Fundamentals of Reliability Analysis

ENRE 602 Fall 2018

Course Objectives

To provide an overview of the techniques, methods, and models methods used in various aspects of reliability engineering. Probabilistic modeling; probabilistic definition of reliability; use of data to assess model parameters; Principal methods of reliability analysis, including fault tree and reliability block diagrams; Failure Mode and Effects Analysis (FMEA); event tree construction and evaluation; reliability data collection and analysis; Bayesian analysis; parameter estimation. Focus on problems related to mechanical systems, process plants, energy systems and infrastructures, and other engineered systems.

Required Resources

1. Reliability Engineering and Risk Analysis, 3rd Edition, (2017) M. Modarres, M. Kaminskiy, V. Krivtsov, CRC, New York, New York. ISBN-13: 978-1498745871
2. Probability Distributions Used in Reliability Engineering, A.N. O'Connor (2011). *The PDF version of this book will be posted for download.*
3. Additional readings and software to be posted on course website.
4. Excel, Matlab, R, or Python.

Graded Assignments

- Assignments: 25%
  - Homework (Approximately 6, due at 1:00pm Wednesdays)
  - Quizzes/Classwork (unannounced)
- Midterm, **Oct 17**, 2.5 hours: 35%
- Final Exam (Cumulative), **Dec 12**, 2.5 hours: 40%
- Participation: 1%

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Use ELMS to contact me for course-related topics, excused absences, etc.

Class Meets
Wednesdays
1-3:40pm
JMP 2217

Office Hours
Wed 10:00am-12:00pm
(In person, phone, or webex).

Prerequisites
Multivariable calculus (calculus III). Students must be proficient in Excel, Matlab or Python.

Course Website
ELMS (aka Canvas) (www.elms.umd.edu) will be the main platform for course-related information and communication. Monitor ELMS for deadlines and announcements.

Course Delivery

This class is offered as both an on-campus and an off-campus course via UMD's Distance Education Program. Typically this course has an even split of students in the on-campus and off-campus sections. If you are enrolled in the on-campus section (0101), you are expected to attend in person. If you are in section 0101 and unable to attend a class you may watch the missed lecture online, but you may not make up missed quizzes.

Policies & Expectations

It is the policy of the course instructor to apply the same performance expectations to all course participants regardless of their academic, employment, or family status.

Students who need accommodation for disability, religious observances, or other foreseeable events should notify me **before the third week of classes.**

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The assignment dates are not flexible. You will not be allowed to make up an assignment unless you meet the university policy criteria for excused absence or accommodation. Students claiming excused absence must do so in writing. You may not make up missed quizzes - if you have an excused absence, the quiz will be dropped. **Absences stemming from work duties (other than mandatory military obligations) do not quality for an excused absence.** In case of inclement weather or other class cancellation, see ELMS for make-up materials. **Assignment due dates will not change even if campus is closed.**

Students are expected to take responsibility for their learning. You are expected to spend significant time outside of class to master this material. A good rule of thumb is 2-3 hours outside of class for each hour spent in class, but you may need to spend more or less. The course resources (lectures, textbook, office hours, slides, discussion boards, software) and the assignments are all part of the learning. Use all of them.

You may also need to use additional resources (e.g., journal papers, library, internet searches, tutors) to master certain topics, or if your performance does not match your goals. See the last page for some additional resources. **If you have not used calculus recently, I strongly encourage you to brush up on calculus before the second class.**

It is your responsibility to know and abide by the University of Maryland's policies that relate to all courses. This includes: academic integrity, attendance and excused absences, student and instructor conduct, accessibility and accommodations, grades and appeals, and copyright and intellectual property. It is your responsibility to understand these policies. Information about these policies can be found at: http://www.ugst.umd.edu/courserelatedpolicies.html

