

THE OHIO STATE UNIVERSITY
Mechanical and Aerospace Engineering

AEROENG 8194–0010: Random Dynamical Systems
Spring 2022

Course Handout

NOTE: Modifications to this syllabus may be required during the semester. Any changes to the syllabus will be announced in class.

Pre-requisites:

ECE 6001 (or equivalent) and basic knowledge of functional analysis, or instructor permission. Working knowledge of at-least one programming language is required.

Course Objectives:

The objective of this course is the treatment of stochastic dynamic systems encountered in science and engineering. We begin with the fundamentals of deterministic dynamical systems, axiomatic theory of probability as developed by Kolmogorov, and measure theory. Focus then shifts to the *practice* of uncertainty analysis in nonlinear dynamic systems, including the exploration of existing tools such as generating functions, numerical simulations, sequential Monte Carlo, stochastic linearization, moment closure, Fokker-Planck equations and Bayesian data fusion. Broad ranging applications in uncertainty forecasting and nonlinear parameter and state estimation will be studied.

Contribution of course to meeting the professional component (ABET):

The table below describes the contribution of this course to development of specific components of professional growth as described in the ABET program criteria. The components have been divided into three streams: aeronautical (ae), astronautical (as) and mechanical (me):

Aeronautical		Astronautical		Mechanical		
(ae1) Aerodynamics:	×	(as1) Orbital mechanics:	✓	(me1) Apply principles of engineering, basic science & mathematics (inc. multivar. calculus & differential eqns) to model, analyze, design & realize physical systems, components or processes:	✓	
(ae2) Aerospace materials:	×	(as2) Space environment:	×		(me2) Work professionally in both thermal and mechanical systems areas:	×
(ae3) Structures:	×	(as3) Attitude determination and control:	×			
(ae4) Propulsion:	×	(as4) Telecommunications:	×			
(ae5) Flight mechanics:	✓	(as5) Space structures:	×			
(ae6) Stability and control:	×	(as6) Rocket propulsion:	×			
Mathematics: 60 %, Engineering Sciences: 40 %						

There is high coverage for professional components (me1) and medium coverage for (ae5) and (as1). In addition to the program criteria described above, this course will contribute to the development of proficiency in the area of probabilistic analysis of dynamical systems. This is essential for engineering design. Also, the course will cover the use of computational tools to solve problems in probabilistic analysis.

Relationship of course to program outcomes (ABET):

This course will meet several program outcomes as described in the ABET criteria, described in the table below.

Program outcome	Met?	Program outcome	Met?
(a) an ability to apply knowledge of mathematics, science, and engineering	✓	(b) an ability to design and conduct experiments, as well as to analyze and interpret data	×
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	×	(d) an ability to function on multidisciplinary teams	×
(e) an ability to identify, formulate, and solve engineering problems	✓	(f) an understanding of professional and ethical responsibility	×
(g) an ability to communicate effectively	✓	(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	×
(i) a recognition of the need for, and an ability to engage in life-long learning	×	(j) a knowledge of contemporary issues	×
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	✓		

There will be high coverage for outcomes (a), (e) and (k) in this course. These outcomes will be assessed throughout the semester via regular homework assignments (to be completed by individual effort), selected problems on exams, and a term-project which will require teamwork. Outcome (k) will be thoroughly assessed via the term project, which will involve the use of advanced computational tools. Outcome (g) will be assessed via end-term presentations of the team project in which each member will participate. In addition to the program outcomes checked above, this course will also result in the ability to function in teams (not multidisciplinary teams, as in outcome (d)) and the ability to distribute work in an efficient manner to avoid redundancy while maintaining coherence in the produced report/presentation.

Instructor: Mrinal Kumar (kumar.672@osu.edu). Office Location: E530 Scott Labs, Telephone: (614) 688-2884.

Best way to reach me: **email: kumar.672@osu.edu**

VIRTUAL office hours: Tu-Th 10:00 - 11:00 am

VIRTUAL additional office hour by appointment only: MW 10:00 - 11:00 am.

Location: @ Zoom (online)

Zoom Meeting ID: 993 8328 7702

Passcode: 921448

Direct Zoom Link: <https://osu.zoom.us/j/99383287702?pwd=SFd4UDd4aEVKeDFHaGVVR1lwVkJQUT09>

Teaching Assistant: Not Applicable

Class meeting times: MW 2:20 - 3:40 pm

Meeting location: Bolz Hall Room 124 (Bldg #146, 2036 Neil Ave Mall)

See [OSU MAP here](#)

How this Online Course Will Work

Mode of delivery: This course will have **in person lectures**. There are two weekly lecture sessions. I will attempt to record these using my laptop and post the lectures online. **All office hours will be online at the Zoom link provided above.** This has shown to be efficient in the past and allows the option of recording the Q&A sessions for future reference. A video camera is not needed for joining the office hours. All exams will be administered in person in our regular classroom.

