Fundamentals of Reliability Engineering

ENRE 447
Spring 2025

1. Course Objectives

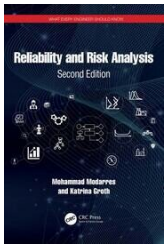
Reliability engineering is an engineering field that studies life performance of engineering structures, components and systems. It develops understanding of probable causes of failure and insight into how to prevent, mitigate, and recover from failures. This course provides a general survey of the techniques of reliability engineering with a focus on theoretical basis and quantitative methods, with frequent examples of application. The focus is on fundamental methods commonly used in practice, along with numerous examples. Topics include mathematical definition of reliability, probabilistic models to represent failure phenomena, statistical life models for non-repairable components, reliability data analysis, failure modes and effects analysis, risk analysis, and system reliability models including fault trees, event trees. Students will learn how to apply these techniques to problems related to engineering systems, with example cases for process plants, energy systems and infrastructure.

2. Course Format

This is on-campus, interactive, lecture-style course; it is also recorded for online (asynchronous) viewing via UMD's Distance Education Technology Services (sections starting with a letter; graduate students only). Lectures are given from slides and will be punctuated by discussion and active learning exercises. Bring a computer to class for exercises involving calculations. Course materials are posted on ELMS. Students are encouraged to use ELMS discussion boards to communicate about the course. The course resources (lectures, lecture notes, textbooks, assignments, discussion boards, software, and office hours) are all designed to complement each other. **Use them all.**

3. Course Resources

Required



1. M. Modarres and K. Groth (2023) "Reliability and Risk Analysis," 2nd Edition.
ISBN: 9781032309729 (paperback) or
ISBN: 9781032309736 (hardback).
(You need a printed copy; no digital access code)
2. Software: either Excel, Matlab, or Python.
3. Additional materials posted on ELMS.

4. Assessment (Grading)

- Formative assignments: 20%
  - Homework (HW) (~weekly; lowest dropped)
  - Classwork and Participation (CAP): Total worth 1 HW
- Midterm 40%
- Final Exam (Cumulative), 2.0 hours: 40%

Final grading will be on the +/- scale. Exams may or may not be curved. The cut-offs for final grades will be at least: 90% (A- or above), 80% (B- or above), 70% (C- or above), 65% (D- or above). The actual cut-offs may be adjusted depending on class performance.

Class Meets

Mondays, 3:30-6:00pm
JMP 2121
If needed, some weeks will be asynchronous using recorded lectures.

Prof. Katrina M. Groth
EGR 0151B
(301) 405-5215
https://umd.zoom.us/j/3014055215
kgroth@umd.edu (Do not email me about class. Use ELMS instead).

TA: Mohamed Nassar
EGR 0159
MNassar8@umd.edu
https://umd.zoom.us/my/mnassar8?pwd=NVBIczV1TWRJU2l0VTZqZDhPZ1FRUT09

Office Hours

*Office hours are in person. Only online students may attend via Zoom. To attend by Zoom, come at beginning or notify host to expect you later. If no one is online in the first ~5 minutes, we close Zoom.

Professor:
*Drop in**: M 2-3 pm
By appt: M after 6:15pm
TA:
*Drop in**: M 10-11am; Th 6:30-7:30 pm

Course Website

ELMS (Canvas) www.elms.umd.edu

Prerequisites

Calculus II. Students must be proficient in Excel, Matlab or Python. Familiarity with probability and statistics is beneficial.

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ENRE 447 Spring 2025

5. Schedule & Course Contents

Wk	Prof	Date	Module	Reading & assignment
1	KG	Jan 27	Module 1: Course Overview & Reliability Engineering Perspective & Fundamentals	Syllabus; Grading Rubric; Ch. 1
2	KG	Feb 3	Module 2: Basic Reliability Math: Probability	Ch. 2.1 – 2.6
3	KG	Feb 10	Module 2: Basic Reliability Math: Probability	Ch 2.7; HW 1 due
4	KG	Feb 17	Module 3: Elements of Component Reliability	Ch. 3
5	KG	Feb 24	Module 4: Basic Reliability Math: Statistics	Ch 4; HW 2 due
6	KG	Mar 3	Module 5A Part 1: Reliability Data Analysis & Model Selection Review for midterm	Ch. 5.1-5.3; HW 3 due
7	TA	Mar 10	**Midterm Exam + Selected topic**	HW 4 due
		Mar 17	**(No Class)**	
8	KG	Mar 24	Module 5A Part 2: Reliability Data Analysis & Model Selection	Ch 5.4-5.5
9	KG	Mar 31	Module 6A: System Reliability Analysis	Ch 6.1-6.3.1; HW 5 due
10	KG	Apr 7	Module 6B: System Reliability Analysis	Ch 6.3.2-6.6
11	KG	Apr 14	Module 6B: System Reliability Analysis	Review Ch. 1 alongside Ch. 6.4- 6.6; HW 6 due
12	KG	Apr 21	Module 6C: System Reliability Analysis (FMEA)	Ch 6.7 After class: read an article w/ HW 7);
13	KG	Apr 28	Module 6D: Bayesian Networks	Add'l reading on ELMS; HW 7 due
14	TBD	May 5	Module 9: Risk Analysis & Selected topic	Ch 9
15	KG	May 12	Review for Exam	
16	TA	May 15 8-10am	**Final Exam**	