Assignments & Schedule

Date	Module	Reading & Assignments (Additional readings may also be assigned). Reading to be done before class.
Week 1 (Aug 29)	Course Introduction & Module 1	Course syllabus & Grading Rubric Ch. 1
Week 2	Module 2	Ch. 2.1 – 2.4 & related sections in O'Connor
Week 3	Module 2	Chapter 2.5 – 2.8 & related sections in O'Connor HW 1 due
Week 4 (Sept 19)	Module 3	Ch. 3.1- 3.2 & related sections in O'Connor
Week 5	Module 3	Ch.3.3-3.5, 3.7 & related sections in O'Connor HW 2 due
Week 6	Module 3	Ch. 3.6 & related sections in O'Connor
Week 7	Selected topic + Review for midterm	HW 3 due
Week 8 (Oct 17)	**Midterm Exam**	
Week 9	Module 4	Ch 4.1
Week 10	Module 4	Ch 4.2-4.4 (ok to skim BDDs, MLDs) HW 4 due
Week 11	Module 4	Ch 4.5
Week 12	Module 5	Ch 5.1-5.2 (ok to skim 5.1.5-5.1.6, 5.1.10,) HW 5 due
Week 13 (Nov 21)	(No Class, Thanksgiving break)	
Week 14	Module 5	Ch 5.2, 5.4
Week 15 (Dec 5)	Selected topic + Review for Final	HW 6 due
Week 16	**Final Exam**	

Note: This is a tentative and subject to change as necessary – attend class and monitor the course ELMS page for any changes to deadlines. In the unlikely event of a prolonged university closing, or an extended absence from the university, adjustments to the course schedule, deadlines, and assignments will be made based on the duration of the closing and the specific dates missed.

Assignments must be submitted at or before the beginning of class on the due date. Assignments submitted after the deadline will be marked late unless there is an excused absence (as defined in University policy) or by prior arrangement with the instructor. The penalty for a late assignment is a deduction of 5% per hour. **No credit will be given for assignments received after solutions are posted.**

Assignments must be submitted via Gradescope (www.gradescope.com) or in person The class code is: **MPXYZ3**. Submitted materials must be neat and professional. Submissions must be legible and have all pages viewable right-side up. Circle your answers. Assignments that do not adhere to this policy may receive penalties, and in extreme cases will receive a grade of 0.

For homework, use of online & print resources is allowed but you must cite your sources (except for the two textbooks). You may use standard office tools for graphics and word processing to prepare assignments. You may use Excel, Python, R and Matlab unless otherwise noted. **Wolfram Alpha is NOT permitted on exams and quizzes, and thus is discouraged for homework**. Additional software may be permitted on a case-by-case basis. Please notify me *before* using additional software in assignments. Unauthorized use of other software will be considered a violation of student code of conduct.

Students may collaborate on homework in small groups (2-4 people) if the following guidelines are met:

1) You should attempt the problems alone first.
2) The only persons you may discuss homework with are students from the current semester of ENRE602, the instructor and TA, or individual tutors. You may be asked to clearly state, at the top of the homework, who you worked with and on which problem(s).
3) Each student must turn in homework that is original to them. Each student must answer each question in their own words. You are expected to run your own calculations and document your own work. That is, the homework you turn in has to represent your solutions and your interpretation of the results.
4) "Collaboration" means you can check your answers with other students in your group, and discussing how to approach problems, perform certain operations, or implement functions. "Collaboration" is NOT when one person solves a problem and others copy the answer, or when students divide up the problems and each person only does a few; *these are examples of cheating.*
5) You may only collaborate on "solve out" problems. You may not collaborate on problems that involve writing, creating, interpreting, etc.

No collaboration is allowed for quizzes and exams unless otherwise noted.

Students are expected to monitor their grades in ELMS. If I have made a mistake, notify me and I will correct it. I am happy to discuss any of your grades with you during office hours. Any formal grade disputes must be submitted in writing within one week of receiving the grade.

