ISE 111: Engineering Probability

Syllabus: Fall Semester 2017

Course Description

This course is an introductory course to the field of Probability designed for engineering students. This course focuses primarily on the study of Probability Theory. We may also cover some Statistics toward the end. Probability Theory is also of great use in and of itself in all branches of Engineering for understanding and modeling phenomena that exhibit random behavior. Probability Theory also provides the theoretical and mathematical basis for statistics, and thus must be studied first before one can truly understand statistics (which comes later in ISE 121).

The field of Statistics pertains to the presentation, analysis and interpretation of data. Engineers will be faced with the need to analyze data on a daily basis in the real world, and thus a good grounding in the basics of statistics is invaluable. Statistics is inherently inductive since inference is made about a whole population on the basis of information/data obtained from a sample from the population.

Unlike Statistics, Probability theory is inherently deductive, and has nothing to do with sample data. Rather it is a field of mathematics from which results and conclusions are derived from propositions and assumptions. A typical easy problem that one could solve using probability theory is "given that the probability of a coin flip coming up heads is 0.5, what is the probability that I will get exactly 5 heads if I flip the coin 10 times?" Note the absence of any sample data in this problem. Given an assumption (probability of a head is 0.5) one deduces the conclusion (the probability of exactly 5 heads is 0.2461).

Statistics is probably more useful for most engineers than probability. However, the theory that underlies statistics is probability, which makes its study necessary as well. The study of Probability Theory can be fun and interesting, but also difficult, confusing and frustrating. In particular, the use of counting methods to compute probabilities, which comes early in the class, is likely the most confusing and frustrating part of the course (in addition to hopefully being fun). Who would have thought that counting is hard?!

Course Objectives

Upon completion of this course, students will:

- Learn the basic tools of probability theory
  - Know the basic axioms and set theory upon which probability theory is based including sample spaces and events, mutual exclusivity, conditional probability, independence, and Bayes theorem.
o Be able to solve problems in counting and probability using techniques including permutations, combinations, permutation of like objects, “multi-choose”, and probability trees.
o Understand the concept of random variables and probability mass functions, densities, and distributions.
o Understand the concept of expectation and be able to apply it in decision making
o Understand the mean and variance of a random variable.
o Understand Chebyshev’s inequality.
o Know various well-known distributions and how they are used in practice.
o Understand Poisson processes and what they are used for in practice
o Understand joint, marginal, and conditional distributions
o Understand covariance and correlation
o Be able to apply the theory of expectation to solve decision problems involving the maximization of expected return

- Learn the mindset necessary to successfully apply probability theory in solving real engineering problems, namely:
  
o Develop curiosity and a healthy skepticism about the assumptions inherent in probability models, and how to use sensitivity analysis to investigate
  o Be able to identify necessary components of a probability model and discover sources of data necessary to build the components to solve an engineering problem
  o Create value by understanding how to apply measures of value and risk to engineering decision problems.

Prerequisites

Math 22 (Calculus II) is a pre-requisite. You should be taking Math 23 (Calculus III) this semester, or have taken it already, since we will use some material from it (double integrals, in particular) later in our course. If you have not taken Math 22, or are retaking it this semester due to poor grades, you should drop this course now; we will offer it again next semester. In past years we sometimes let students who didn't have the prerequisite into ISE 111, only to see them struggle all semester long and end with very unsatisfactory grades.

Contact Information

Professor
Dr. Robert H. Storer
477 Mohler Lab, 758-4436
E-mail rhs2@lehigh.edu
Home Page: www.lehigh.edu/~rhs2/rhs2.html
Office Hours: MWF 10:00 – 11:30 and 1:30-2:30
Grader
Yinan Liu  YIL715@lehigh.edu
358 Mohler Lab
Office Hours Thursday 11-12 and Thursday 4-5

Textbook (required)

Montgomery and George C. Runger, published by John Wiley and Sons and the
associated "Student Workbook with Solutions", by Heecheon You.

We will be covering the following chapters in the following order: 2, 3, 4, 5. There will
be 4 midterm (50-minute) exams, at (approximately) the ends of chapters 2, 3, and 4 (see
schedule). The final will be cumulative, but with extra emphasis on chapter 5. In truth,
we do not use the textbook much at all. However it is a valuable resource. Also, you will
almost surely use the same textbook when you take ISE 121 next semester, so do not sell
it back to the bookstore at the end of this semester.