*Unless otherwise noted: Reading is to be done before class. Assignments due at start of class. This is subject to change as necessary.

Module 1) Perspective & Fundamental Concepts
- Why Study Reliability?
- Reliability, risk, availability, maintainability
- Failure modes, mechanisms, causal factors

Module 2) Reliability Math: Probability
- Events and random variables
- Set theory & Boolean logic
- Laws and math of probability
- Bayes' theorem
- Probability distributions

Module 3) Component Reliability
- Reliability Function
- MTTF, MRL, MTBF
- Hazard rate, failure rate
- Bathtub curve
- Common probability distributions for component reliability

Module 4) Reliability Math: Statistics
- Descriptive statistics
- Empirical distributions
- Parameter estimation (point and interval)
- Hypothesis testing, goodness of fit
- Linear regression

Module 5) Data Analysis & Model Selection
- Types of reliability data
- Complete and censored data
- Reliability data sources
- Nonparametric methods for reliability
- MLE parameter estimation for reliability models

Module 6) System Reliability Analysis
- System configurations
- Reliability block diagram method Complex system evaluation methods
- Logic model (Fault tree and success tree) construction and evaluation
- Event trees and event sequence diagrams
- Failure modes and effects analysis

Module 9) Risk Analysis
- Quantitative Risk Assessment (QRA)
- Probabilistic Risk Assessment (PRA)
- Processes and strengths

5.1. Learning Outcomes

A student completing this course satisfactorily will be able to:

a) Define key terms, including reliability, risk, availability, maintainability, failure mode, failure mechanism and use those to evaluate their impact on engineering problems.
b) Apply multiple qualitative and quantitative methods to analyze reliability and risk, including probabilistic and statistical modeling and analysis, failure modes and effects analysis, and system reliability modeling including reliability block diagrams, fault trees, event trees.
c) Formulate solutions to reliability and risk problems for engineering components and systems
d) Communicate about reliability engineering with technical stakeholders.

6. Policies & Expectations

6.1. General

e) 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. Information about these policies can be found at: http://www.ugst.umd.edu/courserelatedpolicies.html
f) By submitting any assignment for this course, the student agrees that he or she has both read and understood this syllabus and further agrees to comply with the expectations therein as well as with any of the instructor's decisions regarding any policy not specifically stipulated in this syllabus.
g) I apply the same performance expectations to all course participants regardless of their academic, employment, family status, or demographic characteristics.
h) Students are expected to take responsibility for their learning. You will need to spend significant time to master this material. A good rule of thumb is 2-3 hours outside of class for each hour spent in class (so, 10-15hrs/week on this class), but you may need to spend more or less to achieve your goals. 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. This is encouraged, as long as you are staying within the bounds and spirit of the collaboration and academic integrity policies
i) It is your responsibility to check ELMS frequently for updated course information. You must also check your *university-issued* email address regularly for any official university communications.
j) Students are expected to monitor their grades in ELMS. I am happy to discuss any of your grades with you during office hours. If I have made a data-entry mistake, notify me and I will correct it. Any formal grade disputes must be submitted in writing within one week of receiving the grade.
k) Instructor may choose to convert this to a fully online asynchronous course at any time.

6.2. Communication

This is a mixed synchronous and asynchronous class, which adds extra communication challenges. Therefore, adherence to communication policies is necessary.

a) **Share your questions with the group**. It is more efficient and benefits everyone if questions are shared with the group in either the classroom, office hours, or ON ELMS.
b) **Use office hours or speak to me after class.** I will stay late after class by appointment. Requesting appointments at other times should be done only for emergencies.
c) **All written communication must go through ELMS.**
    a. *For private topics* (e.g., grades, accommodations): Message Prof. & TA via ELMS Inbox.
    b. *For any other topic*: Use the ELMS discussion board to both ask and answer questions. Participating in these discussion helps everyone enhance understanding & communication, and other students are likely to have similar questions or may know the answer to your question.

