IE 604 Advanced Statistics / Design of Experiments

Mechanical and Industrial Engineering Department

Instructor: Professor Bengu
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LMS: CANVAS
Office hours: After class and by appointment, WebEx, Zoom, GoogleMeet can also be used if needed.

Honor Code

Academic Integrity is an effective component of the future of the students and the University (and eventually the future of all of us). NJIT honor code will be uphold. It is expected that students will do their own work. Copying somebody else's assignment/exams is not tolerated. Material used that was developed by others should be properly cited in assignments (no plagiarism). Violations will be referred to the Office of the Dean of Students. See NJIT honor code for more details. Please do not put your instructor in this position!

Course Description

Design and Analysis of Experiments course is for graduate students and also for seniors who are introduced to basic statistics before. It is designed to help engineering/business students as well as working practitioners- in statistical analysis and –by designing and analyzing experiments to improve the quality, or efficiency or performance of working systems/products.

The course starts with project examples illustrating the importance of experimental design as a tool for engineers and scientists used for product design and development as well as process development and improvement. Later it demonstrates the use of experimental design in developing products that are robust to environmental factors and other sources of variability. Students learn how to use DOE, design of experiment tools to substantially reduce development lead-time and cost, leading to processes and products that perform better in the field and have higher reliability than those developed using other approaches. Students gain solid experience in using current *Statistical Data Analytics programs*, as well as built their own *Design of Experiment apps* ready to be used at work. The text has comprehensive coverage with new examples, exercises, and problems (such as biochemistry and biotechnology); new topics such as response surface; nested and split-plot design; and the residual maximum likelihood method.

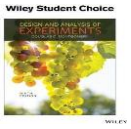
Course Objective

The course objective is to learn with hands on approach how to plan, design and conduct experiments efficiently and effectively, and analyze the resulting data to obtain objective conclusions for improving the quality, efficiency and performance of working systems. All experiments conducted by engineers and scientists are designed experiments; some of them are poorly designed, and some others are well designed. A well-designed experiment can lead to reduced development lead-time for new processes and products, improved manufacturing process performance, and products that have superior function and reliability. Well-designed experiments allow you to obtain reliable, valid results faster, easier, and with fewer resources than with poorly designed experiments. You will learn how to plan, conduct and analyze experiments efficiently in this course and how to compare the alternative designs. You will also built your own DOE tool that you can compare with Minitab 2^k factorial designs. The semester is completed in two phases; at first the design of experiments and at second how to make inferences from the statistical analysis of data obtained from their projects; at the end the students' practical implementation issues are discussed as part of the course project.

Course Material

Textbook: ***Design and Analysis of Experiments***, ***9th*** Edition by Douglas C. Montgomery, Wiley.

ISBN-13: 978-1-119-11347-8 www.wileystudentchoice.com



Canvas LMS

Canvas is used throughout the semester to distribute all course material as well as to collect all student submissions *(also e-mail when stated)*. *Canvas learning management systems (LMS) is accesssible via student's UCID accounts from your home, from NJIT (and Rutgers) labs, or libraries or from any computer with access to the Internet.*

Provided material: Slides*(ppt),*Videos*(webex),* Reading Matr'l. , Excel files, HW & project examples.

Weeks	**Chapter**	**Topic**	**HW Sets** Announced in class
1		Introduction to the Semester Project	HW1
2	Ch. 1 & 5	Introduction to Factorial Designs	HW2
3	Ch. 5	Introduction to Factorial Designs continued	HW3
4	Ch. 6	The 2^k Factorial Design	HW4
5	Ch. 6	The 2^k Factorial Design continued	
6		Examples of Factorial Design to prepare for the Exam	ME5
7	Ch. 2	**Midterm Exam** /Simple Comparative Experiments	
8	Ch. 2	Basic Statistical Concepts – Single Sample	HW6
9	Ch. 3	Experiments with a Single Factor: The Analysis of Variance	HW7
10	Ch. 3 & 4	Randomized Blocks, Latin Squares, and Related Designs	HW8
11	Ch. 7	Blocking and Confounding in the 2^k Factorial Design	HW9
12	Ch. 8	Two-Level Fractional Factorial Designs	Project report due 10
13		**Semester Project Presentation**	FE11 exam
14		Final exam and project presentation review	PP12 presentation
15		**Final Exam dates announced by NJIT, click here**	

Software used:

Minitab, *Design-Expert, JMP, and SAS.*

- ***Minitab*** is used for design of experiments and analysis, regression and ANOVA, as well as statistical analysis of two sample comparisons, ranging from six-sigma to design of experiments. The students can download the software from NJIT IST Software page free for a year. Students are recommended to access Minitab tutorials from Minitab tutorial webpage.

