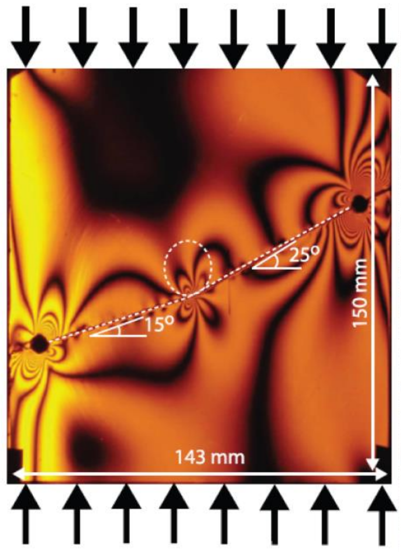
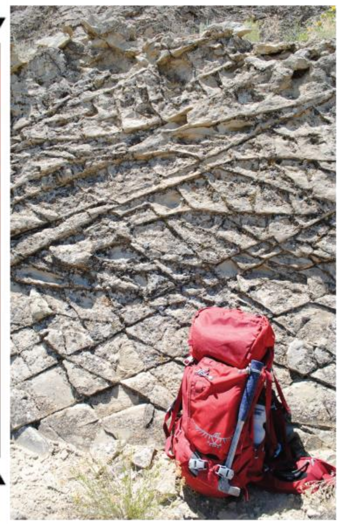
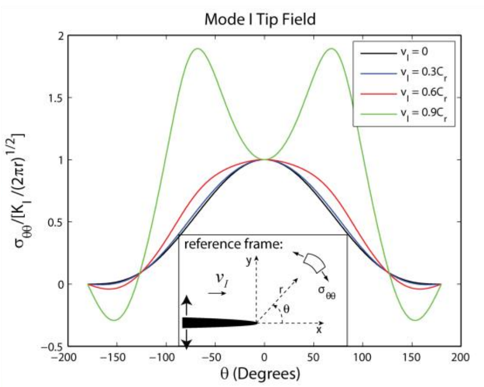
SPRING 2017

GEOL 5303: ROCK FRACTURE MECHANICS*

*Undergrads: Register for **Selected Topics in Geology** GEOL 4305-005







Basic Course Information:

Course number: GEOL 4305-005 (Undergrad) and GEOL 5303-001 (Grad)

Time: Lecture TTH 9:30 – 11:00 AM

Location: GS 202

Primary Text: There will not be a required textbook for this course. The course reader will be composed of course notes distributed in pdf format, excerpts from books on rock and fracture mechanics, as well as classic and modern articles from scientific journals.

Instructor Information:

Dr. W. Ashley Griffith

- **Faculty Profile:** http://www.uta.edu/profiles/william-griffith
- **Office:** GS 233A
- **Office hours:** Tues 1:30PM-3:30PM, Wed 1:30PM-3:30PM or by appointment
- **Phone: 817-272-9666**
- **email:** wagriff@uta.edu

Course Description:

Principles and tools of elasticity theory and fracture mechanics are applied to the origins and physical behaviors of faults, dikes, joints, veins, solution surfaces, and other natural structures in rock. Special emphasis will be given to incorporation of field observations of fractures in rock with engineering rock fracture mechanics and the elastic theory of cracks in order to explore the role of natural fractures in brittle rock deformation in the earth's crust with applications to crustal deformation, structural geology, petroleum geology, earthquake seismology, engineering geology, and hydrogeology.

Prerequisites:

While there are no specific prerequisites, ability to use basic Calculus as well as an undergraduate course in Structural Geology, Engineering Geology, or Engineering Statics and/or Mechanics will be helpful. Basic topics from Linear Algebra and Functions of a Complex Variable will be used, however the relevant tools will be discussed in the class and course notes.

Learning Outcomes: Upon successful completion of this course, students should be able to:

- Use Matlab organize, compute and visualize quantitative model data
- Understand and manipulate field quantities and scalar, vector, and tensor data
- Idealize complicated geological problems related to fracture mechanics by reducing them to essential, constrainable elements
- Apply principals of continuum mechanics and elasticity theory to construct and the Linear Elastic Fracture Mechanics (LEFM) boundary value problems
- Apply principals of LEFM to explain the behavior of natural fractures in outcrop, as well as natural and induced hydraulic fractures
- Communicate the results of quantitative analysis via technical writing

Grading:

Grades will be determined by problem sets, two exams, and a term project. The grade breakdown is as follows:

Final Exam	10%
Problem Sets	60%
Term Project	30%
Total	100%

<u>Assignments turned in late will be dropped one letter grade for each business/school day they are late. It is the student's responsibility to turn assignments in and to write the date the assignment is turned in next to their names on the top of the assignment.</u>

Problem Sets and Exams:

There will be five problem Sets in this class, each with approximately 4-5 questions. The problem sets will be mostly quantitative in their nature.. **Some of the problems assigned may be challenging. In an attempt to give you every chance to "get" the problems, problem sets are subject to a "redo" policy. You may redo problems that you missed, and hand your corrected answers WITH the original graded proplem set for up to half the credit you missed. Redos are due with the next problem set (e.g., the**

redo's for Problem Set 1 are due when you turn in Problem Set 2). Redos associated with the final problem set will be due the last day of exams. Problem sets turned in late will be dropped one letter grade for each business/school day they are late. It is the student's responsibility to turn assignments in and to write the date the assignment is turned in next to their names on the top of the assignment. No-shows for presentations & late Term projects will not be accepted.

