**ChE 220 - Process Data Analysis**

**Chemical Engineering Department**

**University of Waterloo**

**Course Description:**

Statistics is the science of collecting, organizing, and interpreting numerical data for the purpose of drawing conclusions and making decisions. Emphasis will be placed on statistical reasoning and data analysis and many examples will be drawn from engineering applications. The main topics are typical engineering measurements, graphical presentation and numerical treatment of data, probability theory, statistical inference, and regression analysis.

**Instructor:**

***Prof. A. Elkamel***

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**Email:** I check my e-mail ([aelkamel@uwaterloo.ca](mailto:aelkamel@uwaterloo.ca)) almost daily and try to

respond in a reasonable amount of time.

**Official Office Hours:** Mondays & Wednesdays: 4:30 p.m. – 5:30 p.m.

or [by appointment]

**Teaching Assistant:**

Mohamed Alnifro  
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Office Hours:  Fridays: 2: 30 - 4:30 p.m. or [Email Arrangement]

**Scheduled Sessions:**

Mondays [2:30 p.m. - 3:20 p.m] DWE-2527

Wednesdays [2:30 p.m. - 4:20 p.m] DWE-2527

**Tutorials:**

Mondays [3:30 p.m. - 4:20 p.m.] DWE-2527

**Online Communication:**

I will be making frequent use of UW-LEARN and I will be sending e-mails quite often to the class. So make sure you make a habit out of checking UW-LEARN and your e-mail.

**Major Topics:**

**Reading Assignment**

1. **Role of Statistics in Engineering**  Sections 1-1 to 1-6
   1. Course Introduction
   2. The Engineering Method and Statistical Thinking
   3. Collecting Engineering Data
   4. Mechanical and Empirical Models
   5. Probability and Probability Models
2. **Probability** Sections 3.1 - 3.7 and 4.1
   1. Sample Spaces and Events
   2. Interpretations of Probability
   3. Addition Rules
   4. Conditional Probability
   5. Multiplication Rules
   6. Independence
   7. Bayes’ Theorem
   8. Random Variables
3. **Discrete Probability Distributions** Sections 4.1, 4.2, 4.4, and 4.7
   1. Cumulative Distribution Function
   2. Discrete Uniform Distribution
   3. Binomial Distribution
   4. Poisson Distribution
   5. Joint Distributions
4. **Continuous Probability Distribution** Sections 5.1 - 5.5, and 5.10
   1. Continuous Uniform Distribution
   2. Normal Distribution
   3. Normal Approximation to the Binomial and Poisson

Distribution.

d. Joint Distributions

1. **Treatment of Data**  Sections 2.1 - 2.8 and 5.12
   1. Data Summary and Display
   2. Random Sampling
   3. Stem-and-Leaf Diagrams
   4. Frequency Distributions and Histograms
   5. Box Plots
   6. Time Sequence Plots
   7. Probability Plots

6.  **Point Estimation of Parameters** Sections 6.1 - 6.4, 7.1, and 7.3.

1. General Concepts
2. Sampling Distributions
3. Methods of Point Estimation
4. Sampling Distributions of the Mean and Variance

7. **Statistical Intervals for a Single Sample** Sections 7.2, 9.1, and 10.1

* 1. Confidence Interval on the Mean of a Normal

Distribution

* 1. Confidence Interval for Variance and Standard Deviation
  2. Confidence Interval for a Proportion

8. **Tests of Hypothesis for a Single Sample** Sections 7.3 - 7.6, 9.2, and 10.2

1. Tests on the Mean of a Normal Distribution
2. Testing for Goodness of Fit

9. **Statistical Intervals for Two Samples** Sections 8.1- 8.4, 9.3, and 10.3

* 1. Inference for a Difference in Means
  2. Paired t-Test
  3. Inference on the Variance
  4. Inference on Proportion

10. **Simple Linear Regression** Sections 11.1 - 11.3

1. Empirical Models
2. Least Squares
3. Hypothesis Tests
4. Confidence Intervals
5. Adequacy of the Model
6. Transformations

11. **Multiple Linear Regression** Sections 11.4 - 11.7

a. Multiple Linear Regression Models

b. Confidence Intervals

c. Model Adequacy

d. Polynomial Regression Models

12. **Process Quality Improvement**  Chapter 15

(If time permits)

**Course Objectives:**

* + To introduce the student to the ideas of probability and statistical inference with an emphasis on hypothesis testing, analysis of variance, and linear regression.
  + To introduce the student to data analysis.
  + To teach the use of statistical tables and the analysis of engineering data.
  + To make the student gain experience with engineering and scientific statistical examples with an emphasis on chemical engineering applications.

