# MATH 386/586 Linear Statistical Models

**Spring 2020**

**Section 001 1:50 to 2:50 M W F**

**Instructor:** Dr. Chris Edwards (edwards@uwosh.edu) **Phone:** (920)-948-3969 **Office:** Swart 123

**Classroom:** Swart 101 **Text:** *Applied Linear Statistical Models* 5th edition, by Kutner, Nachtsheim, Neter, and Li. I will also use excerpts from *Fundamental Concepts in the Design of Experiments* 5th edition, by Hicks and Turner.

**Catalog Description:** A unified approach to the application of linear statistical models in analysis of variance (ANOVA) and experimental design. In ANOVA, topics from single-factor ANOVA and multifactor ANOVA will be considered. Experimental design will include randomized blocks, Latin squares, incomplete block designs, and Factorial Designs. Prerequisite: Mathematics 256 and Math 301 each with a grade of C or better.

**Learning Objectives**: Linear models in statistics are the backbone of many applications, including regression and ANOVA techniques. Math 385 focuses students on the regression aspect of modeling while Math 386 focuses students on the ANOVA aspect. In Math 386, students will learn how to calculate and interpret ANOVA estimates, including parameter estimates, fits, and residuals, and will be able to perform statistical inference. In addition to one-way ANOVA, successful students will understand the issues introduced in multi-factor studies, including blocking and other experimental designs. Finally, the successful student will be able to plan and analyze complicated experimental designs, such as block designs and split plot designs.

Upon successful completion of the course, students are expected to have the ability to complete the following:

- Identify and understand the components and assumptions for the single factor ANOVA model
- Use statistical inference on model coefficients, including confidence intervals and hypothesis tests
- Understand the need for multiple comparison techniques
- Use a variety of multiple comparison techniques, including Bonferroni's, Tukey's, and Scheffé's
- Perform diagnostics and remedial measures to improve an ANOVA model
- Calculate estimates and perform inference for two-way ANOVA
- Use Tukey's test for additivity
- Recognize and analyze Randomized Complete Block designs
- Be able to use software to analyze General Linear Models
- Understand the differences introduced with Random Models
- Identify nested designs, including Split Plot designs
- Recognize various experimental designs, including Latin Squares, Balanced Incomplete Block Designs, and Factorial Designs

**Grading:** Final grades are based on 290 points:

| | Topic | Points | Tentative Date | Chapters |
|---|---|---|---|---|
| Exam 1 | One-Factor ANOVA | 70 pts. | March 2 | KNNL 15 to 18 |
| Exam 2 | Multifactor ANOVA | 70 pts. | April 10 | KNNL 19 to 21, 23 to 25 |
| Exam 3 | Experimental Designs | 70 pts. | May 15 | KNNL 26 to 29, HT 10 to14, 16 |
| Homework | 10 Points Each | 80 pts. | Mostly Weekly | |

**Grades:** Grades will be assigned by the following schedule.

| Grade | Points (Percent) | Grade | Points (Percent) | Grade | Points (Percent) |
|---|---|---|---|---|---|
| A | 261 (90 %) | B- | 223 (77 %) | D+ | 183 (63 %) |
| A- | 252 (87 %) | C+ | 212 (73 %) | D | 174 (60 %) |
| B+ | 241 (83 %) | C | 203 (70 %) | D- | 165 (57 %) |
| B | 232 (80 %) | C- | 194 (67 %) | F | 164 or fewer |

**Homework:** I will collect four homework problems approximately once every other week. The due dates are listed on the course outline below. I suggest that you work together in small groups on the homework if you like, but don't forget that I am also a resource for you to use. Often we will use computer software to perform our analyses; include printouts where appropriate, but please make your papers readable. In other words, I don't want 25 pages of printout handed in if you can summarize it in two. You should be practicing how to write legible reports in addition to learning the statistical techniques.

**Office Hours:** Office hours are times when I will be in my office to help you with the course. You may ask questions about your homework, about the text, about topics from class, or any other issues you may have. You will not be bothering me as I have set aside these times in my schedule solely for talking to students about coursework. There will be many other times when I am in my office. If I am in and not busy, I will be happy to help. For the Spring 2020 semester, I will often be in my office 11:30 to 1:00, Monday, Wednesday, and Friday; please confer with me to make sure I'm available. Or, make an appointment. I can meet other times!

**Philosophy:** I strongly believe that you, the student, are the only person who can make yourself learn. Therefore, whenever it is appropriate, I expect ***you*** to discover the mathematics we will be exploring. I do not feel that lecturing to you will teach you how to do mathematics. I hope to be your guide while we learn some mathematics, but ***you*** will need to do the learning. I expect each of you to come to class prepared to digest the day's material. That means you will benefit most by having read each section of the text and the Day By Day notes ***before*** class.

My personal belief is that one learns best by doing. I believe that you must be truly engaged in the learning process to learn well. Therefore, I do ***not*** think that my role as your teacher is to tell you the answers to the problems we will encounter; rather I believe I should point you in a direction that will

allow you to see the solutions yourselves. To accomplish that goal, I will find different interactive activities for us to work on. Your job is to use me, your text, your friends, and any other resources to become adept at the material. The Day By Day notes also include Skills that I expect you to attain.