[See this link for **Help with CarmenCanvas**]

[See this link for **Getting Started with CarmenZoom**]

Pace of instructional activities: In person lectures will follow the schedule printed on the registrar's website. Every attempt will be made to record all lectures and have them be available for viewing during the entire semester. There will be approximately 10 homework assignments in all. See page 4 for a tentative schedule of HW: Table (??).

Attendance and participation requirements: Consistent engagement is expected. If any problems arise in regards to attendance, please contact the instructor as soon as possible. Communication is important. You are encouraged to participate and ask questions.

All lecture notes/slides/videos will be posted on CarmenCanvas, so if you do miss a lecture, you are expected to view the missed material before the next lecture.

Course Technology: For help with your password, university email, CarmenCanvas, CarmenZoom or any other technology issues, questions, or requests, contact the Ohio State IT Service Desk. Standard support hours are available at [this link](#), and support for urgent issues is available 24/7.

- Self-Service and Chat support: ocio.osu.edu/help
- Phone: 614-688-4357(HELP)
- Email: servicedesk@osu.edu
- TDD: 614-688-8743

Required Equipment

- Computer: Mac (OS X) or PC (Windows 7+) with high-speed internet
- Webcam (for office hours - optional)
- Microphone
- Other: a mobile device (smartphone or tablet) or landline to use for BuckeyePass authentication

Textbook/Software: No official textbook is assigned for this course. However, the student must have access to at-least one programming language (e.g. MATLAB).

There are several excellent books in the general area of probability theory and random processes, but none cover all the topics of interest in this course. Therefore, no textbook is officially assigned. Attending class regularly and taking notes should be sufficient for understanding the material in this course. Classroom instruction will be based on extensive boardwork and notes will be provided when necessary. The following books can be used as reference texts for the material covered in class and are highly recommended:

1. *Probability and Random Processes*, by Geoffrey Grimmett and David Stirzaker, Oxford University Press USA, 3rd edition (Aug 2, 2001), ISBN-10: 0-19-857222-0, ISBN-13: 978-0-19-857222-0
2. *Probability and Random Processes: With Applications to Signal Processing*, by Henry Stark and John W. Woods, Publisher: Prentice Hall, 3rd edition (Aug 3, 2001), ISBN-10: 0-13-020071-9, ISBN-13: 978-0-13-020071-6
3. *A Probability Path*, by Sidney I. Resnick, Modern Birkhäuser Classics, Birkhäuser, 2014 edition, ISBN-10: 978-0-81-768408-2
4. *Stochastic Differential Equations: An Introduction with Applications*, by Bernt Øksendal, Publisher: Springer, 6th Edition (2005), ISBN-10: 3-540-25662-8
5. *Stochastic Processes and Filtering Theory*, by Andrew H. Jazwinski, Dover Publications (Nov 12, 2007), ISBN-10: 0-48-646274-9, ISBN-13: 978-0-48-646274-5
6. *Beyond the Kalman Filter: Particle Filters for Tracking Applications* by Branko Ristic, Sanjeev Arulampalam and Neil Gordon, Publisher: Artech House, 2004. ISBN: 978-1-58053-631-8
7. *Introduction to Probability*, by Dimitri Bertsekas and John N. Tsitsiklis, Publisher: Athena Scientific; 2nd edition (July 15, 2008); ISBN-10: 1-88-652923-X, ISBN-13: 978-1-88-652923-6
8. *Random Vibration and Statistical Linearization* by J. B. Roberts and P. D. Spanos, Dover Publications (Dec 9, 2003), ISBN-10: 0-48-643240-8, ISBN-13: 978-0-48-643240-3

Course outline: The table below provides a tentative weekly schedule for the material covered in this course:

