sanctions, please see the Student Conduct Code <http://campuslife.wvu.edu/office_of_student_conduct> . Should you have any questions about possibly improper research citations or references, or any other activity that may be interpreted as an attempt at academic dishonesty, please see me before the assignment is due to discuss the matter.”

**Social Justice**

**Statement :** “West Virginia University is committed to social justice. I concur with that commitment and expect to maintain a positive learning environment based upon open communication, mutual respect, and nondiscrimination. Our University does not discriminate on the basis of race, sex, age, disability, veteran status, religion, sexual orientation, color or national origin. Any suggestions as to how to further such a positive and open environment in this class will be appreciated and given serious consideration.

If you are a person with a disability and anticipate needing any type of accommodation in order to participate in this class. Please advise me and make appropriate arrangement with Disability Services (304-293-6700).”

**Approximate Syllabus**

(Reading is from HF unless otherwise noted.)

## Class Date Topic Reading Assignment Due

 1 1/8 Introduction, Mole Balances for Reactors 1

 2 1/10 Reactor Design Equations and Examples 2

 3 1/15 Batch Reactor Design 4 PS 1

 4 1/17 Flow Reactor Design

 5 1/22 Design of Multiple Reactors PS 2

 6 1/24 Pressure Effects in Flow Reactors

 7 1/29 More Reactor Design Examples and Review PS 3

 8 1/31 Multiple Reactions **6**

 9 2/5 Multiple Reactions PS 4

 10 2/7 Heat Effects in Reactors and Review 8

 11 2/12 **Exam 1** (Through lecture 9)

 12 2/14 **No class**

 13 2/19 Adiabatic and Non-isothermal Reactor Design

 14 2/21 Adiabatic and Non-isothermal Reactor Design Examples

 15 2/26 Temperature Effects in Equilibrium Reactions PS 5

 16 2/28 Multiple Steady States

 17 3/5 Types of Reactors, Equipment PS 6

 18 3/7 Temperature Effects with Multiple Reactions

 - SPRING RECESS -

 19 3/19 External Diffusion Effects 11

 20 3/21 External Diffusion Effects PS 7

 21 3/26 Pore Diffusion Effects in Catalysts 12

 22 3/28 Pore Diffusion Effects in Catalysts PS 8

 23 4/2 Review

 24 4/4 **Exam 2**

 25 4/9 Residence Time Distributions 13

 26 4/11 Residence Time Distributions

 27 4/16 Non-ideal Reactor Models 14 PS 9

 28 4/18 Design Project Presentations

 29 4/23 Non-ideal Reactor Models

 30 4/25 Course Review PS 10

 5/2 **FINAL EXAM 8 – 10 a.m.**