**Student Learning Objectives:**

* + Identify the role that statistics can play in chemical engineering problem solving and in decision making. (1,2)
  + Be familiar with the different ways of collecting data and recognize the concept of variability and its effect on data collected. (1,2)
  + Distinguish the difference between mechanistic models and empirical models. (1,2)
  + Demonstrate an understanding of sample space and events for random experiments and the basic concepts for calculating probabilities of events, joint events, conditional probabilities, and the use of Bayes’ theorem. (1,2)
  + Demonstrate an understanding of discrete and continuous random variables. (1,2)
  + Demonstrate an understanding of probability mass/density function and cumulative distribution function. (1,2)
  + Compute and interpret statistical parameters (mean, variance, median, range, etc.) and be able to construct and interpret normal probability plots and visual data displays including the stem-and-leaf display, the histogram, and the box plot and how to use them to compare samples of data. (1,2)
  + Estimate the parameters of a population or a probability distribution, explain properties of point estimators, understand the central limit theorem, and explain the importance of the normal distribution as a sampling distribution. (1,2)
  + Construct confidence intervals on the mean and variance of a normal distribution and population proportion. (1,2)
  + Demonstrate an understanding of hypothesis testing and employ standard tests of statistical hypotheses to determine whether statistical conjectures are consistent with sample data. (1,2,3)
  + Apply least-squares curve fitting and regression to find the best fitting line through a set of points and assess relationship among variables. (1,2,3)
  + Explain the concepts of confidence interval and prediction interval as applied to least-squares curve fitting and regression. (1,2)
  + Develop an adequate background for follow-up study in statistical methodology to logically approach problem definition and solution. (1,2,3,5)
  + Apply computational tools (e.g. Matlab, Excel, etc.) to conduct simple statistical investigations. (1,2,5)

**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 project management** | An ability to appropriately incorporate economics and business practices 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. |

**Course Reference Material:**

1. Richard A. Johnson, Probability and Statistics for Engineers, Eighth Edition, Prentice Hall.
2. Course notes.

**Computer Usage:** Throughout the course the students are encouraged to use the statistical capabilities of Excel, R, or the 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.

**Homework:**

Homework is an essential element in learning the type of material being taught in this course. There will be six assignments, roughly one every two weeks. Homework assignments will be due during the tutorial sessions unless a change is announced in class. All solutions will be posted on the course web site. Homework assignments are due at the beginning of the tutorial. Homework must be handwritten. Late homework will not be accepted. If you will be out of town, make sure you submit your solutions early or have a friend bring them to class.

**Reading Assignments:**

For each lecture you should plan to spend two hours reading your notes, handouts, and books. The best time to study is the same day as the lecture, so that no unclear points remain. Not keeping up is a sure way of failing to meet the course objectives.

**Exams and Quizzes:**

All exams and quizzes will be closed books, closed notes, unless otherwise indicated. Remember that according to university regulations the penalty for dishonesty is severe: at least failure of the course (not just the exam). Make-up exams will not be given. Any student who cannot take an exam as scheduled must make special arrangements with Dr. Elkamel before the exam is given.

Quizzes and workshops will be given regularly to make sure you are up to date.

A one and a half hour in-class mid-term exam will be given on Monday, February 29, 2016.

The final exam will cover all material in the course, including any new material since the last quiz. The final exam time and location will be announced later.

**Course Grading:** The course grade will be computed based on two possible weighting schemes:

|  |  |
| --- | --- |
| **Scheme 1:** Homework and Workshops : 7.5% Quizzes : 7.5%  Midterm : 35%  Final : 50% | **Scheme 2:** Homework and Workshops : 7.5% Quizzes : 7.5%  Midterm : 20%  Final : 65% |

The final grade will be based on the maximum of the grades under each scheme.

**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**.

**Religious Observances:** Campus policy regarding religious observances requires that faculty make every effort to reasonably and fairly deal with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. In this class, please let your instructor know of any conflict at least two weeks in advance.

**Students with Disabilities:** The Office for Persons with Disabilities (OPD), located in Needles Hall, Room 1132, collaborates with all academic departments to arrange appropriate accommodations for students with disabilities without compromising the academic integrity of the curriculum. If you require academic accommodations to lessen the impact of your disability, please register with the OPD at the beginning of each academic term.

**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 classroom and will not hamper the ability of instructor to teach and students to learn.  Common examples of inappropriate behavior include, but not limited to:

* Eating in class.
* Monopolizing classroom discussions.
* Not respecting the rights of other students to express their viewpoints.
* Entering class late or leaving early.
* Usage of cell phones in the classroom (cell phones should be put in quiet/vibration mode during the lecture).
* The use of computers in class for purposes other than note taking.

***Ending Note:***

*I would like to note that I as well as the TA of this course are here to help you. Please feel free to ask for assistance if you should require any.*