Web Page

We will post some things, including homework assignments, the tentative course
schedule, and this syllabus, on the course web page using Coursesite. To reach it, go to

http://coursesite.lehigh.edu/

and log in with your usual e-mail address and password. You will also be able to access
your grades through the system. You are responsible for keeping track of your grades and
general progress in the course.

Active Learning Activities

This year, we are incorporating active learning techniques into the course. These
include:

Think-Pair-Share exercises (approximately one per lecture)
- In these activities, you will pair up with another student and will be given a
  problem or concept or issue to discuss and work out an answer. After about 5
  minutes, I will randomly pick a group to present their solution or thoughts

Big Problems and Mini-Projects
- Seven of the nine homework assignments will include one “big problems” that
  requires significant effort and thoughtfulness to solve
- Two of the nine homework assignments will be “Mini-Projects” that require more
  effort than a “big problem”.
• On the day each homework assignment is due, two students will be randomly selected to present their solutions to the problem.

Grading Policy

Your final numeric score will be determined as follows:

20% : Homework and Mini-Projects (9 assignments)
10% : Class participation as determined by me
45% : Midterm exams (3 of them, 15% each)
25% : Final Exam

Plus and minus grading will be used for final grades. Final grades will be "curved".

Class participation requires that you actually be in class, thus data on class attendance will be taken. To facilitate this, assigned seating will be used so that I can quickly determine who is missing each day. If you have to miss a class for a legitimate reason, and you inform me in advance, I will excuse the absence.

Class participation will also include participation in Think-Pair-Share exercises and in presenting “big problem” and Mini-Project solutions

Course Philosophy

I see this course as a partnership between the textbook, lectures, and homework; all of them work to help you learn. Tests serve to ensure that you are learning the material, but they cannot test everything all at once. There will be problems on the homework that are much harder than anything that would be on a test. The homework is supposed to be hard, just like training for a sport. You should allocate enough time for it; ideally, you should start it well before office hours, so you can use office hours efficiently.

Academic Honesty

Integrity and Honesty are vital in life, especially for engineers, since the systems we design or modify can improve people's quality of life, or can do irreparable harm. Using probability and statistics ethically requires that we state all of the facts and assumptions in as clear a manner as possible, to avoid "lying with statistics". We are also bound by honor to give credit where it is due. In this class, you might ask others for help with a homework assignment. Once you write up your answer in your own words to turn in, it is a good idea to include a mention of their help on any particular problem. It is dishonest to copy homework solutions from past years that you might obtain or have. On quizzes and exams, of course, your work should be entirely your own. Violations of academic honesty will result in disciplinary proceedings.
Here is the statement of the Lehigh Student Senate on academic integrity: “We, the Lehigh University Student Senate, as the standing representative body of all undergraduates, reaffirm the duty and obligation of students to meet and uphold the highest principles and values of personal, moral and ethical conduct. As partners in our educational community, both students and faculty share the responsibility for promoting and helping ensure an environment of academic integrity. As such, each student is expected to complete all academic course work in accordance to the standards set forth by the faculty and in compliance with the University's Code of Conduct. “

**Typical Difficulties**

Here, we list some of the problems that students typically encounter in the course. You won't understand some of the terms right now, but look back at this section as the course goes along and you will understand it better.

The hardest part of this course is usually figuring out which type of probability distribution to use in a particular situation. That is, "word problems" are what this course is all about. This is not made easier by the fact that the names of the distributions, like the names of the chemical elements, have no apparent system to them. It takes a lot of practice to become familiar with what tool to use for any particular situation, so hang in there, practice, and it will eventually "click" for you.

Other difficulties tend to be:

- Accidentally reporting the probability of something NOT happening, instead of it happening, or vice versa.
- Getting mixed up between "all parts are not bad" and "not all parts are bad".
- Figuring out when an approximation is justifiable.
- Remembering the difference between "independent" and "mutually exclusive".
- When to use $\text{Var}(X_1+X_2+X_3)$ and when to use $\text{Var}(3^*X_1)$

**Schedule Notes**

Do not purchase your Winter break airline tickets before the schedule for final exams is posted. You will not be allowed to "take the exam early because you have already purchased a non-refundable airline ticket". The last possible day for the exam is **Wednesday, Dec. 20th**.

**Syllabus statements:**

**Accommodations for Students with Disabilities:**

If you have a disability for which you are or may be requesting accommodations, please contact both your instructor and the Office of Academic Support Services, Williams Hall, Suite 301 (610-758-4152) as early as possible in the
semester. You must have documentation from the Academic Support Services office before accommodations can be granted.