You'll get many pairs of eyes on your question before I even see it. And explaining something to someone else is a great way to test and reinforce your learning.

c. If you are answering homework questions on ELMS: don't give the whole solution immediately; give some pointers to help the person get back on track (and follow up with more pointers if needed). Don't just post your solution immediately.

d) *Do not ask me questions during the break*, this is when I prepare for the next part of class.
e) My message response time is 48 business hours. I do not respond evenings and weekends.
f) I will not respond in writing to questions which: 1) are answered on this syllabus or 2) require extensive discussion (judged by me) or 3) do not adhere to this communication policy.
g) If you are confused by something on the syllabus or an assignment, start your message with "I read the syllabus and the assignment directions, and…" so I know what to fix.

6.3. Attendance

a) If you are enrolled in the on-campus section (0101), you are expected to attend *in person*.
b) DO NOT come to campus if you or a household member has a contagious illness. Participate as an online student.
c) Students who need accommodation for disability, religious observances, or other foreseeable events must notify me **by the end of the second week of class.**
d) Students claiming excused absence must do so in writing via ELMS. University policy excuses the absences of students for illness (self or dependent), religious observances, participation in University activities at the request of University authorities, and compelling circumstances beyond the student's control. Absences stemming from work duties (other than mandatory military obligations or university obligations) do not quality for an excused absence. For more information, see the University's Excused Absence Policy (https://policies.umd.edu/assets/section-v/V-100G.pdf). Excused absences and academic accommodations do not alter the academic requirements for the course.
e) In case of inclement weather or other class cancellation, see ELMS for make-up materials and instructions. 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.

6.4. Assignments

a) Homework assignments must be submitted at the *beginning of class* on the due date.
b) CAP (classwork and participation) assignments are due by the deadline on ELMS (typically midnight on the day before class).
c) Exams are due on the day of the exam. Online students, see Section 8 for specifics.
d) Assignments submitted after the deadline will be marked late unless there is an excused absence. Deduction of 10% for the first hour, and 2% per hour thereafter. No credit will be given for assignments received after solutions are posted.
e) Homework and CAP must be submitted via ELMS as a single file. No zip files will be accepted.
f) Submitted materials must be neat and professional. Submissions must be legible and have all pages readable right-side up. Circle your answers. See the posted grading rubric for additional requirements. Assignments that do not adhere to this policy may receive penalties, including a grade of 0.
g) I strongly encourage you to complete all assignments and attend all classes because it directly relates to success in this course. That said, I understand that life happens and you may need to miss a class or a homework. Instead of asking you to explain your personal situation, I drop the lowest homework grade.

6.5. Software, Electronics, and Open/Closed Book

a) You may use standard office tools for word processing and graphics to prepare homework assignments.
b) The software, electronics, and notes policy will be written on exams & quizzes. These will often be augmented by oral instructions.
c) On some assignments I will write specific terms. ***All of these terms exclude the "Cheater Resources" defined in Section 6.6.***

a. **"Approved software"** means you may use graphing calculators, Excel (including RARE), Python, R, and Matlab unless otherwise noted on a specific problem. Wolfram Alpha is NOT permitted on any assignment. Additional software may be permitted on a case-by-case basis by speaking to me *in advance*. Use of any other software is a violation of academic integrity policy.
b. **"Open everything"** means you may use notes (my lecture notes & your notes), textbooks, the approved software, and online & print resources equivalent to those available in the library (e.g., encyclopedias, textbooks, concept videos, probability tables). If you use any resources (other than the course textbooks, materials I distribute, and the approved software) on assignments, you must cite them appropriately using Chicago or IEEE citation style. Once solutions are posted for an assignment, you can add them to your notes and use them on subsequent assignments that are open note. Video or audio notes are not allowed on exams or quizzes.
c. **"Open everything but internet"** or **"Open book, notes, and computer, closed internet"** means you can use the textbooks, notes, your computer, and the approved software but may NOT use the internet or any communications devices/apps/programs etc. For this, all devices should be placed in airplane mode unless it interferes with your ability to use the allowable software. In this case, you should be in "mental airplane mode" which means you can still be connected to the network, but you cannot use anything involving a web browser, communication tool, messaging app, other human, etc. My written lecture notes are part of the "open notes," but you must download them onto your device if you want to use them. Videos and audio – including the course videos -- are not part of the "open everything" on exams.

d) Most homework and CAP assignments are "open everything" unless otherwise noted. The finalized exam format and policy will be discussed in class the week before the exam and written on the exam.