The final exam will be primarily conceptual in nature, and entirely essay-based. The idea is that the problem sets will get you solving problems related to fractures, while the exams will test your ability to comprehend the significance of the problems. In a typical exam format, I will provide you with several (8-12) sample questions ahead of time for you to study, and the questions on the exam will be a few questions from that list.

Term Project:

The term project will be discussed more detail in a **separate handout**, but it will (A) consist of a written and oral portion and (B) have intermediate due dates throughout the semester. The objective of this term project will be for each student to conduct a quantitative analysis of some problem directly related to rock fracture mechanics. I strongly encourage you to choose a project that complements your own research or interests. I will consider it a true success if it becomes part of your thesis: I don't want to waste your time any more than I want to waste my own. In order to ensure that everyone uses time wisely, there are several due dates on the course schedule below.

Tentative Schedule of Topics

PN = Pollard notes.

Date	Topic	Reading	Due Dates
January 17	Introduction; Atomistic Estimate of Rock Strength	PN Chp 1, p 1-21 PN Chp. 2, p 1-8	
January 19	Atomistic Estimate of Rock Strength Continued; Derived and Empirical Continuum Measures of Rock Strength	PN Chp. 2, p. 1-19	
January 24	Griffith's Local Failure Criterion	PN Chp. 3, p. 1-17	
January 26	Griffith's Global Energy-Based Failure Criterion	PN Chp. 3, p. 18-25	
January 31	Link between field observations of fractures in rock and fracture mechanics	Pollard and Aydin, GSA Bull, 1988	
February 2	Stress & Notation Review; Plane Elastostatic Problem I: Constitutive, Equilibrium, and Compatibility Equations	PN Chp 4, p. 1-10	Prob Set 1 Due
February 7	Plane Elastostatic Problem	PN Chp 4, p. 11-13	

	II: Governing Equations, Variables, and the Airy Stress Function; Complex Representation		
February 9	LEFM: Stress function for the uniformly-loaded crack; the Westergaard Stress function	PN Chp. 4, p. 17-23; Crider et al. (1996) – in place of PN Chps 5 & 6	
February 14	Near and Far Field Stresses and Displacements	Crider et al. (1996) – in place of PN Chps 5 & 6	
February 16	Stress & Displacement Discontinuity on the Crack Plane	Crider et al. (1996) – in place of PN Chps 5 & 6	
February 21	Application: Joint Spacing	Crider et al. (1996) – in place of PN Chps 5 & 6	
February 23	The near-tip field	PN Chp 6, p. 24-30	Prob Set 2 Due
February 28	Criteria for Propagation I: The stress intensity factor	PN Chp 7, pg. 1-21	
March 2	Criteria for Propagation II: The energy release rate	PN Chp 7, pg. 1-21	
March 7	The process zone I: Irwin's model	PN Chp 7	
March 9	The process zone II: Dugdale-Barenblatt	PN Chp 7	Final Project Topic & Brief Abstract Due
March 13-18	No Class – Spring Break		
March 21	Strain Energy near the tip of an LEFM crack	PN Chp 7	
March 23	Process zones in Rocks	PN Chp 7	Prob Set 3 Due
March 28	Mixed Mode I-II Crack Paths	PN Chp 8	
March 30 (**March 31 is last day to drop classes)	Maximum Circumferential Tensile Stress Theory	PN Chp 8	Final Project Detailed Outline Due
April 4	Rate Effects I	Excerpts from Freund, Dynamic Fracture Mechanics (1990)	
April 6	Rate Effects II	Excerpts from Freund, Dynamic Fracture Mechanics (1990)	
April 11	Quasi-Static Model of Rock Strength based on LEFM	Ashby and Sammis (1990)	
April 13	Dynamic Model of Rock Strength based on LEFM	Bhat et al. (2012)	Prob Set 4 Due
April 18	Laboratory Rock Mechanics		Final Project Rough Draft Due
April 20	Laboratory Rock Mechanics		

April 25	Laboratory Rock Mechanics		
April 27	Laboratory Rock Mechanics		
May 2	Laboratory Rock Mechanics		
May 4	Laboratory Rock Mechanics		Prob Set 5 Due
May 5	No Class		Final Project Paper Due
May 11 (8:00AM-10:30PM)	Final Exam		

Grade Grievances: Any appeal of a grade in this course must follow the procedures and deadlines for grade-related grievances as published in the current University Catalog.