Material	Week #	Assignment Due?
Deterministic dyn sys, steady state, numerical sims, linear perturbation theory	1	×
	2	✓
Review: axiomatic theory of prob, theory and tools for discrete and cts random variables	3	✓
	4	✓
Martingales, crossings, stopping times. Random walks, Wiener process (noise model), Brownian Motion. Markov processes	5	×
	6	✓
	7	✓
	8	× (Take-home Midterm)
Stochastic diff eqs, existence of solutions, numerical simulation, Chapman-Kolmogorov and Fokker-Planck equations, the filtering problem	9	×
	10	✓
	11	✓
	12	✓
Stochastic linearization, direct moment closure	13	×
	14	✓
Sequential Monte Carlo, Markov chain Monte Carlo	15	✓
	16	× (Take-home endterm)

Attendance/Other expectations: Students are expected to attend all lectures although there are no penalties for missing classes. Any activity that acts as a distraction for other students (e.g. talking on phone/texting/Rubik’s cube/juggling etc.) is not permitted while class is in progress.

Grading policy: Because of the nature of the subject, course evaluation will be based on homework problems, an end-term project and take-home exams. All homework assignments are to be completed individually. You are encouraged to discuss assigned problems with fellow students, but must turn in your own submission. Shared computer programs will not be considered for evaluation. No collaboration is permitted in the take-home tests! The following are the details of grade distribution:

- **HW assignments (8 - 10) :** 40%
- **Mid-term take-home exam (1):** 20%
MIDTERM DATES: Mar 7 - 8. This is an OPEN BOOK/OPEN NOTES EXAM.
- **End term project evaluation:** 20%
PROJECT PRESENTATIONS: April 29 (Friday) 12 - 2 pm, Scott N044
- **End term take-home final exam:** 20%
ENDTERM: May 2 - 3. This is an OPEN BOOK/OPEN NOTES EXAM.

Late HW policy: You are allowed to turn in 1 assignment late without penalty (your 1st late submission). The 2nd late submission will incur a penalty of 25% and 50% the 3rd onwards.

[Link to: OSU ACADEMIC CALENDAR](#)

Make-up exam policy: You must obtain permission from the instructor well in advance if you require to re-schedule your mid-term or end-term exam due to unavoidable circumstances. It may be difficult to accommodate last moment requests.

Grading scale:

Score	Grade	Score	Grade	Score	Grade	Score	Grade	Score	Grade
> 92	A	> 86	B+	> 76	C+	> 66	D+	< 50	E
> 89	A-	> 82	B	> 72	C	> 62	D		
		> 79	B-	> 69	C-	> 59	D-		

The above table represents a *guideline* for letter-grade allocation. In borderline cases, I reserve the right to assign a grade different from the grade derived from the table above. Such an assignment will be based on the progressive performance of the student in the course. For example, a student ending up with a final score of 88.2 *may* be awarded an A- (instead of B+) if her performance has progressively improved over the course of the semester.

Note: A C- will not be a qualifying grade for critical tracking courses. In order to graduate, students must have an overall GPA and an upper-division GPA of 2.0 or better (C or better). Note: a C- average is equivalent to a GPA of 1.67, and therefore, it does not satisfy this graduation requirement. For more information on grades and grading policies, please visit: [the registrar’s website HERE](#)

Make-up exam policy: Due to large size of the class, there will be no early/late exams. Please make your travel arrangements according to the exam dates specified in the syllabus.

Academic Misconduct: The Ohio State University and the Committee on Academic Misconduct (COAM) expect that all students have read and understand the university’s [Code of Student Conduct](#), and that all students will complete all academic and scholarly assignments

with fairness and honesty. It is the responsibility of the COAM to investigate or establish procedures for the investigation of all reported cases of student academic misconduct. The term “academic misconduct” includes all forms of student academic misconduct wherever committed; illustrated by, but not limited to, cases of plagiarism and dishonest practices in connection with examinations. Instructors shall report all instances of alleged academic misconduct to the committee (Faculty Rule 3335-5-487). For additional information, see the Code of Student Conduct at [THIS LINK](#).

Other sources on this topic:

- The Committee on Academic Misconduct web pages [[COAM Home](#)]
- Ten Suggestions for Preserving Academic Integrity [[LINK](#)]

Accommodation for Students with Disabilities: Students with disabilities that have been certified by the Office for Disability Services will be appropriately accommodated and should inform the instructor as soon as possible of their needs. The Office for Disability Services is located in 098 Baker Hall, 113 W. 12th Avenue; Phone: 292-3307, TDD 292-0901, VRS 429-1334; [ODS WEBSITE LINK](#)

Accessibility of course technology: This online course requires use of Carmen (Ohio State’s learning management system) and other online communication and multimedia tools. If you need additional services to use these technologies, please request accommodations with your instructor.

