CHEMICAL ENGINEERING 425 (CHE 425)
Strategies for Process Improvement and Product Development

Calendar Description : CHE 425 LEC 0.50, Course ID : 011994

A course in practical statistics at a level one step beyond an elementary course. Material includes regression analysis for linear and nonlinear models, analysis of variance, statistical inference, single and multiple comparisons, and an introduction to the design of experiments including single factor designs, multifactor designs, response surface methods, d-optimality (with empirical and mechanistic models), and the analysis of undesigned data. Applications to process improvement, product development, and research problems will be explored. Use of statistical analysis software to apply these techniques. [Offered: F, W, S, last offered as CHE 425 winter 2024]
Prereq: Level at least 3B Chemical Engineering.

Instructor:

Dr. Léna Ahmadi, P. Eng.
Let's connect: https://ca.linkedin.com/in/lenaahmadi
Email: I check my e-mail (Lena.ahmadi@uwaterloo.ca) daily and try to respond in a reasonable amount of time.
Office Hours: By appointment

Teaching Assistant:

PhD Candidate: Debela Tadele
Office: E6 – 5120
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Office Hours: Wednesdays: 5:00 PM – 6:00 PM or by appointment

Scheduled Sessions:

Lectures:	Tuesdays	[4:30 AM - 6:20 AM]	DWE 2529
	Thursdays	[12:30 PM - 1:20 PM]	DWE 3516
Tutorials:	Thursdays	[1:30 PM - 2:20 PM]	DWE 3516

(Any update will be announced later)

Online Communication:

I will be making frequent use of UW-LEARN, and I will be sending e-mails (one at the beginning of each week) to the class. So please make sure you make a habit out of checking UWLEARN and your e-mail.

Course Reference Material:

1. Douglas C. Montgomery. Design and Analysis of Experiments (8th, 9th or 10th edition), Wiley: to complement lecture notes; the three editions are very similar.
2. Course Notes (to be posted on LEARN a few days before each chapter is initiated, Ch 1 to 8); additional handouts may be distributed during lectures or posted via LEARN. © Professor Alex Penlidis, 2019. The notes are for individual use only in connection with this course. It may not be resold or used to make additional copies.

"We are still facing unusual and challenging times. The instructor reserves the right to modify course topics and/or assessments with due notice. In the event of further challenges, the instructor will work with the Department to find reasonable and fair solutions."

Any comments: Feel free to email me, or just please post it here: https://www.surveymonkey.com/r/KLXSWHL and yes, it is

Grading

Assignments	40%
Quiz #1 to 4	40%
Final Quiz (#5)	20%
Bonus workshops	up to 2%

This is a quantitative course on Applied Stats, and more specifically on the design of experiments (DOE) and the related analysis of data sets. The course will discuss the role of statistical design of experiments (and subsequent data analysis) for process/recipe improvement and product development (modeling, process troubleshooting and steps towards optimization). Topics will cover linear regression situations; given the need for an experimental investigation, determine an optimal experimental design (and alternative scenarios); screening designs, and single and multifactor factorial designs (combined with regression and analysis of variance principles) in aid of process understanding and further process/ product design. **Very few undergrad (or grad) curricula cover this (internationally)!**

Assignment problems and examples in notes/book (and exercises given in class during lectures) are important to understand principles and techniques. Numerical results are as important as the methodology/algorithms! Most of the chapters in the course notes are glorified examples!

Major Topics (Tentative):

Major Topics **Course Note (CN)**	Reading Assignment **Montgomery book (Mb)**
Chapter 1: Statistical Background: Quick review of a typical 2nd year Engineering/ Science introductory Statistics course	Mb CHAPTER 2 (Do not bother with sec. 2-4.3)
Chapter 2: Regression Analysis: Linear regression with matrix calculus; analysis of variance (ANOVA); diagnostics/residuals	Mb CHAPTER 10

Chapter 3: Statistical Design of Experiments: Overview	Mb CHAPTER 1
Chapter 4: Design/Analysis of Single Factor Experiments: Randomization; replication; multiple comparisons	Mb CHAPTER 3 (Study ONLY sections 3.1 to 3.4.2).
Chapter 5: Blocking: Single Factor Expts with Blocking Paired comparisons; multiple comparisons; special metrics	Mb CHAPTER 4 (Study ONLY parts related to Table 4-2; Eqns (4-8) to (4-12); Example 4-1; sections 4.1, 4.1.1 and 4.1.2)
Chapter 6: Multifactor Experiments: Two-level factorial experiments and related models	Mb CHAPTER 5 (Do not bother with sec. 5-3.5, 5-3.7 and 5-5) Mb CHAPTER 6 (Sections 6-1 to 6-5) Mb CHAPTER 7
Chapter 7: Multifactor Experiments: Two-level fractional factorials and screening designs	Mb CHAPTER 8 (Study sections 8.1 to 8.6)
Chapter 8: Concluding Remarks (what to do next)	

