ME529/EE529 STOCHASTIC PROCESSES IN ENGINEERING
FALL 2023

INSTRUCTOR: Goodarz Ahmadi, Room 267 CAMP (315-268-2322)
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Office Hours: Monday and Wednesday 12:30 - 3:30 pm
(Some meetings by appointment on Zoom)

TEXT: None. Lectures notes are available on the web.

Recommended Book: A. Papoulis, Probability, Random Variables and Stochastic Processes, McGraw Hill. https://www.amazon.com/Probability-Random-Variables-Stochastic-Processes/dp/0071226613

TA:

Course Description

Review of the theory of probability. Single and multiple random variables topics, including distributions, moments, conditional probability, central limit theorem, and laws of large numbers. Stochastic processes. Stationary and nonstationary processes. Time averaging and ergodicity. Correlation and power spectrum. Langevin's equation and Markov processes. Poisson and Gaussian processes. Response of linear systems. Approximate methods for the analysis of nonlinear stochastic equations. Application to engineering problems, including random vibrations, turbulence, estimation theory, signal detection, and others

Delivery Method

The course is offered in blended mode, both in-person in the class as well as online (asynchronous). The lectures will be captured by Echo 360 and made available to students.

COURSE WEB SITE:

https://webspace.clarkson.edu/projects/fluidflow/public_html/courses/me529/index.html
https://sites.clarkson.edu/gahmadi/courses/me529/

Course Objectives

- To provide the students with a fundamental understanding of probabilistic methods in engineering.
- To provide a fundamental understanding of the stochastic processes.
- To provide the students with the essential mathematical tools for handling random processes.
- To provide a fundamental understanding of the stochastic simulation techniques.
- To familiarize the students with the applications of probabilistic and stochastic methods in modern engineering problems.

Course Learning Outcomes

Objective 1:

- Students will be able to evaluate the statistical properties of random variables and can handle probabilistic transformations.

Objective 2:

- Students will become familiar with stationary and nonstationary stochastic processes, including Poisson, Wiener, and white noise processes.
- Students will be able to analyze linear stochastic differential equations using spectral and correlation techniques.

Objective 3:

- Students will become familiar with Markov processes and the Langevin equation.
- Students will be able to formulate the Fokker-Planck equation for linear and nonlinear stochastic differential equations.
- Students will be able to analyze nonlinear stochastic differential equations with the use of perturbation and equivalent linearization techniques.
- Students will become familiar with the concept of stochastic stability.

Objective 4:

- Students will perform stochastic simulations in their respective fields of interest.
- Students will become familiar with the applications of stochastic processes in engineering, including random vibrations, turbulence, and related topics.

COURSE OUTLINE

Course Schedule & Graded Activities

Dates	Module Title	Learning Materials (readings, videos, etc.)	Activities
Week 1	**I. Review of Engineering Mathematics**	• Special functions • Review of differential equations • Fourier transform	Homework
Weeks 2-4	**II. Introduction to the Theory of Probability**	• Axioms of Probability, Probability Space, Repeated Trials • Random Variables, Density, and Distribution Functions • Characteristic Function, Statistical Moments • Functions of Several Random Variables • Probabilistic Transformation and Central Limit Theorem	Homework
Week 5-7	**III. Random Processes**	• Introduction to Stochastic Processes • Poisson Process, Wiener, and White noise Processes • Stationary and Nonstationary Processes • Stochastic Calculus, Correlation, and Power Spectra	Homework
Week 8-9	**IV. Stochastic Differential Equations**	• Linear System Analysis, • Differential Equations with Random Forcing Functions • Spectral Method for Stationary Systems, • Nonstationary Response Analysis	Homework
Weeks 10-11	**V. Markov Processes**	• Langevin's Equation and Brownian Motion • Markov Processes, Ito's Equation • Louiville and Fokker-Planck Equations • Nonlinear Stochastic Systems	Exam- 1

		• Method of Moments of Fokker-Planck Equation	
Weeks 11-12	**VI. Nonlinear System Analysis**	• Nonlinear Stochastic Differential Equations • Perturbation Method • Equivalent Linearization Technique	Homework
Weeks 13-14	**VII. Random Systems**	• Stochastic Differential Equations with Random Coefficients • Stochastic Stability • Introduction to Karhunen - Loeve Expansion	Homework Computer Projects
Week 14-15	**VIII. Applications**	• Random Vibrations (Cars on rough roads, earthquake response of structures) • Reliability (Structures, engines, etc.) • Linear Stochastic Estimation • Neural Network (Machine learning, big data) • Turbulent Fluid Flow (Environmental and biological data Analysis) • Transport, Dispersion, and Diffusion Processes	Homework
Final Exam Week			Final Exam

COURSE TOPICS

I. Review of Engineering Mathematics
- Special Functions
- Differential Equations
- Fourier Transform

II. Introduction to the Theory of Probability
- Axioms of Probability, Probability Space, Repeated Trials
- Random Variables, Density, and Distribution Functions
- Characteristic Function, Statistical Moments
- Functions of Several Random Variables
- Probabilistic Transformation and Central Limit Theorem

