MSE 7772 – Fall 2021
Fundamentals of Fracture Mechanics
Mondays and Wednesdays 12:30-1:45 PM
Location: Cherry Emerson 320

Course Description: The learning objectives are to understand the basic concepts of linear-elastic fracture mechanics (LEFM) and elastic-plastic fracture mechanics (EPFM) so that we can analyze and engineer structural components that contain cracks. The course will emphasize the fundamental underpinnings of fracture mechanics and its use in material evaluation and life prediction for components. Micro-mechanisms of crack growth for metals and ceramics will also be covered.

Prerequisites: The prerequisite for this class (ME 3201/MSE 3005) is a junior-level mechanical behavior of materials course. You should only enroll in this class if have completed coursework (or other training) so that you are comfortable with the content typically taught in ABET-accredited, undergraduate engineering programs (i.e., calculus, linear algebra, differential equations, physics, chemistry, introduction to materials science and engineering, statics, deformable bodies, and mechanical properties of materials).

Structure & Expectations: This in-person section requires that you are available to participate during the scheduled time window. The course content is delivered via in-person lectures and is supported by content posted on the Canvas learning management system. Please do not enroll in this section if you have a time conflict or other constraints that will limit your ability to participate in the class during the scheduled period. In addition to lecture, the instructor and TA will be available for consultation via office ours and appointments. The tentative schedule for the lectures and other activities are listed in the syllabus. Electronic message boards and other group communication platforms (e.g., Piazza) will not be used by the instructor. Exams will be administered in-person during the scheduled class period. Changes and updates to the course will be highlighted in the syllabus and posted on Canvas. Finite element modeling software licensed by Georgia Tech will be used for the course project.

The usual Institute guidelines for workload apply to this course: In addition to attending lectures, you should expect to spend ~3 hours per 50 minutes of scheduled class time on reading, homework, studying, and other aspects of the class. The course structure is a series of in-person lectures supported by readings, homework, and a project report. Your final grade will be based on a series of written assessments (exams and a project).

Instructor:
Prof. Christopher Muhlstein,
Bunger Henry Building, Room 121
Tel: (404) 385-1235
e-mail: christopher.muhlstein@mse.gatech.edu

Office Hours: Tuesdays 1:00-2:00 PM (or by appointment)

Please note that these office hours are open to everyone in the class. The TA's office hours are by appointment. To meet students' requirements, needs, and comfort levels, meetings and office hours will be offered in-person, virtually, or outdoors.

Email and Tech Policy: You must use your Georgia Tech issued email address or the messaging option in Canvas when contacting the instructor or teaching assistant(s). Email originating from outside the Georgia Tech network may be ignored to protect your personal information and comply with Federal and Georgia Tech policies.

Textbook (Required): T.L. Anderson, *Fracture Mechanics: Fundamentals and Applications,4th Edition*, CRC Press- Taylor & Francis Group, New York (2017). ISBN: 0849342600
Note: The textbook for this course is required, and you are expected to have used it as a resource. Not using the textbook as a resource will probably compromise your performance in the class.

Resources (Optional): A comprehensive "Supplemental Reading Lists" is posted on Canvas. These electronic reference materials are (generally) available for free through the Georgia Tech Library or an open-access license agreement. These reference materials are helpful when reviewing concepts that are prerequisites for this course. The list also includes references for advanced topics in elasticity and fracture mechanics.

Course Website: Canvas (http://canvas.gatech.edu) will be used to post all of the course content (syllabus, lecture notes, homework, homework-solutions, word, etc.). Important announcements will also be sent to your Canvas account so please check it regularly. Notice of updates to the Syllabus will be announced on Canvas.

Course FAQ: A detailed course "frequently asked questions" document is posted on Canvas. This document has detailed, practical guidance for the course (e.g., how to study for exams, how to estimate your final grade, etc.). Please be sure to read the FAQ at the start of the semester, and review it before you contact the instructor. Notice of updates to the FAQ will be announced on Canvas.