Communication

It is your responsibility to check ELMS for updated course information. Use ELMS to contact me for course-related topics, excused absences, etc. Do not wait until the last minute to contact me for anything that needs a

response. I will not respond in writing to questions which need prolonged discussion. You must come to (or phone- or WebEx- during) office hours for longer questions. As an alternative, you may also post on the ELMS discussion board.

Students from all sections are encouraged to interact & ask questions in class and via ELMS discussion boards. Please use these resources to work together and to ask *and* answer questions. Participating in these discussion helps everyone enhance understanding. Explaining something to someone else is a great way to test and reinforce your learning.

Lecture Notes

I choose to provide my lecture notes as a courtesy to students to make it easier for you to follow the concepts. **These notes are NOT a substitute for taking your own notes or for reading the textbook! They are my draft notes designed for teaching purposes. They may (will) contain errors, typos, unexpected fonts, missing citations, and more.** I may change content in my final preparations for class. I may add or remove slides. I will not fix all of the errors; instead, I will point out the important errors during the lecture**. You should not use my notes if these problems become a distraction for you.**

Course materials must not be distributed to persons who are not registered in ENRE602.

Important notes for off-campus students:

- The Distance Education & Technology Services provides the capabilities that record and deliver course content to you. Sometime things don't work perfectly (e.g., you may be unable to hear student discussions in class; my microphone has static; the camera operator doesn't capture everything written on the board). If this happens: **you should contact DETS** and ask them to correct the problem. If there is an ongoing problem that DETS has not resolved, please let me know.
- The Office of Advanced Engineering Education (OAEE) oversees the exam proctoring process. I do not communicate with the proctors or set the proctoring policies. Early in the semester you will be contacted by OAEE to set up your proctoring arrangements. You are also welcome to come to campus to take exams during the scheduled class time – notify the TA to ensure that we print you a copy. If you or your proctors have questions, you should contact OAEE. Proctors will receive the exams and instructions from OAEE; I cannot provide the exam to the proctors.

Course Contents

Module 1) Perspective & Fundamental Concepts

- Why Study Reliability?
- Reliability, risk, availability, maintainability
- Failure Models, Failure Mechanisms
- Performance Measures

Module 2) Probability & Statistics

- Axioms of Probability
- Set Theory
- Bayes' Theorem
- Probability Distributions

- Estimation, hypothesis testing
- Goodness of fit
- Regression

Module 3) Component Reliability

- Reliability Function
- Failure Rate
- Hazard rates
- Common Distributions in Component Reliability
- Component Reliability Model Selection
- Parameter estimation
- Data analysis
- Bayesian Estimation Procedures

Module 4) System Reliability Analysis

- Reliability Block Diagram Method
- Fault Tree and Success Tree Methods
- Event Tree Method
- Master Logic Diagram
- Failure Mode and Effect Analysis

Module 5) Repairable Components/Systems: reliability and availability

- HPP, NHPP, Renewal processes, Markov processes
    - Data Analysis for Repairable Systems
- Availability of Repairable Systems
- System Analysis Techniques

Module 6) Selected Topics in Reliability Modeling

- To be announced

Where to Get Additional Help!

The University of Maryland provides ample resources to support your learning. **Everyone needs help sometimes**. You are expected to take personal responsibility for your own learning. This includes acknowledging when your performance does not match your goals and doing something about it. If you need some expert guidance on time management, note taking, and exam preparation, so I encourage you to consider visiting http://ter.ps/learn and schedule an appointment with an academic coach. Sharpen your communication skills by visiting http://ter.ps/writing and schedule an appointment with the campus Writing Center. Finally, if you just need someone to talk to, visit http://www.counseling.umd.edu. If you're not familiar with ELMS, an orientation is available here: https://go.umd.edu/elmsstudent.
You can obtain resources by searching "calculus refresher." Here is one such example: www.stat.wisc.edu/~ifischer/calculus.pdf. Similarly, you can find tutorials on Excel, Python, Matlab, and R online. The university also provides access to training courses via https://www.lynda.com/.