III. Random Processes
- Introduction to Stochastic Processes
- Poisson Process, Wiener, and White noise Processes
- Stationary and Nonstationary Processes
- Stochastic Calculus, Correlation, and Power Spectra

IV. Stochastic Differential Equations
- Linear System Analysis, Differential Equations with Random Forcing Functions
- Spectral Method for Stationary Systems, Nonstationary Response Analysis

V. Markov Processes

- Langevin's Equation and Brownian Motion
- Markov Processes, Ito's Equation
- Louiville and Fokker-Planck Equations
- Nonlinear Stochastic Systems
- Method of Moments of Fokker-Planck Equation

VI. Nonlinear System Analysis

- Nonlinear Stochastic Differential Equations
- Perturbation Method
- Equivalent Linearization Technique

VII. Random Systems

- Stochastic Differential Equations with Random Coefficients
- Stochastic Stability
- Introduction to Karhunen - Loeve Expansion

VIII. Applications

- Random Vibrations (Cars on rough roads, earthquake response of structures)
- Reliability (Structures, engines, etc.)
- Linear Stochastic Estimation
- Neural Network (Machine learning, big data)
- Turbulent Fluid Flow (Environmental and biological data Analysis)
- Transport, Dispersion, and Diffusion Processes

EVALUATION METHOD:

Exam 1 (Friday, November 3, 2023, CAMP 178, 3:00-4:20 pm) 25%
Final Exam (Final Exam week) 40%
Projects (Due December 2, 2021) 25%
Homework 10%

Grading

Grade Ranges

Graduate Letter Grades

Course Average	Grade	Quality Points
97+	A+	4.0
93-96	A	4.0
90-92	A-	3.667
87-89	B+	3.334
84-86	B	3.0
80-83	B-	2.667
76-79	C+	2.334
70-75	C	2.0
<70	F	0

Course Policies

Etiquette Expectations & Learner Interaction

Educational institutions promote the advancement of knowledge through positive and constructive debate--both inside and outside the classroom. Please visit and follow: Netiquette and Electronic Learner Interaction Guidelines.

Institutional Policies & Regulations

Academic Integrity

Students are expected to abide by the standards of academic honesty, as described in the Clarkson Regulations. The work or words of others must be properly cited. Please refer to Clarkson Library's Guide to Plagiarism and Citing Sources.

Students with Disabilities Policy

Clarkson University welcomes inquiries and applications from individuals who have disabilities. Information relating to disabling conditions is not a determining factor in admission decisions. The University strives to make all facilities and programs accessible to students with disabilities by providing appropriate academic adjustments and other appropriate modifications (accommodations), as necessary. Timely notification of any need for accommodations due to a disability is encouraged so that the Office of Accommodative Services (OAS) may provide for students in an efficient manner.

For more information or other appropriate campus referrals, contact:

Director of Accommodative Services
Clarkson University
PO Box 5645
Potsdam, NY 13699-5635
Phone: 315-268-7643
Fax: 315-268-2400
Email: oas@clarkson.edu
Office of Accessibility Services Website

Instructor Participation

During this course, as your instructor, you can expect me to

- Respond to emails and voicemails within 1 day
- Grade activities and assessments within 3 days
- Be an active participant on the discussion board

Lecture Capture Policy

The lectures are captured and will be available on Moodle.

REFERENCES

1. T.T. Soong, Random Differential Equations in Science and Engineering, Academic Press (1973). https://www.elsevier.com/books/random-differential-equations-in-science-and-engineering/soong/978-0-12-654850-1
2. J.L. Lumley, Stochastic Tools in Turbulence, Academic Press (1970).

https://www.elsevier.com/books/stochastic-tools-in-turbulence/lumey/978-0-12-395772-6
3. S. Karlin and H.M. Taylor, A First Course in Stochastic Processes, Academic Press (1975). https://www.elsevier.com/books/a-first-course-in-stochastic-processes/karlin/978-0-08-057041-9
4. C.V. Heer, Statistical Mechanics, Kinetic Theory and Stochastic Processes, Academic Press (1972). https://www.elsevier.com/books/statistical-mechanics-kinetic-theory-and-stochastic-processes/heer/978-0-12-336550-7
5. Friedman, Stochastic Differential Equations and Applications, Vol. 1 and Vol. 2, Academic Press (1975).
6. https://www.elsevier.com/books/stochastic-differential-equations-and-applications/friedman/978-0-12-268201-8
7. R.L. Stratonovich, Topics in the Theory of Random Noise, Vol. 1 and Vol. 2, Gordon and Breach (1967). https://www.abebooks.co.uk/book-search/title/topics-theory-random-noise/author/stratonovich/
8. S.H. Crandall and W.D. Mark, Random Vibration in Mechanical Systems, Academic Press (1963). https://www.elsevier.com/books/random-vibration-in-mechanical-systems/crandall/978-1-4832-3259-1
9. R.W. Clough and J. Penzien, Dynamics of Structures, McGraw Hill (1975). https://www.amazon.com/Dynamics-Structures-Ray-W-Clough/dp/0070113920
10. H. Tennekes and J.L. Lumley, A First Course in Turbulence, MIT Press (1972). https://mitpress.mit.edu/books/first-course-turbulence