- ***Design-Expert and JMP*** Student version of the software are available as a packaging option with the 9th edition of this book *(text book).* The student version of the JMP software might be downloaded from here. Design expert software trial version is free for one month and could be downloaded from here.

- ***Microsoft Excel***
  Students are introduced to MSExcel initially for statistical analysis and built their own DOE app. Students can immediately apply this valuable practical skill at their job in the absence of Statistical Analysis software. Excel- Data Analysis Add-in tool will be used.

- ***Statistical Analysis Software (SAS)***
  This software provides a higher level of sophistication in applying statistical techniques through topics such as advanced data management and predictive analytics. The students are given an introduction and they use the software to work out examples. The students can download SAS the software from NJIT IST Software page free.

Grading: Final grade will be composed as follows:

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1. **Homework and pop quizzes**	**10%**	***Grade***	***GPA Point***
2. **Midterm Exam**	**30%**	***A*** *89.9 - 100*	***4.0***
3. **Semester Project**	**30%**	***B+*** *86.9 - 89.9*	***3.5***
4. **Final Exam**	**30%**	***B*** *79.9 - 86.9*	***3.0***
		C+ *76.9 - 79.9*	***2.5***
		C *69.9 - 76.9*	***2.0***
		D *59.9 - 69.9*	***1.0***
		F *0 - 59.9*	***0***

WEEKLY DETAILS AND RESOURCES

Chapter	Topic
1 & 5	**Introduction to Factorial Designs** ▯ Basic Definitions and Principles ▯ The Advantage of Factorials ▯ The Two- Factor Factorial Design – Statistical Analysis of the Fixed Effects Model – Model Adequacy Checking – Estimating the Model Parameters

	– Choice of Sample Size – The Assumption of No Interaction in a Two-Factor Model – One Observation per Cell ▯ The General Factorial Design ▯ Fitting Response Curves and Surfaces **Resources:** ▯ **Slides** (Textbook slides for Chapter 1 & 5, Slides 1 & 2) ▯ **Files** (Excel templates)
6	**The 2 ^{k} Factorial Design** ▯ The 22 Design ▯ The 23 Design ▯ The General 2^k Design ▯ A Single Replicate of the 2^k Design ▯ Additional Examples of Unreplicated 2^k Designs ▯ 2^k Designs are Optimal Designs ▯ The Addition of Center Points to the 2^k Design ▯ Why We Work with Coded Design Variables **Resources:** ▯ **Slides** (Textbook slides for Chapter 6, Slide 2) ▯ **Files** (Excel templates)
2	**Simple Comparative Experiments** ▯ Basic Statistical Concepts ▯ Sampling and Sampling Distributions (Normal Distribution) – Confidence Intervals – Hypothesis Testing – Choice of Sample Size ▯ Inferences about the Differences in Means, Randomized Designs – The Case Where $\sigma\sigma 21 \neq \sigma 22$ – The Case Where $\sigma\sigma 21$ and $\sigma\sigma 22$ Are Known – Comparing a Single Mean to a Specified Value ▯ Inferences About the Differences in Means, Paired Comparison Designs – The Paired Comparison Problem – Advantages of the Paired Comparison Design Inferences ▯About the Variances of Normal Distributions **Resources:** ▯ **Slides** (Textbook slides for Chapter 2, Slide 3) ▯ **Files** (Excel templates)

3	**Experiments with a Single Factor: The Analysis of Variance** The Analysis of Variance Analysis of the Fixed Effects Model – Estimation of the Model Parameters

