

ASEN 6412

Uncertainty Quantification (UQ)

Fall 2026

Class meetings: Mon/Wed 1:00 PM - 2:15 PM in AERO 114

Instructor:

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Office hours: Mon/Wed 12:00 - 1:00 PM at AERO 363, otherwise by appointment.

Zoom link (only office hours): <https://cuboulder.zoom.us/j/3158335482>

Prerequisites:

Prerequisite is a *B* or better in ASEN 5070, APPM 5520, APPM 5570, ECEN 5612, or equivalent courses with instructor consent.

References:

- R. Smith, Uncertainty Quantification: Theory, Implementation, and Applications, SIAM, 2013
- R. Ghanem and P.D. Spanos, Stochastic Finite Elements: A Spectral Approach, Dover, 1991
- D. Xiu, Numerical Methods for Stochastic Computations: A Spectral Method Approach, Princeton University Press, 2010
- O. P. Le Maitre and O. M. Knio, Spectral Methods for Uncertainty Quantification: With Applications to Computational Fluid Dynamics, Springer Verlag, 2010
- R. Aster, B. Borchers, and C. Thurber, Parameter Estimation and Inverse Problems, Elsevier Academic Press, 2005

Grading:

- Homework (30%)
- Mid-term exam (30%)
- Final project (40%) with the following break down: Proposal (20%), Presentation (40%), and Report (40%)

Some notes:

- Homework problems involve combinations of analytical, numerical, or paper review tasks
- Please answer homework problems as clear and clean as possible. 10% of the homework grade goes to clarity
- No late homework submissions will be accepted unless there is an emergency
- Sharing thoughts on homework problems is encouraged; however, every student must submit their homework

Course objectives:

This course will provide an introduction to recent techniques for representation and propagation of uncertainty in PDE/ODE-based systems. Students will be exposed to the state-of-the-art techniques for building probabilistic models (from data) and simulation of random processes, as well as numerical solution of PDEs/ODEs in the presence of uncertainty. A number of case studies from computational solid and fluid mechanics will be discussed.

Course content (tentative):

- (Quick) review of basic probability and statistics:
 - Probability space, random variables, vectors, and processes
 - Convergence of random sequences
- Simulation of random variables, vectors, and processes with *known* distribution:
 - Simulation of random variables: Inversion and rejection techniques
 - Karhunen-Loeve expansion
 - Simulation of Gaussian and non-Gaussian random vectors and processes
- Introduction to modeling/simulation of random processes with *unknown* distribution:
 - Parameter estimation methods – Maximum likelihood and Bayesian
 - Generative modeling – Variational Auto-Encoders (VAEs)
- Solution of PDEs/ODEs with random inputs:
 - Monte Carlo techniques – Standard sampling, Latin Hypercube sampling, and importance sampling
 - Multi-level (and Multi-fidelity) Monte Carlo techniques
 - Polynomial chaos and generalized polynomial chaos expansions
 - Tensor-product and Smolyak sparse grid methods
 - Gaussian process regression (Kriging)
- Advanced topics:
 - Global sensitivity analysis
 - Application of Deep Neural Networks (DNNs) in UQ
 - Application of model reduction techniques in UQ (low-rank, sparse, and multi-fidelity) techniques

Syllabus Statements

Honor Code

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code. Violations of the Honor Code may include but are not limited to: plagiarism (including use of paper writing services or technology [such as essay bots]), cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty. Understanding the course's syllabus is a vital part of adhering to the Honor Code.

All incidents of academic misconduct will be reported to Student Conduct & Conflict Resolution: Student-Conduct@colorado.edu. Students found responsible for violating the Honor Code will be assigned resolution outcomes from Student Conduct & Conflict Resolution and will be subject to academic sanctions from the faculty member. Visit Honor Code for more information on the academic integrity policy.

Accommodation for Disabilities, Temporary Medical Conditions, and Medical Isolation

If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services to your faculty member in a timely manner so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities in the academic environment.

Information on requesting accommodations is located on the Disability Services website. Contact Disability Services at 303-492-8671 or DSinfo@colorado.edu for further assistance. If you have a temporary medical condition, see Temporary Medical Conditions on the Disability Services website.

Accommodation for Religious Obligations

Instructional faculty members must make every reasonable effort to accommodate all students who have conflicts with scheduled exams, assignment deadlines or required attendance due to a religious observance. Whenever possible, students must notify the instructional faculty member at least two weeks in advance of the expected exam, assignment deadline, or attendance conflict to request an accommodation for religious observance. If the start date of the course is less than two weeks before the date of requested accommodation, students must notify the instructional faculty member on the start date of the course. See the Student Academic Accommodations for Religious Observances Policy for more information.

Student Names and Pronouns

CU Boulder recognizes that students' legal information does not always align with how they identify. If you wish to have a name other than your legal name appear on your instructors' class rosters and in Canvas, or if you wish to choose pronouns to appear on your instructors' class rosters and in Canvas, visit the Registrar's website for instructions on how to change your personal information in university systems.

Classroom Behavior

Students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote, or online. Failure to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, marital status, political affiliation, or political philosophy.

Additional classroom behavior information

- Student Classroom and Course-Related Behavior Policy.
- Student Code of Conduct.
- Office of Institutional Equity and Compliance.

Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation

CU Boulder is committed to fostering a productive and welcoming learning, working, and living environment. University policy prohibits protected-class discrimination and harassment, sexual misconduct (harassment, exploitation, and assault), intimate partner abuse (dating or domestic violence), stalking, and related retaliation by or against members of our community on- or off-campus. Denial of an approved accommodation for disability, religious observance, or pregnancy or pregnancy related medical conditions may be discriminatory.

The Office of Institutional Equity and Compliance (OIEC) addresses these concerns, and individuals who have been subjected to misconduct can contact OIEC at 303-492-2127 or email OIEC@colorado.edu. Information about university policies, OIEC reporting options, and OIEC support resources including confidential services can be found on the OIEC website.

Faculty and graduate instructors are required to inform OIEC when someone discloses misconduct regardless of when or where it occurred. This is to ensure that those impacted receive outreach from OIEC about

resolution options and support resources. To learn more about reporting and support options for a variety of concerns, visit the Don't Ignore It page.

Mental Health and Wellness {Faculty: The following is a recommended syllabus statement but not required}

The University of Colorado Boulder is committed to supporting students' mental health and overall well-being. If personal, academic, or emotional challenges are affecting your wellbeing or success, Counseling and Psychiatric Services (CAPS), is here to help. CAPS offers counseling, referrals, psychiatric care, crisis support, and much more. Visit CAPS in the C4C, or call (303) 492-2277, 24/7.

Acceptable Use of AI in This Class

Specific AI use guidelines, if any, will be specified for each HW problem and must be followed closely.