Statistics 110: Probability Harvard iTunes U Course

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Book: *Introduction to Probability* by Joe Blitzstein and Jessica Hwang (Chapman & Hall, 2014)

Prerequisites: single-variable calculus, familiarity with matrices.

Description: A comprehensive introduction to probability, as a language and set of tools for understanding statistics, science, risk, and randomness. Basics: sample spaces and events, conditional probability, and Bayes Theorem. Univariate distributions: density functions, expectation and variance, Normal, t, Binomial, Negative Binomial, Poisson, Beta, and Gamma distributions. Multivariate distributions: joint and conditional distributions, independence, transformations, and Multivariate Normal. Limit laws: law of large numbers, central limit theorem. Markov chains: transition probabilities, stationary distributions, convergence.

Shorter Description: The world is replete with randomness and uncertainty; probability and statistics extend logic into this realm. We will systematically introduce the ideas and tools of probability, which are useful in statistics, science, philosophy, engineering, economics, finance, and everyday life. Both the mathematical results of the subject and applications to solving problems will be studied, with examples ranging from gambling to genetics.

Even Shorter Description: How to understand and work with randomness and uncertainty through probability models, random variables and their distributions, and thinking conditionally.

Homework: Solving a lot of problems is an extremely important part of learning probability. To help with this, we provide about 250 practice problems, with detailed solutions. We highly recommend working hard on solving each problem *before* studying the solution. Many of the problems can be solved in more than one way. The Strategic Practice (SP) problems are grouped by theme, while the Homework and Exam practice problems require figuring out the relevant strategies and tools and then applying them.

Table of Contents:

- Lecture 1, Sept 2, 2011 sample spaces, naive definition of probability, counting, sampling
- Lecture 2, Sept 7, 2011 Bose-Einstein, story proofs, Vandermonde identity, axioms of probability
- SP 1 (naive definition of probability, story proofs), HW 1
- Lecture 3, Sept 9, 2011 birthday problem, properties of probability, inclusion-exclusion, matching problem
- Lecture 4, Sept 12, 2011 independence, Newton-Pepys, conditional probability, Bayes' rule
- Lecture 5, Sept 14, 2011 law of total probability, conditional probability examples, conditional independence
- SP 2 (inclusion-exclusion, independence, thinking conditionally), HW 2
- Lecture 6, Sept 16, 2011 Monty Hall problem, Simpson's paradox

- Lecture 7, Sept 19, 2011 gambler's ruin, first step analysis, random variables, Bernoulli, Binomial
- Lecture 8, Sept 21, 2011 random variables, CDFs, PMFs, discrete vs. continuous, Hypergeometric
- SP 3 (conditioning, Simpson's paradox, gambler's ruin, Bernoulli, Binomial), HW 4
- Lecture 9, Sept 23, 2011 independence, Geometric, expected values, indicator r.v.s, linearity, symmetry, fundamental bridge
- Lecture 10, Sept 26, 2011 linearity, Putnam problem, Negative Binomial, St. Petersburg paradox
- Lecture 11, Sept 28, 2011 sympathetic magic, Poisson distribution, Poisson approximation
- SP 4 (distributions and expected values for discrete r.v.s, indicator r.v.s, linearity of expectation), HW 4
- Lecture 12, Sept 30, 2011 discrete vs. continuous distributions, PDFs, variance, standard deviation, Uniform, universality
- Lecture 13, Oct 3, 2011 standard Normal, Normal normalizing constant
- Lecture 14, Oct 5, 2011 Normal distribution, standardization, LOTUS
- Lecture 15, Oct 7, 2011 midterm review, extra examples
- SP 5 (Poisson distribution and Poisson paradigm, seeking sublime symmetry, continuous distributions, LOTUS), HW 5
- midterm review handout
- midterm exam, Fall 2011
- Lecture 16, Oct 14, 2011 Exponential distribution, memoryless property [this shorter lecture since the first part of class was devoted to giving back and discussing midterms]
- Lecture 17, Oct 17, 2011 moment generating functions (MGFs), hybrid Bayes' rule, Laplace's rule of succession
- Lecture 18, Oct 19, 2011 MGFs to get moments of Expo and Normal, sums of Poissons, joint distributions
- SP 6 (Exponential distribution and memorylessness, moment generating functions (MGFs)), HW 6
- Lecture 19, Oct 21, 2011 joint, conditional, and marginal distributions, 2-D LOTUS, expected distance between Uniforms, chicken-egg
- Lecture 20, Oct 24, 2011 expected distance between Normals, Multinomial, Cauchy
- SP 7 (joint, conditional, and marginal distributions), HW 7

- Lecture 21, Oct 26, 2011 covariance, correlation, variance of a sum, variance of Hypergeometric
- Lecture 22, Oct 28, 2011 transformations, LogNormal, convolutions, proving existence
- SP 8 (covariance and correlation, transformations, existence), HW 8
- Lecture 23, Oct 31, 2011 Beta distribution, Bayes' billiards, finance preview and examples
- Lecture 24, Nov 2, 2011 Gamma distribution, Poisson processes
- Lecture 25, Nov 4, 2011 Beta-Gamma (bank-post office), order statistics, conditional expectation, two envelope paradox
- Lecture 26, Nov 7, 2011 two envelope paradox (cont.), conditional expectation (cont.), waiting for HT vs. waiting for HH
- SP 9 (Beta and Gamma distributions, order statistics, conditional expectation), HW 9
- Lecture 27, Nov 9, 2011 conditional expectation (cont.), taking out what's known, Adam's law, Eve's law, projection picture
- Lecture 28, Nov 14, 2011 sum of a random number of random variables, inequalities (Cauchy-Schwarz, Jensen, Markov, Chebyshev)
- SP 10 (conditional expectation and conditional variance, inequalities), HW 10
- Lecture 29, Nov 16, 2011 law of large numbers, central limit theorem
- Lecture 30, Nov 18, 2011 Chi-Square, Student-t, Multivariate Normal
- Lecture 31, Nov 21, 2011 Markov chains, transition matrix, stationary distribution
- Lecture 32, Nov 28, 2011 Markov chains (cont.), irreducibility, recurrence, transience, reversibility, random walk on an undirected network
- Lecture 33, Nov 30, 2011 Markov chains (cont.), Google PageRank as a Markov chain
- SP 11 (law of large numbers, central limit theorem, Multivariate Normal, Markov chains), HW 11
- Lecture 34, Dec 2, 2011 a look ahead, final review, other statistics courses, regression example, sampling from a finite population example
- final review handout
- final exam, Fall 2011