**Math 586 Expectations:** Expectations for the graduate students are understandably more rigorous than for the undergraduate student. Students taking Math 586 will have an extra theoretical problem added to each homework, to be assigned during the semester. In addition, a final project worth 50 points will be due at the end of the semester. This project will involve a complete analysis of a data set, including model estimation, development, and validation.

Homework Assignments: (subject to change if we discover issues as we go)

| | | |
|---|---|---|
| Homework 1, due February 17 | Chapter 15:<br>Chapter 16: | 15.13, 15.22<br>16.7, 16.25 |
| Homework 2, due February 28 | Chapter 17:<br>Chapter 18: | 17.8, 17.14<br>18.4, 18.23 |
| Homework 3, due March 13 | Chapter 19: | 19.6, 19.14, 19.15, 19.32 |
| Homework 4, due March 20 | Chapter 20:<br>Chapter 21: | 20.2, 20.4<br>21.5, 21.6 |
| Homework 5, due April 8 | Chapter 23:<br>Chapter 24:<br>Chapter 25: | 23.4<br>24.12, 24.13<br>25.3 |
| Homework 6, due April 22 | Chapter 26:<br>Chapter 27: | 26.9, 26.10<br>27.3, 27.4 |
| Homework 7, due May 1 | Chapter 28: | 28.6, 28.7, 28.14, 28.15 |
| Homework 8, due May 13 | Chapter 29: | 29.7, 29.20, 29.21, 29.22 |

| Monday | Wednesday | Friday |
|---|---|---|
| February 3 Day 1<br>Introduction<br>MATH 301 Review | February 5 Day 2<br>Overview<br>Chapter 15 | February 7 Day 3<br>Single Factor ANOVA<br>Sections 16.1 to 16.4 |
| February 10 Day 4<br>Partitioning SS<br>Section 16.5 | February 12 Day 5<br>$F$-Test / Alternative Model<br>Sections 16.6 to 16.7 | February 14 Day 6<br>Power<br>Sections 16.10 to 16.11 |
| February 17 Day 7<br>**Homework 1 Due**<br>Contrasts<br>Sections 17.1 to 17.3 | February 19 Day 8<br>Multiple Comparisons I<br>Sections 17.4 to 17.5 | February 21 Day 9<br>Multiple Comparisons II<br>Sections 17.6 to 17.7 |
| February 24 Day 10<br>Diagnostics<br>Sections 18.1 to 18.2 | February 26 Day 11<br>Remedial Measures<br>Sections 18.5 to 18.7 | February 28 Day 12<br>**Homework 2 Due**<br>Case Study / **Review**<br>Section 18.8 |
| March 2 Day 13<br>**Exam 1** | March 4 Day 14<br>Two Factor ANOVA with Replicates<br>Sections 19.1 to 19.3 | March 6 Day 15<br>Two Factor ANOVA<br>Sections 19.4 to 19.7 |
| March 9 Day 16<br>Two Factor Multiple Comparisons<br>Sections 19.8 to 19.10 | March 11 Day 17<br>Two Factor ANOVA with No Replicates<br>Chapter 20 | March 13 Day 18<br>**Homework 3 Due**<br>Randomized Blocks - Model<br>Sections 21.1 to 21.4 |
| March 16 Day 19<br>Randomized Blocks - Analysis<br>Sections 21.5 to 21.9 | March 18 Day 20<br>Unequal Two Factor ANOVA<br>Sections 23.1 to 23.2 | March 20 Day 21<br>**Homework 4 Due**<br>Unequal Comparisons<br>Section 23.3 |
| March 30 Day 22<br>Multi Factor Models<br>Sections 24.1 to 24.4 | April 1 Day 23<br>Multi Factor Tests<br>Sections 24.5 to 24.7 | April 3 Day 24<br>Random Models<br>Sections 25.1 to 25.3 |
| April 6 Day 25<br>Mixed Models<br>Sections 25.4 to 25.7 | April 8 Day 26<br>**Homework 5 Due**<br>**Review** | April 10 Day 27<br>**Exam 2** |
| April 13 Day 28<br>$EMS$ Rules<br>Appendix D | April 15 Day 29<br>Nested Designs<br>Sections 26.1 to 26.8 | April 17 Day 30<br>Repeated Measures<br>Sections 27.1 to 27.4 |
| April 20 Day 31<br>Split Plots<br>Hicks 11 | April 22 Day 32<br>**Homework 6 Due**<br>BIBD's<br>Sections 28.1 to 28.2 | April 24 Day 33<br>BIBD's<br>Hicks 16.6 |
| April 27 Day 34<br>Latin Squares<br>Sections 28.3 to 28.5 | April 29 Day 35<br>$2^f$ Factorials<br>Sections 29.1 to 29.3 | May 1 Day 36<br>**Homework 7 Due**<br>$3^f$ Factorials<br>Hicks 10 |
| May 4 Day 37<br>Confounding I<br>Hicks 12 | May 6 Day 38<br>Confounding II<br>Hicks 12 | May 8 Day 39<br>Fractional Factorials I<br>Hicks 13 |
| May 11 Day 40<br>Fractional Factorials II<br>Hicks 13 | May 13 Day 41<br>**Homework 8 Due**<br>**Review** | May 15 Day 42<br>**Exam 3** |

Last updated January 26, 2020