Course Discussion: *Electronic class discussion platforms (e.g., Piazza) will not be used by the instructor or TA.* Email and message board exchanges are not an effective way to discuss or clarify concepts in the class. Please be sure to ask questions during lecture or office hours. If there is a question that you would like to see addressed in lecture, you are encouraged to send the question via email in advance.

Exams and Project: All exams will be closed book and administered in-person. No formula sheets other than the ones provided with the exam will be allowed. Exams #1 will be 75 minutes long and administered in-person during the scheduled class period on the date noted on the syllabus. The scheduled class period is set by the GT Registrar and is listed at the start of this syllabus. Exam #2 (Final Exam) will be 2 hours and 50 minutes long and administered in-person during the final exam period as scheduled by the Registrar. Please note that the final exam schedule has been known to change during the semester because of extenuating circumstances (e.g., global pandemic), and is *not* controlled by the course instructor. While we try to keep the syllabus current, students are responsible for verifying the exam time with official schedule maintained by the GT Registrar.

All exams will be scored and returned electronically via Canvas using Gradescope. Students are responsible for insuring that their computing, internet access, and other technology are available and perform as needed for the class. The FAQ contains additional recommendations for browser and system setup and testing.

The late penalty for electronically submitted assessments (e.g, the project) will be

set based on the relevant system timestamps. If you use a computing platform that suppresses or modifies the timestamps of your submission, your submission will be immediately forwarded for an academic integrity review.

The exams will emphasize topics that are detailed in the textbook as outlined below.
1. Exam #1- tentatively Ch. 1 and 2 on 10/6/2021
2. Exam #2- tentatively Ch. 3, 5-7, and 11 on 12/10/2021

The course project is due at the end of the term, but there will be several milestones where you will need to submit files electronically to document your progress. The milestones will contribute to your project grade as detailed in the Project Description, and are outlined below.

1. Project Milestone #1- tentatively on 9/8/2021
2. Project Milestone #2- tentatively on 9/29/2021
3. Project Milestone #3- tentatively on 10/27/2021
4. Project Report- tentatively on 12/1/2021

Simulia 2021 (ABAQUS/Isight/ FE-Safe/Tosca) will be used for the course project, and is licensed to students, faculty, and staff in the College of Engineering. The links for the license and installation files are available at: software.oit.gatech.edu. Students are responsible for insuring that they have access to computing resources needed for the course. The required resources will be detailed in the Project Description.

Gradescope:

Gradescope is an online assessment tool that is integrated in Canvas and allows for both electronic and handwritten answer submission. Gradescope also facilitates the scanning and scoring of handwritten and electronic submissions. It is essential for us to test the system to be sure that it works for everyone. Please familiarize yourself with Gradescope by going to this durable link about submitting assignments at YouTube: https://youtu.be/pgklq6JDatA.

Gradescope will be used to electronically score and return your exams and project.

Additional information about the tool can be found in the help section at gradescope.com, including guidance on various strategies to make electronic files from your handwritten pages. A specific guide for using Gradescope with Canvas can be found at: https://help.gradescope.com/article/5d3ifaeqi4-student-canvas .

Grades:

Your grade in the course will be determined based on your performance on two, hand written examinations, and a project report. All exams will be closed notes, closed book tests (i.e., no supplementary materials of any kind are to be used).

- The first examination (50 minutes long) will be held during the regular meeting time of the class on the date indicated on the syllabus. The last examination (2 hours 50 minutes) will be administered during the final exam period at the time and location set by the Registrar (same room location as the regular lecture).
- Final grades will be curved at the instructor's discretion based on a strategy that will be discussed during the first class meeting. Additional guidance on the curve and grade cutoffs are also posted on Canvas.
- There are penalties for late exam and project submission. Late course

project submissions will be penalized at a rate of 2 percentage points (of the assessment) for each hour past the submission cutoff.

Assessment (Tentative Chapters)	Percentage of Final Grade
Exam #1 (LEFM)	30%
Exam #2 (EPFM & Mechanisms)	40%
Project Report	30%

Midterm grades: Midterm grades will be reported as "S" or "U". A "U" will indicate unsatisfactory performance, i.e., a "D" or "F." The midterm grade will be determined by the grade on the first examination.