[\[Link to CarmenCanvas accessibility\]](#)

[\[Link to CarmenZoom accessibility\]](#)

Health and Safety Requirements: All students, faculty and staff are required to comply with and stay up to date on all university safety and health guidance ([see this website](#)), which includes wearing a face mask in any indoor space and maintaining a safe physical distance at all times. Non-compliance will be warned first and disciplinary actions will be taken for repeated offenses.

Grievances and Solving Problems: According to University Policies, if you have a problem with this class, you should seek to resolve the grievance concerning a grade or academic practice by speaking first with the instructor or professor. Then, if necessary, take your case to the department chairperson, college dean or associate dean, and to the provost, in that order. Specific procedures are outlined in Faculty Rule 3335-7-23. Grievances against graduate, research, and teaching assistants should be submitted first to the supervising instructor, then to the chairperson of the assistant’s department.

Title IX: All students and employees at Ohio State have the right to work and learn in an environment free from harassment and discrimination based on sex or gender, and the university can arrange interim measures, provide support resources, and explain investigation options, including referral to confidential resources. If you or someone you know has been harassed or discriminated against based on your sex or gender, including sexual harassment,

sexual assault, relationship violence, stalking, or sexual exploitation, you may find information about your rights and options at titleix.osu.edu or by contacting the Ohio State Title IX Coordinator at titleix@osu.edu. Title IX is part of the Office of Institutional Equity (OIE) at Ohio State, which responds to all bias-motivated incidents of harassment and discrimination, such as race, religion, national origin and disability. For more information on OIE, visit equity.osu.edu or email equity@osu.edu.

Counseling Services: As a student you may experience a range of issues that can cause barriers to learning, such as strained relationships, increased anxiety, alcohol/drug problems, feeling down, difficulty concentrating and/or lack of motivation. These mental health concerns or stressful events may lead to diminished academic performance or reduce a student's ability to participate in daily activities. The Ohio State University offers services to assist you with addressing these and other concerns you may be experiencing. If you or someone you know are suffering from any of the aforementioned conditions, you can learn more about the broad range of confidential mental health services available on campus via the Office of Student Life Counseling and Consultation Services (CCS) by visiting [THIS WEBSITE](#) or calling (614) 292- 5766. CCS is located on the 4th Floor of the Younkin Success Center and 10th Floor of Lincoln Tower. You can reach an on-call counselor when CCS is closed at (614) 292-5766 and 24 hour emergency help is also available through the 24/7 National Prevention Hotline at 1-(800)-273-TALK or at [THIS LINK](#)

Student Emergency Financial Support: The Student Advocacy Center staff members are continuing to serve students during normal business hours and are accepting online appointments. The Student Emergency Fund is available to students who may otherwise be at risk of dropping out of college due to an unexpected financial emergency. If you, or a student you know, are experiencing an unplanned expense, the Student Emergency Fund may be an option. Their office is accepting applications and may be able to award up to \$1,000 to eligible students. [Learn more and apply at this link.](#)

The *Together As Buckeyes Emergency Grants Program*, funded primarily by the federal Coronavirus Aid, Relief and Economic Security (CARES) Act, is available to all students — undergraduate, graduate and professional — through the Student Financial Aid office. To apply for a grant, students need to complete a one-page Emergency Request Form ([link](#)) and provide any supporting documentation. The Office of Student Financial Aid will process applications after determining eligibility based on each student's circumstances and guidance from the U.S. Department of Education.

The Student Wellness Center offers financial coaching through the Scarlet and Gray Financial nationally recognized peer financial coaching program. Through the program, students will learn about financial goal setting, banking basics, budgeting, credit education, debt repayment education and saving and retirement education. [Learn more at this link.](#)

Respect for Diversity: The Ohio State University affirms the importance and value of diversity in the student body. Our programs and curricula reflect our multicultural society and

global economy and seek to provide opportunities for students to learn more about persons who are different from them. We are committed to maintaining a community that recognizes and values the inherent worth and dignity of every person; fosters sensitivity, understanding, and mutual respect among each member of our community; and encourages each individual to strive to reach his or her own potential. Discrimination against any individual based upon protected status, which is defined as age, color, disability, gender identity or expression, national origin, race, religion, sex, sexual orientation, or veteran status, is prohibited.

Copyright: The materials used in connection with this course may be subject to copyright protection and are only for the use of students officially enrolled in the course for the educational purposes associated with the course. Copyright law must be considered before copying, retaining, or disseminating materials outside of the course.