6.6. Academic Integrity & Collaboration

a) Integrity is one of the most important attributes of engineers because we are entrusted with peoples' lives every day. Please do not compromise your integrity in this, or any, class. I take this responsibility seriously, and I will take action without warning if I suspect academic dishonesty. The standard penalty for academic dishonesty is a grade of XF and may result in you being expelled from the university.
b) You must be familiar with the UMD Code of Academic Integrity (https://www.president.umd.edu/administration/policies/section-iii-academic-affairs/iii-100a). In particular, be aware of the definition of "Academic Dishonesty," which is defined in the Code and further detailed by the Office of Student Conduct (https://www.studentconduct.umd.edu/academic-dishonesty), as any of the following acts, when committed by a student:
    1. CHEATING: fraud, deceit, or dishonesty in any academic course or exercise in an attempt to gain an unfair advantage, and/or using or attempting to use unauthorized materials, information, or study aids in any academic course or exercise.
    2. FABRICATION: unauthorized falsification or invention of any information or citation in any academic course or exercise.
    3. FACILITATING ACADEMIC DISHONESTY: knowingly helping or attempting to help another to violate any provision of this Code.
    4. PLAGIARISM: representing the words or ideas of another as one's own in any academic course or exercise.
    5. SELF-PLAGIARISM: the reuse of substantial identical or nearly identical portions of one's own work in multiple courses without prior permission from the current instructor or from each of the instructors if the work is being submitted for multiple courses in the same semester
c) **Use of "Cheater Resources" is prohibited in all assignments. "Cheater Resources" include, but are not limited to:** any problem solution or solutions manual except those given to you by the instructor of this class; all documents, notes or materials from previous semesters; anything you receive from a test bank (on or off campus), "homework help" or "course notes and extra materials" site (e.g., Chegg); any

solutions posted on a group chat, or other communication platform where the instructor is not involved; Any essay writing or problem solving service; any AI writing tools such as ChatGPT;

d) *Possession of any portion of the textbook solution manual or assignment solutions from previous semesters is cheating.* The only solutions you may use are the ones posted by the instructor on the course website after an assignment has been submitted.
e) Assume that external assistance is prohibited unless specifically authorized by the instructor. Notify me *before* using additional resources in assignments if you have questions about allowability.
f) No collaboration is allowed for quizzes and exams unless otherwise noted.
g) Students may collaborate on homework assignments in small groups (2-4 people) if the following guidelines are met:
   1. "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.*
   2. All students must turn in homework that is original to them. You (singular) must answer each question in your own words, run your own calculations and document your own work. The work you turn in has to represent your solutions and your interpretation of the results.
   3. The only persons you may discuss specific assignments with are students from the current semester of ENRE447, the instructor and TA, or individual tutors. You should clearly state, at the top of the assignment, who you worked with and on which problem(s).
   4. You may only collaborate on "solve out" problems. You may not collaborate on problems that involve writing, creating, interpreting, etc. without prior approval.

						
Homework	✓	✓	✓ with limits	X	✓ with limits	X
Quizzes & Classwork	Sometimes	Sometimes	X	X	Sometimes	X
Exam	✓	Sometimes	X	X	X	X

6.7. Lecture Notes

a) I choose to provide my lecture notes as a courtesy to students to make it easier for you to follow the concepts. Yes, you can use them on "open note" assignments. But, **my notes are NOT a substitute for taking your own notes, participating in class, or for reading the textbook!**
b) These are draft notes and are designed for teaching purposes. They 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 point out the important errors during the lecture**.** Do not use my notes if these problems become a distraction for you. If you catch an error, please post it on the ELMS board so I can confirm and update my notes for next year. I will not re-upload my slides unless there is a major error which impedes understanding.

6.8. Copyright

a) All course materials are copyrighted. This includes, but is not limited to: recorded lectures, lecture notes and slides, presentations, assignments, exams, solutions, announcements, discussion board posts. You may make copies of course materials for your own use and may retain them indefinitely. You may share

your notes with your classmates in *this semester* of this course. You may not and may not allow others to reproduce or distribute course materials without my express written consent.

b) Persons who publicly distribute or display or help others publicly distribute or display copies or modified copies of an instructor's Course Materials may be considered in violation of the University Code of Student Conduct, Part 9(k).