Homework: Homework problems will be given at the start of each chapter. Homework is not to be turned-in and will not be graded. You are responsible for using the provided solutions to gauge their understanding of the material. You are strongly encouraged to work on the homework and extra problems from the book. Neglecting the homework will jeopardize your performance in the class. You are allowed/encouraged to study with other students (including working together on the homework assignments). You can ask question regarding your homework, although you should try to think about the problems before asking me or the TA(s).

Make up policy: Make-up exams will only be permitted when absences are due to legitimate reasons such as illness, religious observance, or other events recognized by the Institute as a valid excuse. In any case, you must contact the instructor in advance of the test in writing (email is fine) to schedule a make-up exam. If you do not contact the instructor in advance, it may not be possible to schedule a make-up test. When possible, make-ups will be administered during the week following the originally scheduled date. Make-up exams may be different from those administered during the regular examination period.

Extenuating Circumstances: Please be sure to meet with the Dean of Students if you encounter extenuating circumstances that interfere with your ability to attend class and/or prepare for exams. The Dean's office is your best resource when you are not comfortable discussing the details of your personal situation.

Grade Accuracy: Errors in grading and/or recording of scores for quizzes and exams must be addressed within 7 days of posting on Canvas by contacting the instructor in writing via email. Disputes after this one-week period will not be considered.

Final Exam Conflicts: The Institute has established the policies for final exam scheduling conflicts that are summarized in the list below. If you need to request an accommodation, please contact the instructor via email and include a list of all of your courses (course numbers and sections) and their exam periods on the day in question. If you have additional questions about the Institute's policies, please refer to the regulations in the course catalog (http://catalog.gatech.edu/rules/12/) and the Office of the Registrar's website at https://registrar.gatech.edu/info/exam-guidelines. Please note the following Institute policies:

- "All students should check the Final Exam Schedule against their own class schedule and report any conflicts to the instructor(s) as soon as possible. It is the responsibility of each student to see that all possible conflicts are resolved by the instructor and the proper authorization received no later than

2 weeks before the Monday of exam week. A special period is provided as a conflict period in which to reschedule conflicting examinations. Refer to the Final Exam Schedule for the conflict date. Other periods within the exam week may also be used for conflicting examinations provided no student is forced to take more than two examinations in one day."

- "Any course that is offered outside the normal scheduling format must make arrangements to give way to courses offered in the normal time slot. If a conflict arises between two courses that offer finals outside the normal scheduling format, the conflict will be resolved by the instructor rescheduling the examination for the course with the lower number. The common final for any course may not take up more than one exam period."
- "Time Conflict#1: Two examinations scheduled for the same period, neither course being examined at other hours, or no available hour on the student's schedule to take the exam with another section. Resolution#1: This conflict may be resolved by the instructor rescheduling the examination, for the course with the lower number, to the conflict period stated on the Final Exam Schedule, or to another period mutually agreed on by the instructor and the student."
- "Time Conflict #2: Three examinations scheduled in one day. Resolution #2: To resolve this conflict, the examination scheduled for the middle period will be rescheduled to the conflict period stated on the Final Exam Schedule or to another period mutually agreed on by the instructor and student."

Academic Integrity:

All students in this class are expected to respect the *Georgia Tech honor code* and behave in a professional manner when it comes to academic integrity. Any students violating the honor code or suspected of academic misconduct will be turned over to the office of Academic Integrity, Dean of Students to investigate the incident(s). Cheating off of another person's test is unethical and unacceptable. Cheating off of anyone else's work is a direct violation of the GT Academic Honor Code, and will be dealt with accordingly. *For any questions involving any Academic Honor Code issues, consult me, my teaching assistants, or* http://www.policylibrary.gatech.edu/student-affairs/academic-honor-code.

Recording of Classes:

Classes may not be recorded by students without the express consent of the instructor unless it is pursuant to an accommodation granted by the Office of Disability services. Class recordings, lectures, presentations, and other materials posted on Canvas are for the sole purpose of educating the students currently enrolled in the course.

