EECE 6932 Advanced Probability Theory for Engineers
Fall 2021

Goal:

To build up modern analytical and computational capabilities in probability and stochastic processes, and to apply them to the probabilistic modeling and analysis of engineering problems, signals and systems that involve uncertainty.

Course description:

Axiomatic probability theory, projection theorem for Hilbert spaces, conditional expectations, modes of stochastic convergence, strong law of large numbers, central limit theorem, Markov chains, mean-square calculus, stationarity, ergodicity, introduction to martingales and their application to optimization, introduction to extreme value theory with applications in computing.

Prerequisites:

EECE 6010 and EECE 6020, or consent of instructor.

Instructor:

Professor Majeed M. Hayat; Room 289-A; Tel: 414-288-7772;
E-mail: majeed.hayat@marquette.edu

Classroom & time

Olin Engineering 116; TuTh 5:00PM - 6:15PM

Office hours

R: 2:00–3:00; W 3:00–4:00

Textbook and Notes:

Mandatory reading materials: Lecture notes, to be posted on D2L.

Required: *Probability Essentials*, by J. Jean Jacod and Philip Protter, Springer, 2004.

Optional: *Probability and Stochastic Processes for Electrical and Computer Engineers*, by J. A. Gubner, Cambridge University Press, 2006.

Topics:

1. Foundation of probability and random variables: Sigma algebras; probability measure; measurability and random variables; physical interpretation of sigma algebras; expectations; Markov, Jensen and Holder inequalities; distributions, distribution functions and densities; independence; construction of a probability measure.
2. Fundamentals of Hilbert-space theory and the projection theorem.

3. Conditional expectation:
The conditional expectation as a projection; properties of conditional expectations; non-linear (optimal) Estimation; applications in engineering.
4. Convergence of random sequences. Types of stochastic convergence, basic limit theorems for expectations (dominated convergence theorem, Fatou's lemma, and bounded convergence theorem), Kolmogorov's zero-one law, Borel-Cantelli Lemma, relationship among modes of convergence, strong law of large numbers, the basic central-limit theorem, the Berry-Essen theorem (without proof).
5. Introduction to Markov chains: Definition and examples; recurrence and transience; n-step distribution; basic limit theorems; characterization of the stationary distribution; application to birth-death chains.
6. Introduction to stochastic processes: Definition and characterization; strict-sense and wide-sense stationarity; power spectral density; correlation functions; orthogonality principle; the Wiener-Kinchin Theorem; mean-square ergodic theorem.
7. Commonly encountered stochastic processes: Poisson, Wiener, and renewal processes; compound Poisson process; shot noise and its generalizations; continuous-time Markov processes. Applications.
8. Martingales and their use in optimization: Doob's optional sampling theorem with applications to sale policy and pricing.
9. Elements of extreme value theory
GEV distributions: Gumbel, Frchet and Weibull extreme value distributions; applications to computing.

Computer usage:

A number of homework assignments require the use of Matlab

Course requirements

- 50% Homework & computer assignments.
- 25% Take home midterm examination.
- 25% Take home final examination.

Tentative grading policy

90 or above: A
75–89: B
60–74: C
59 or below: F

Important dates and events

Withdrawal deadline: November 19 Midterm (online): Given on Tuesday October 12. Due on October 14, in class Last class period: December 9 Thanksgiving Holiday: No class on Nov 25 Take-home examination (online): Given on December 13. Due on Tuesday, December 14, 7:45 PM.

Additional references

A. Papoulis, *Probability, Random Variables, and Stochastic Processes.* McGraw-Hill, 1991. [A good undergraduate/graduate reference for probability and stochastic processes for engineers]

H. Stark and J. W. Woods, *Probability and Random Processes with Applications to Signal Processing*, 3rd Edition, Prentice-Hall, 2002. [A good undergraduate/graduate reference for probability and stochastic processes for engineers]

G. R. Grimmett and D. R. Stirzaker, *Probability and Random Processes.* Oxford Science Publications, 1992. [An introductory undergraduate/graduate course on probability and stochastic processes]

W. Feller, *An Introduction to Probability and Its Applications, vol. 1.* Wiley, 1968. [A classic textbook on probability theory]

Y. S. Chow and H. Teicher, *Probability Theory: Independence, Interchangeability, Martingales,* Springer Texts in Statistics (New York), 3rd ed., 1997. [A graduate textbook on probability theory]

P. Billingsly, *Probability and Measure.* Third Edition, Wiley Series in Probability and Mathematical Statistics, 1995. [A classic graduate textbook on probability theory]

W. Rudin, *Real and Complex Analysis.* New York: McGraw Hill, 1987. [A classic textbook on measure theory and analysis]

W. Rudin, *Principles of Mathematical Analysis.* New York: McGraw Hill, 1976. [A classic textbook on elementary analysis]

S. Karlin and H. M. Taylor, *A First Course in Stochastic Processes.* Academic Press: New York, 1975. [A good undergraduate/graduate textbook on stochastic processes]

S. Karlin and H. M. Taylor, *A Second Course in Stochastic Processes.* Academic Press: New York, 1981. [An excellent undergraduate/graduate textbook on continuous-time stochastic processes]

P. G. Hoel, S. C. Port, and C. J. Stone, *Introduction to Stochastic Processes.* Waveland Press, Inc. 1987. [Another good textbook on stochastic processes]

H. V. Poor, *An Introduction to Signal Detection and Estimation.* Second Ed., Springer-Verlag, 1994. [An excellent textbook on applications of probability and stochastic processes to communications, signal processing and control]

Attendance

It is your responsibility as a Marquette University student to protect the health and safety of our community in this course. The University has mandated vaccination for all students for the academic year 2021-2022. COVID Cheq will still be used, but those fully vaccinated that provide documentation will no longer receive the daily symptom screening survey. Instead, they will receive a daily email providing a green check. You may be required to show your automated green check to show clearance for entry into campus buildings. If you are experiencing symptoms related to COVID-19, you must follow the link in the automated email to report symptoms. Visit Marquettes What to do if you are exposed to COVID-19 or test positive website (www.marquette.edu/coronavirus/what-to-do-if-you-are-exposed-or-test-positive.php) for university guidelines on the best course of action.

Instructors are expected to provide opportunities for students who miss classes due to symptoms, exposure, COVID-19 diagnosis, quarantine, and/or isolation to make up graded in-class assignments. Labs, clinicals and other field-based classes are the exceptions to this because it may be impossible to make up classwork in these types of classes.