Attendance:

At The University of Texas at Arlington, taking attendance is not required. Rather, each faculty member is free to develop his or her own methods of evaluating students' academic performance, which includes establishing course-specific policies on attendance. As the instructor of this course, attendance in lab is mandatory. Attendance in lecture is up to you, but if you miss class, you are responsible for learning the material. I will not take extra time to teach you things you should have learned by coming to class.

Drop Policy:

Students may drop or swap (adding and dropping a class concurrently) classes through self-service in MyMav from the beginning of the registration period through the late registration period. After the late registration period, students must see their academic advisor to drop a class or withdraw. Undeclared students must see an advisor in the University Advising Center. Drops can continue through a point two-thirds of the way through the term or session. It is the student's responsibility to officially withdraw if they do not plan to attend after registering. **Students will not be automatically dropped for non-attendance**. Repayment of certain types of financial aid administered through the University may be required as the result of dropping classes or withdrawing. For more information, contact the Office of Financial Aid and Scholarships (http://wweb.uta.edu/aao/fao/).

Americans with Disabilities Act: The University of Texas at Arlington is on record as being committed to both the spirit and letter of all federal equal opportunity legislation, including the Americans with Disabilities Act (ADA). All instructors at UT Arlington are required by law to provide "reasonable accommodations" to students with disabilities, so as not to discriminate on the basis of that disability. Any student requiring an accommodation for this course must provide the instructor with official documentation in the form of a letter certified by the staff in the Office for Students with Disabilities, University Hall 102. Only those students who have officially documented a need for an accommodation will have their request honored. Information regarding diagnostic criteria and policies for obtaining disability-based academic accommodations can be found at www.uta.edu/disability or by calling the Office for Students with Disabilities at (817) 272-3364.

Title IX: The University of Texas at Arlington is committed to upholding U.S. Federal Law "Title IX" such that no member of the UT Arlington community shall, on the basis of sex, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any education program or activity. For more information, visit www.uta.edu/titleIX.

Academic Integrity: Students enrolled all UT Arlington courses are expected to adhere to the UT Arlington Honor Code:

> *I pledge, on my honor, to uphold UT Arlington's tradition of academic integrity, a tradition that values hard work and honest effort in the pursuit of academic excellence.*
>
> *I promise that I will submit only work that I personally create or contribute to group collaborations, and I will appropriately reference any work from other sources. I will follow the highest standards of integrity and uphold the spirit of the Honor Code.*

UT Arlington faculty members may employ the Honor Code as they see fit in their courses, including (but not limited to) having students acknowledge the honor code as part of an examination or requiring students to incorporate the honor code into any work submitted. Per UT System *Regents' Rule* 50101, §2.2, suspected violations of university's standards for academic integrity (including the Honor Code) will be referred to the Office of Student Conduct. Violators will be disciplined in accordance with University policy, which may result in the student's suspension or expulsion from the University.

Student Support Services: UT Arlington provides a variety of resources and programs designed to help students develop academic skills, deal with personal situations, and better understand concepts and information related to their courses. Resources include tutoring, major-based learning centers, developmental education, advising and mentoring, personal counseling, and federally funded programs. For individualized referrals, students may contact the Maverick Resource Hotline by calling 817-272-6107, sending a message to resources@uta.edu, or visiting www.uta.edu/resources.

Electronic Communication: UT Arlington has adopted MavMail as its official means to communicate with students about important deadlines and events, as well as to transact university-related business regarding financial aid, tuition, grades, graduation, etc. All students are assigned a MavMail account and are responsible for checking the inbox regularly. There is no additional charge to students for using this account, which remains active even after graduation. Information about activating and using MavMail is available at http://www.uta.edu/oit/cs/email/mavmail.php.

Student Feedback Survey: At the end of each term, students enrolled in classes categorized as "lecture," "seminar," or "laboratory" shall be directed to complete an online Student Feedback Survey (SFS). Instructions on how to access the SFS for this course will be sent directly to each student through MavMail approximately 10 days before the end of the term. Each student's feedback enters the SFS database anonymously and is aggregated with that of other students enrolled in the course. UT Arlington's effort to solicit, gather, tabulate, and publish student feedback is required by state law; students are strongly urged to participate. For more information, visit http://www.uta.edu/sfs.

Final Review Week: A period of five class days prior to the first day of final examinations in the long sessions shall be designated as Final Review Week. The purpose of this week is to allow students sufficient time to prepare for final examinations. During this week, there shall be no scheduled activities such as required field trips or performances; and no instructor shall assign any themes, research problems or exercises of similar scope that have a completion date during or following this week unless specified in the class syllabus. During Final Review Week, an instructor shall not give any examinations constituting 10% or more of the final grade, except makeup tests and laboratory examinations. In addition, no instructor shall give any portion of the final examination during Final Review Week. During this week, classes are held as scheduled. In addition, instructors are not required to limit content to topics that have been previously covered; they may introduce new concepts as appropriate.

Selected Bibliography

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