Students may not record or share the materials or recordings, including screen capturing or automated bots, unless the instructor gives permission. Digitally proctored exams may require students to engage the video camera, but those recordings will not be shared with or disclosed to others without consent unless legally permitted.

Electronic Devices:

Remember that exams are closed to all reference materials, and your answers will be hand written. During a quiz or exam, you will need to use a commercially available calculator that cannot communicate with other devices without a direct physical connection (i.e., no wireless, IR or other communication capabilities). Programmable and graphing calculators are allowed, but their memories should be

appropriately cleared. Your use of a calculator should be consistent with the class policy that reference materials of any kind are *not permitted* on quizzes or exams.

Word: Use of any previous semester course materials is allowed for this course; however, we remind you that while they may serve as examples for you, they are not guidelines for any tests, quizzes, homework, projects, or any other coursework that may be assigned during the semester

Special Needs: Georgia Tech values diversity and inclusion; we are committed to a climate of mutual respect and full participation. Our goal is to create learning environments that are usable, equitable, inclusive, and welcoming. If there are aspects of the instruction or design of this course that result in barriers to your inclusion or accurate assessment or achievement, please notify the instructor as soon as possible. Students with disabilities should contact the Office of Disability Services to discuss options of removing barriers in this course, including accommodations. ODS can be reached at 404.894.2563, dsinfor@gatech.edu or disabilityservices.gatech.edu.

Course Objectives: The primary learning objective of the course is to thoroughly understand the basic concepts of linear-elastic fracture mechanics (LEFM) and elastic-plastic fracture mechanics (EPFM) for predicting fracture and crack growth in structural components that contain cracks. The course will emphasize the fundamental underpinnings of fracture mechanics and its use in material evaluation and life prediction for components. Micro-mechanisms of crack growth for metals and ceramics will also be covered.

Course Outcomes: 1. Students demonstrate an understanding of linear elastic fracture mechanics. 2. Students demonstrate an understanding of elastic-plastic fracture mechanics 3. Students will demonstrate an understanding of material fracture and crack growth mechanisms. 4. Students will demonstrate the ability to perform basic stress and fracture mechanics analyses using finite element methods.

Teaching Assistants: You are encouraged to contact your TA for questions/problems related to the course. Below is a list of the contact information for the TA.

TA: Zach Towner
e-mail: ztowner6@gatech.edu
Office Hours: by appointment

Student Resources: The Dean of Students Office, CARE Center, Counseling Center, Stamps Health Services, and the Student Center are valuable resources. The CARE Center and the Counseling Center, Stamps Health Services, and the Dean of Students Office will offer both in-person and virtual appointments. Student Center services and operations are available on the Student Center website. For more information on these and other student services, contact the Dean of Students or the Division of Student Life.

Sexual Harassment: MSE is committed to a community that actively resists sexual and gender harassment. If you see or experience any of the following: sexual harassment, domestic and dating violence, sexual assault and stalking, resources are available:

- **Confidential VOICE Advocates** (www.voice.gatech.edu) can provide support 24/7 and explore resources and options. If after hours, call GTPD

dispatcher at 404-894-2500 and ask to speak to the On-Call VOICE Advocate. You do not need to make a report nor provide any information other than your phone number for a VOICE advocate to contact you.

- Sexual violence or harassment can be reported directly to Georgia Tech's **Title IX Coordinator**, James Newsome, (404) 385-5583 burnsnewsome@gatech.edu.

Please note that faculty, staff and TAs are mandatory reporters and are required to inform the Title IX Coordinator should they become aware that you or any student has experienced sexual violence or sexual harassment.

COVID-19: Students are expected to be familiar with and abide by the Institute guidelines, information, and updates related to Covid-19. Find campus operational updates, Frequently Asked Questions, and details on campus surveillance testing and vaccine appointments on the Tech Moving Forward site.

Instructor Illness: Faculty may cancel a class if they have an illness or emergency situation and cover any missed material at their own discretion. You will be notified as quickly as possible of changes to the course schedule via Canvas. The syllabus will be updated on an ongoing basis to reflect changes and corrections during the semester.