	– Unbalanced Data Model Adequacy Checking – The Normality Assumption – Plot of Residuals in Time Sequence – Plot of Residuals Versus Fitted Values – Plots of Residuals Versus Other Variables Practical Interpretation of Results – - Regression Model – Comparisons Among Treatment Means – Graphical Comparisons of Means – Contrasts – Orthogonal Contrasts – Scheffé's Method for Comparing All Contrasts – Comparing Pairs of Treatment Means – Comparing Treatment Means with a Control Sample Computer Output Determining Sample Size – Operating Characteristic and Power Curves – Confidence Interval Estimation Method Other Examples of Single-Factor Experiments – Chocolate and Cardiovascular Health – Discovering Dispersion Effects The Random Effects Model – A Single Random Factor – Analysis of Variance for the Random Model – Estimating the Model Parameters
	The Regression Approach to the Analysis of Variance – Least Squares Estimation of the Model Parameters – The General Regression Significance Test **es:** **Resources Slides** (Textbook slides for Chapter 3, Slide 4) **Files** (Excel templates)

4	**Randomized Blocks, Latin Squares, and Related Designs** ▯ The Randomized Complete Block Design – Statistical Analysis of the RCBD – Model Adequacy Checking – Some Other Aspects of the Randomized Complete Block Design – Estimating Model Parameters and the General Regression Significance Test ▯ The Latin Square Design ▯ The Graeco-Latin Square Design ▯ Balanced Incomplete Block Designs – Statistical Analysis of the BIBD – Least Squares Estimation of the Parameters ▯ Recovery of Interblock Information in the BIBD **Resources:** ▯ **Slides** (Textbook slides for Chapter 4, Slides ▯ **Files** (Excel templates)
7	**Blocking and Confounding in the 2^k Factorial Design** ▯ Confounding in the 2^k Factorial Design ▯ Confounding the 2^k Factorial Design in Two Blocks Another ▯Illustration of Why Blocking Is Important
	▯ Confounding the 2^k Factorial Design in Four Blocks ▯Confounding the 2^k Factorial Design in 2_p Blocks ▯Partial Confounding **Resources:** ▯ **Slides** (Textbook slides for Chapter 7) ▯ **Files** (Excel templates)
8	**Two-Level Fractional Factorial Designs** ▯ The One-Half Fraction of the 2^k Design – Definitions and Basic Principles – Design Resolution – Construction and Analysis of the One-Half Fraction ▯ The One-Quarter Fraction of the 2^k Design ▯ The General 2k–p Fractional Factorial Design – Choosing a Design – Analysis of 2k–p Fractional Factorials – Blocking Fractional Factorials ▯ Alias Structures in Fractional Factorials and Other Designs ▯ Resolution III Designs – Constructing Resolution III Designs

	▯ Resolution IV and V Designs – Resolution IV Designs ▯ **Files** (Excel templates)

Course Requirements

There will be

1. Homework assignments HW *(Canvas submission or e-mailed if stated)*
2. A midterm exam ME *(verbal + canvas +webex+ lockdown browser)*
3. A final exam FE *(verbal + canvas +webex+ lockdown browser)*
4. A semester project presentation (.ppt) PP *(webex)*
5. A project report (.doc) submission PR *(Canvas)*
6. A project work file submission (Minitab, Excel or SAS). *(Canvas)*
7.

Submission: Submitting computer solutions alone will not provide a grade unless a report with explanations is attached. Student must learn not only the theories/techniques to manually solve the questions, but also the use of the software. The software use helps students 1) to verify their homework answers 2) to be computer savvy 3) to be prepared for today's work environment and be efficient at work from early start, 4) better resume. ***However, the main part of the grade will be based on manual solutions*** *(excel based****), which represent your understanding of the theory*** *(this is the part, which gives you the job flexibility).*

Homework and the Semester Project

Homework problems are assigned weekly. It is due the following week and need to be submitted before the time due (or beginning of the class *(if stated))* so that the HW solutions are distributed. Students are encouraged and will be asked to take part in the solution process. ***Do not ask the instructor to accept your homework, after homework solutions are given out!***

Homework assignments are intended for learning practice and they ARE required to be submitted although some may not be graded. However, all the homework questions solutions will be provided or solved in class. The objective of homework is to reinforce the concepts covered in lectures, practicing and implementing solution techniques on problems, and prepare for the midterm and final exams. Homework assignments are individual tasks and must be done without collaboration *(unless otherwise stated).* The work you turn in MUST be your own work. Questions when solved in class *(F2F)* will be done together with students by having students play an active role in solution. Homework will be submitted to the Canvas website before the day and time it is due, with late submission will be counted as a zero. Email submissions to the instructors are not accepted, unless it is stated by the instructor.

Course Project

- Each student will submit preferably a team based course project involving the application of statistical analysis techniques using DOX **on a case study approved by the instructor**.