Assignment Policy

Assignment is an essential element in learning the type of material being taught in this course. There will be four group assignments, roughly one every two-three weeks (Due: Sep 21, Oct 5, Oct 26, and Nov 16, submission: 1 PDF file per group to the Learn drop box). All assignment solutions will be posted on the course web site. Late assignment will receive a penalty of 20 points (out of 100) for each day overdue, and will not be accepted after solutions are posted. ***Students should self-enroll in the group (4 to 5 people) on UWLEARN by 11:59PM, Wednesday, September 14th.*** *If a student was not enrolled in any group by then, randomly I will assign a group to her/him/they with 4 other students on September 15th. If the size is less than 4, I will add student(s) to the group. If there is an individual with who you would prefer not to work as a teammate, feel free to let me know through a confidential email by September 14th (No explanation needed).*

Quizzes:

The exams will give you (and me) a chance to review the material and see where you are, i.e., whether you understand the early basics. All exams will be closed books, and closed notes unless otherwise indicated. Any student who cannot take an exam as scheduled must make special arrangements with the instructor before the exam is given on Sep 22, Oct 6, Nov 3, Nov 17, and Dec 1. Materials allowed: Stats Table, Calculator and a double-sided cheat-sheet (Just formula).

The quiz 5 will cover most of the materials (Topics will be announced later) in the course, including any new material since quiz 4.

Grading Scheme (Tentative):

Deliverables	Available / **Due Date**	Grade
Assignment 1, Group Work	Sep 15 / **Sep 21** (Learn)	10%
Assignment 2, Group Work	Sep 29 / **Oct 5** (Learn)	10%
Assignment 3, Group Work	Oct 20 / **Oct 26** (Learn)	10%
Assignment 4, Group Work	Nov 10 / **Nov 16** (Learn)	10%
Quizzes 1 to 4, Individual	On Sep 22, Oct 6, Nov 3, Nov 17 (in-person)	40%
Quiz 5, Individual	Dec 1 (in-person)	20%
Bonus Group/Individual Activities	After reading week / **last day of classes** (Learn)	Up to 2%

Reading Assignments:
For each lecture you should plan to spend two to three hours reading your notes, handouts, and books. The best time to study is the same day as suggested on "course weekly activities" section of this document, so that no unclear points remain. Not keeping up is a sure way of failing to meet the course objectives.

Intended Learning Outcomes (related to CEAB Graduate Attributes and course accreditation; see also Graduate Attributes Table below; numbers in brackets correspond to the numbered outcomes of the Table on Graduate Attributes below)

<u>After completion of this course, students will be able to:</u>

- Estimate confidence and prediction intervals and construct ANOVA tables (variance decomposition) in both regression and design of experiments situations (1, 2)
- Be fluent with advanced linear regression situations (correlation, prediction, analysis of residuals, model comparisons, model diagnostic checks); metrics to describe parameter uncertainty (3, 4, 5)
- Differentiate between design scenarios vs data analysis (randomization, replication, blocking) (6, 7, 8)
- Design single factor experiments: data analysis, multiple comparisons, comparison-wise vs experiment-wise error, with and without blocking of (lurking) stochastic variables (3, 4, 5, 9)
- Design multifactor experiments: emphasis on 2-level full and fractional factorial designs, assessing significance of factor and factor interaction effects, confounding of effects, benefits of orthogonal designs, estimation of process error, selection of best design fraction, screening designs to generate process information (3, 4, 5, 9)

- Address questions like: why apply experimental designs, what if experiments are not designed, what if experiments do not go as planned, what if results are unexpected, empirical observations vs meaningful physico-chemical interpretations (6, 7, 8, 12)

CEAB Graduate Attributes:

The numbers in parentheses in the students learning objectives above refer to the CEAB Engineering Graduate Attributes defined by the Canadian Engineering Accreditation Board. These are listed below as a reference:

Outcome	Definition
1. A knowledge base for engineering	Demonstrated competence in university level mathematics, natural sciences, engineering fundamentals, and specialized engineering knowledge appropriate to the program.
2. Problem analysis	An ability to use appropriate knowledge and skills to identify, formulate, analyze, and solve complex engineering problems in order to reach substantiated conclusions.
3. Investigation	An ability to conduct investigations of complex problems by methods that include appropriate experiments, analysis and interpretation of data, and synthesis of information in order to reach valid conclusions.
4. Design	An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, economic, environmental, cultural and societal considerations.
5. Use of engineering tools	An ability to create, select, apply, adapt, and extend appropriate techniques, resources, and modern engineering tools to a range of engineering activities, from simple to complex, with an understanding of the associated limitations.
6. Individual and team work	An ability to work effectively as a member and as a leader in teams, preferably in a multi-disciplinary setting.
7. Communication skills	An ability to communicate complex engineering concepts within the profession and with society at large. Such abilities include reading, writing, speaking and listening, and the ability to comprehend and write effective reports and design documentation, and to give and effectively respond to clear instructions.
8. Professionalism	An understanding of the roles and responsibilities of the professional engineer in society, especially the primary role of protection of the public and the public interest.
9. Impact of engineering on society and the environment:	An ability to analyze social and environmental aspects of engineering activities. Such abilities include an understanding of the interactions that engineering has with the economic, social, health, safety, legal, and cultural aspects of society; the uncertainties in the prediction of such interactions; and the concepts of sustainable design and development and environmental stewardship.
10. Ethics and equity	An ability to apply professional ethics, accountability, and equity.
11. Economics and	An ability to appropriately incorporate economics and business practices

project management	including project, risk and change management into the practice of engineering, and to understand their limitations.
12. Life-long learning	An ability to identify and to address their own educational needs in a changing world to sufficiently maintain their competence and contribute to the advancement of knowledge.

Computer Usage: Throughout the course the students are encouraged to use the statistical capabilities of Excel, R-Studio, Statistica, Design of Experiments, SPSS, or MATLAB …. statistics toolbox. These will aid in de-emphasizing the arithmetic considerations and will allow one to concentrate on the use of statistics in analyzing data and testing hypotheses.

How to Succeed: The first step in doing well in this course is to realize that statistics is not a subfield of mathematics but is a distinct discipline. Statistics evolved from the need to systematically combine concepts from philosophy, the sciences, and mathematics in order to construct a coherent methodology for describing phenomena in the presence of random variation. Thus, **to do well in this course you must master the concepts as well as the formulas**.

AccessAbility Services: AccessAbility Services (AAS) is the University's centralized office for the provision of academic accommodations for students with a known or unknown disability, illness, or condition. Even if students are unsure of whether they qualify for AAS support, an AAS consultant can talk them through next steps, and refer them elsewhere if appropriate.

Academic Honesty: Students are expected to know what constitutes academic integrity, to avoid committing academic offences, and to take responsibility for their actions. Students who are unsure whether an action constitutes an offence, or who need help in learning how to avoid offences (e.g., plagiarism, cheating) or about "rules" for group work/collaboration should seek guidance from the course professor, TA, academic advisor, or the Undergraduate Associate Dean. For information on categories of offences and types of penalties, students should refer to Policy #71, Student Academic Discipline. Students who believe that they have been wrongfully or unjustly penalized have the right to grieve; refer to Policy#70, Student Grievance.

Classroom Protocol: Students will maintain a professional attitude in order to maintain a comfortable learning environment in the online classroom and will not hamper the ability of instructor to teach and students to learn. Please make sure to do the followings for online classrooms:

- Mute mic - Please initially join the virtual sessions mic muted.
- Turn off video – to reduce the likelihood of bandwidth issues, please turn off your video.
- Write down your questions in the chat sections during the virtual summary sessions on Thursdays

Common examples of inappropriate behavior include, but not limited to:

- Monopolizing classroom discussions.
- Not respecting the rights of other students to express their viewpoints in the chat.

- Usage of cell phones in the online classroom (cell phones should be put in quiet/vibration mode during the sessions).

Ending Note:

I would like to note that we (me and TA) are here to help you. Please feel free to ask for assistance if you should require any.

Feedback?

https://www.surveymonkey.com/r/KLXSVVHL

Review Basic Stats?

Here is our class YouTube Channel:

https://www.youtube.com/playlist?list=PLbZR-F50F9np3Jgzle2zXCgcApC8EDnCR