MSE 7772 – Fall 2021
Fundamentals of Engineering Fracture Mechanics
Tentative Schedule

Abbreviations: (A) Anderson, (DOW) day of the week, (M T W T F) days of the week, (PM) project milestone, #ZBT Towner practicum lecture

***bold text** indicates important events in the schedule*

Week	DOW	Date	Reading (Anderson)	Topic	Lecture Topics	Assessment & Notes
1	M	8/23	Ch 1	LEFM	1. Intro / History	
	W	8/25	Ch 1		2-3. Overview	
2	M	8/30	2.1		3. Atomic View of Fracture 4. Stress Concentrations	
	W	9/1	2.3 12.1		5. Griffith Energy Balance, Project- FEA setup	#ZBT
3	**M**	**9/6**			**LABOR DAY HOLIDAY**	**NO CLASS**
	T	**9/7**			**FALL VERIFICATION OF PARTICIPATION (VOP)**	**NO CLASS**
	W	9/8	2.4 2.5		6. Energy Release Rate (G) 7. Instability and R-Curves	**PM#1**
4	M	9/13			8-9. Continuum Mechanics Review- Stress and Plasticity	
	W	9/15	2.6		10. Stress Analysis of Cracks (Part 1)	**HW#1**
5	M	9/20	2.6		11. Stress Analysis of Cracks (Part 2)	
	W	9/22	2.7 2.8 12.2		12. Relationship between K and G 13. Crack tip plasticity, validity of LEFM Project- FEA of cracks	#ZBT
6	M	9/27	2.9 2.10		14. Application of K to design and analyses (Part 1) 15. Application of K to design and analyses (Part 2) 16. Influence of specimen thickness on fracture toughness	
	W	9/29	2.10 2.11		17. Plastic zone correction 18. Mixed mode fracture / angled crack	**PM#2**
7	M	10/4			Project Lecture	**HW#2**
	W	10/6			LEFM (Lectures 1-12)	**EXAM#1**

8	M	10/11			**FALL BREAK**	**NO CLASS**
	W	10/13	Ch 3, 9	EPFM	19. Stress strain relationships ahead of blunted crack tip.EPFM: Nonlinear Release rate (J)	
9	M	10/18	Ch 3, 9		20. Calculating driving force J (J integral) - J as stress intensity parameter (HRR)	
	W	10/20	Ch 3, 9	12.3-12.6	21. Calculating driving force J (J integral) - J as stress intensity parameter (HRR) Project- Integral calculations	#ZBT
	S	**10/30**			**DROP DEADLINE**	**NOON-ONLINE**
10	M	10/25	Ch 3, 9		22. Calculating driving force J (J integral) - J as stress intensity parameter (HRR)	
	W	10/27	Ch 3, 9		23. EPFM: CTOD - Relationship with J	**PM#3**
11	M	11/1	Ch 7		24. Lab Tests K and J	**HW#3**
	W	11/3	Ch 5, 6, 11	Mechanisms	25. Toughening Mechanisms for high-toughness ceramics	
12	M	11/8	Ch 5, 6, 11		26. (Part 1). Process Zone Mechanisms for high-toughness ceramics	
	W	11/10	Ch 5, 6, 11		27. (Part 2). Bridging Mechanisms for high-toughness ceramics	
13	M	11/15	Ch 5, 6, 11		28: Cleavage fracture for metals	
	W	11/17	Ch 5, 6, 11		29. Modeling cleavage fracture toughness	**HW#4**
14	M	11/22	Ch 5, 6, 11		30. Ductile fracture in metals	
	W	11/24				
	T	**11/25-11/27**			**THANKSGIVING BREAK**	
15	M	11/29	Ch 5, 6, 11		31. Ductile Crack Growth	
	W	12/1				**PROJECT REPORT**
16	M	12/6			**LAST DAY OF INSTRUCTION**	
	W	12/8			**READING PERIOD**	
	F	**12/10**			**FINAL EXAM**	**11:20AM-2:10PM**
		12/20			**FINAL GRADES DUE**	