**The Principles of Our Equitable Community:**

Lehigh University endorses The Principles of Our Equitable Community [http://www.lehigh.edu/~inprv/initiatives/PrinciplesEquity_Sheet_v2_032212.pdf]. We expect each member of this class to acknowledge and practice these Principles. Respect for each other and for differing viewpoints is a vital component of the learning environment inside and outside the classroom.

**My Exam Policy**

Aside from verified disability accommodations, no exemptions from exams will be given, and no exam scores will be dropped. Only verifiable excuses will be considered for missing an exam: you must inform me prior to the exam, and you must supply me with a written excuse from a doctor or the Dean of Students.

**ISE 111: Tentative Course Schedule, Fall 2017**

Note that we will try to stick to this schedule, but things may slip along the way. Thus this must be considered only as a rough guide.

Unless something drastic happens, we will try to stick to the exam dates.

<table>
<thead>
<tr>
<th>Date</th>
<th>Topic</th>
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<tbody>
<tr>
<td>8/28</td>
<td>Chap 1: General Introduction</td>
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<tr>
<td>8/30</td>
<td>Chap 1: Sample Spaces and Events</td>
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<tr>
<td>9/1</td>
<td>Chap 1: Interpretations of Probability, Addition Rules</td>
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<td>9/4</td>
<td>Chap 2: Counting</td>
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<tr>
<td>9/6</td>
<td>Chap 2: Counting; Last day to Drop without a “W”. HW 1 due (8/8/08 problem)</td>
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<td>9/11</td>
<td>Chap 3: Conditional Probability</td>
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<td>9/13</td>
<td>Chap 3: Conditional Probability and Independence Total Probability Rules;</td>
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<tr>
<td>9/15</td>
<td>Chap 3: Independence, HW 2 due (Phillies Lineup)</td>
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<tr>
<td>9/18</td>
<td>Chap 3: Total Probability Rule and Bayes Theorem</td>
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<td>9/20</td>
<td>Chap 4: Random Variables,</td>
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<td>9/22</td>
<td>Chap 4: Discrete Random Variables, Probability Mass Functions; HW 3 Due (Sell or scrap)</td>
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<tr>
<td>9/25</td>
<td><strong>Exam 1</strong> (Covers Chaps 1,2,3)</td>
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<tr>
<td>9/27</td>
<td>Chap 4: Cumulative Distribution Functions, Binomial</td>
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<tr>
<td>9/29</td>
<td>Chap 4: Binomial, Hypergeometric Distributions</td>
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Chap 4: Hypergeometric Distribution;
Chap 4: Geometric, Negative Binomial, Discrete Uniform
Chap 5: Mean and Variance; HW 4 due (Acceptance Sampling)

Chap 5: Mean and Expectation problems
Chap 5: Mean and Expectation problems
Chap 5: Variance, Chebyshev’s Inequality,

Pacing Break, No Class

Chap 6: Continuous Random Variables; Probability Density Functions,
Chap 6: CDF’s, Mean, Variance, HW 5 (Powerball Mini-Project 1) due

Chap 6: Continuous Uniform Distribution, Normal Distribution
Exam 2 (Covers Chaps 4,5),

Chap 6: Normal Distribution, Normal Approximation to Binomial,

Chap 6: Continuity Correction
Chap 7: Poisson Distribution
Chap 7: Poisson Process HW 6 due (Fish Packaging)

Chap 7: Poisson Process and the Exponential Distribution
Chap 7: More on Poisson Process including Erlang
Chap 7: More on Poisson Process including Erlang

Chap 8: Beta, Lognormal, Weibull Distributions; Last day to drop with a “W” HW 7 due (Earthquake)
Chap 8: Beta, Lognormal, Weibull Distributions
Chap 9: Joint Distributions
Lehigh defeats Laughyette in Goodman Stadium 98-0

Chap 9: Joint distributions, Covariance and Correlation HW 8 due (Repair or replace)
Thanksgiving Break
Thanksgiving Break

Chap 9: Joint Continuous distributions Covariance, Correlation
Exam 3 (Covers Chaps 6,7,8) Properties of E,V,COV
Chap 9: Joint Continuous Distributions

Chap 9: Linear Combinations of Random Variables Normal
Distributions of Functions of Variables HW 9 (Mini-Project 2) due
Review, last Day of Classes.

Final Exam is scheduled for Friday 12/15 8:00-11:00 AM