7. Where to Get Additional Help!

a) The University of Maryland provides ample resources beyond this class to support your learning. You are expected to take responsibility for your own learning. This includes acknowledging when your performance does not match your goals and doing something about it.

b) If you're not familiar with Canvas (ELMS), an orientation is available: https://go.umd.edu/elmsstudent.

c) You may also need to use additional resources (e.g., journal papers, library, internet searches, tutors) to master certain topics, especially if it has been several years since your last math class. Using additional resources is encouraged, as long as you are staying within the bounds of the collaboration and academic integrity policies. The UMD Library has a vast collection of resources, including e-books and journal subscriptions, to make locating external resources very easy.

   a. The libraries also provides a "reload button" for obtaining online resources while being off-campus: https://lib.guides.umd.edu/reload-button.

d) 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.

e) 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. UMD also provides free access to training courses via LinkedIn Learning.

f) The Professor and TA are not tutors. If you have more questions than can be answered during group office hours, you need tutor. Contact me for suggested tutors.

8. FAQ & Policies for online students:

8.1. Course Delivery, Attendance, & Deadlines

a) The online section(s) of this class will be *asynchronous*. This may be subject to change if conditions change. If the course format changes to facilitate synchronous online capability, I will notify the class.

b) This is an asynchronous class, but it is not "on demand." You can choose when you watch the lectures and do the assignments within the week, but you must adhere to the week-by-week schedule of this class. You must have access to the internet and access the course website frequently.

c) This course is conducted in U.S. Eastern Time. I will not change deadlines to accommodate your time zone. You can change your time zone in ELMS to make it easier for you to see the deadlines.

d) The Distance Education & Technology Services provides the capabilities that record and deliver course content to you. Sometime things don't work perfectly, but I don't watch the course videos, so it's up to you to notify me if there is a recurring issue with the filming.

e) If you call or Zoom during office hours and I don't pick up or admit you right away, I am with another student. Please try again in a few minutes.

f) If you plan to watch the videos in multiple sittings: it's ok to pause or stop the video and restart it later, except during a quiz. If I announce a quiz, please plan to complete the quiz and post-quiz discussion in one sitting, or stop the video immediately and return to it when you are able to complete the whole thing. Don't pause again until I change topics – sometimes I discuss the quiz right after it. Do not fast forward the video and then come back to do the quiz later – sometime I go over the answers to the quizzes on the video, and if you watch the video of the answer and then come back to do the quiz, you are cheating.

8.2. Exams

a) Exams are proctored. I do not coordinate proctors or communicate with them. DETS and/or Southern Maryland office and/or Maryland Applied Graduate Engineering (MAGE) oversees the proctoring process (https://mage.umd.edu/proctoring). A few weeks into the semester you will be contacted by DETS or MAGE to set up your proctoring. Proctors receive the exams and instructions from DETS or MAGE a few days before the exam. If you or your proctors have questions, contact DETS or MAGE.
b) You are welcome to come to campus to take exams during the scheduled class time – this is one of the proctoring options you can select with DETS or MAGE. They will notify me.
c) If you are taking the exam with a proctor: you must take the exams on the scheduled date of the exam. You may begin your exam at any time within the 24 hour period on the exam date.

8.3. CAP & Quizzes

a) Keep the course video running during quizzes and partner discussions so that 1) you know how long the exercise is (which isn't always an exact pre-determined time) and 2) you are able to hear any announcements I make during the exercise.
b) You should take the quiz "with the class" and use the same amount of time as the on-campus students (i.e., however long the video goes for). Do not complete the quiz before I announce it in class. You should either: print/open the quiz before the class (without reading the quiz), or pause the video, print/open the quiz, restart the video and start the quiz when I tell the class to start.
c) Partner exercises: I will post a thread on ELMS so you can identify someone who studies at the same time and may be able to be your partner. If you don't have a partner to discuss with during a partner or group activity, that's ok, but don't skip the exercise! Instead, take the time to think and write down your ideas, or talk out loud. This is part of the learning.
d) It's ok to wait to until after class to scan & upload your quiz, but do not change anything on your quiz sheet after the on campus students have turned their quiz in.
e) I may ask you to "swap to grade" your quiz. If you don't have a partner, you can do this by picking up a different pen or changing your font color.