- List of Suggested Projects Titles are provided on our web site.
- The project examples are also on the web site. Student initiated projects are encouraged but requires instructor approval. Students are also encouraged to work in groups, but a group of more than two members requires instructor approval. Every member is responsible of the entire project. Divided project responsibility cannot be accepted.
- After the first two weeks, a project proposal is required. A detailed Project format and guidelines along with examples are available on the course web page. (See course project schedule section also).
- Students are expected to research the use of DOX or Hypothesis testing/Regression literature for possible examples in the subject they have chosen. Min. of 2 research papers must be collected and **summarized**. (See Library Research) Students are also expected to use software tools such as Minitab or SAS in their project based on their choice.

1) The final project report and 2) project presentation 3) software file with data analysis are due 1 week before the day of presentation. Students are requested to submit their progress reports within the semester. Instructor will provide feedback during the semester on how to improve the project. Students must consult with the instructor about their project and their progress. Presentation is due to last day of the class. Final exam day is listed by the institute during the final exam week.

COURSE PROJECT SCHEDULE

1st - 2nd WEEK Students are expected to decide on a subject they want to work on (see Web Site for example projects) after the second class. The idea is to implement the methods students learned in class, on their data set regularly every week.

3rd - 5th WEEK Team up with another classmate and submit your project proposal. Online class members can work alone. Check the "required format and the guidelines" from the Moodle course web site. Use table of contents to write about the methods you want to use in your project. Those who do not submit their project proposal will not be eligible to present their projects.

6th - 8th WEEK Complete a literature search on - your subject of choice and any statistical analysis techniques you are employing- For example, search for the following key words *"An article about forecasted temperature data and DOX or regression or ANOVA" or an article about homerun data and DOX"*. Obtain at least two papers on your subject, review the papers, and summarize this related work. Follow these articles' write-up-format for your project report.

9th - 12th WEEK Check your progress with your instructor. Follow up on the suggestions given. LAST Day of class Make sure that you

1) Upload your files to course website by that time and
2) Submit a hard copy to instructor

Use your last names as filename; NamesProject.doc and (follow project submission guidelines thoroughly)

PROJECT PRESENTATION DAY (Presentations 2 ½ hrs.)

1) Make sure your material is submitted on our web page (canvas)
2) Upload (virtual class) Bring a hard copy (F2F class) of your presentation slides (2 slides/pg) and the report along with a e-copy, and be ready to present.
3) F2F class→ Be in class by ½ hr. before the class starts (it takes time to get ready the computers and the projector)

4) Instructor will ask volunteers to present their projects before the rest of the groups as scheduled. If you want to present your project at an earlier date, you can do so by informing your instructor (1 month in advance) and submitting your material earlier.

Exams

- Midterm and final exams will be based on the course text and lectures. This is an individual effort and must done without collaboration. ***It is a closed book exam and notes are not allowed***. Students are permitted to use the brief formula sheet in the exam containing only complex formulations and tables. Students are expected to use these formula sheets (provided by the instructor) in every class and the exams. Any electronics, such as programmable calculators, laptops or smart phones, are strictly not permitted unless otherwise instructed.
- Only pencils, erasers and statistics calculator are allowed on your exam table. Every other belonging must be kept away at one corner of the room, but not on the next chair.
- Please DO NOT request to get out of your exam table/room in the middle. It is not fair to the rest of the class not to have equal exam conditions. Make sure you take care of your personal needs before the exam.
- Don't start the exam late. No one who arrives more than 10 minutes after the exam starts will be allowed in the exam room.
- Browsing your notes during exams is not allowed. Hats, caps, etc., that keep the eyes hidden from the proctor are not allowed during the quizzes and exams.
- No eating is allowed during the class and exam periods. Please respect your classmate's need to concentrate in the class. Wait and try to use the break time between sessions for this purpose, if needed. You are expected to remain in the classroom for the entire class period. Wandering in and out of the classroom is not allowed
- Make-up exams will not be administered unless a note is received by the instructor from the Dean of Students office. Missed exam without an official note will be counted as zero.

Students with disabilities

Students with disabilities needing accommodations of any nature so as to have a fair opportunity to perform in the class need to contact the counseling center. Staff at the counseling center will determine what constitutes a reasonable accommodation and inform the instructor of what it is.