Lecturer: Ottman Tertuliano — oat@seas.upenn.edu — Towne 275
Location: Towne 309 — Zoom Link
Lectures: M/W 3:30 - 5 PM
Grader: Sumukh Pande — pande@seas.upenn.edu
Office Hours: F 1-2:20 PM Location TBD

Course Description
The course covers fundamentals mechanics and experimental techniques in fracture of brittle and ductile materials. We will cover linear elastic and elastic-plastic fracture mechanics and connect these continuum-based descriptions with microstructure. We will discuss the fracture and toughening mechanisms of metals, ceramics, composites, and nontraditional/biomaterials; topics such as micro-void coalescence, cleavage fracture, transformation toughening, and crack- bridging will be discussed. Fatigue crack propagation and life prediction will be covered. We will have an introduction to dynamic fracture.Throughout the course, we will discuss experimental methods for analyzing fracture behavior of materials (e.g., critical stress intensity, R-curve, CTOD) for bulk and small-scale materials.

Prerequisites
A course graduate level in mechanical behavior of materials and elasticity (e.g, MEAM 519 or equivalent). If you have not taken the formal course prerequisite and are familiar with the topics, I encourage you to try out the first few lectures.

Learning Objectives
By the end of this course, you will be able to

- Discuss the relation between continuum-based K_I and J-integral, as well as cohesive zone δ, including their respective assumptions and limitations/advantages
- Discuss the fracture behavior of a material in the context of its microstructure, e.g., changes in crack growth resistance due to changes in bridging particle physical properties
- Assess viability of experimental methods and parameters for quantifying fracture behavior of different materials and length scales

Topics See page 3 for tentative course schedule

Assessments/ Grading Structure
Problem Sets 50%: The course will have weekly problem sets meant to help you build the foundation to accomplish the stated objectives. You are encouraged to collaborate, but submit your own solutions.
Flipped Class Discussions 25%: In liue of a midterm, we will have student led discussions based on assigned readings. We will have 6 of these days that will work as journal club style discussions. There will be a one page write-up due before to the discussion session. Guidelines for discussion leaders and participants will be provided.

Final Project 25%: Instead of a final exam, we will have individual presentations on a topic related to special topic in fracture, e.g., measuring toughness of battery materials *in operando.* There will be an project white-paper/proposal due and the prompt is generally open ended but your presentation should:

1. describe a problem or question in the field
2. communicate the current progress and techniques employed (this section should include fracture analysis, let me know if you have questions)
3. discuss further interesting directions in to tackle the same problem/question
4. propose how the progress/techniques in (2) can advance or be beneficial for a different problem

Reference Texts/Resources
Fracture Mechanics: fundamentals and applications. T.L. Anderson 2005
Fracture of brittle solids. Brian Law. Available free through Cambridge University Press
Fracture Mechanics. H.L Ewalds and R.J.H Wanhill. Edward Arnold 1984
Fatigue of Materials. Subra Suresh. Available free through Cambridge University Press

Inclusion We will all get the most out of this experience if the class is a safe space for all backgrounds and identifies. I encourage to engage and be respectful. If you have read the syllabus this far, send me an email by the end of Week 2 with just the subject title "firstname_lastname_MEAM633"

Week	Date	Topic	Reference
Week 1	1/10	Lectures start 1/12	-
	1/12	Intro, Experimental Pres, Theoretical Stress	Anderson
Week 2	1/17	MLK Day	-
	1/19	Griffith, Energy Release Rate, Compliance Method	Anderson, Lawn
Week 3	1/24	Griffith, Energy Release Rate, Compliance Method	Anderson, Lawn
	1/26	LEFM, Stress Analysis of Crack Tip,	Anderson, Lawn
Week 4	1/31	LEFM, Stress Analysis of Crack Tip, Crack tip plasticity	Anderson, Lawn
	2/2	No Lecture - May have a make up day,	Anderson, Lawn
Week 5	2/7	K-controlled fracture, crack tip plasticity, mixed mode	Anderson, Lawn
	2/9	DISSCUSSION - Griffith , Toughening in yt-zirconia	Griffith
Week 6	2/14	EPFM fundamentals	Anderson, Hutchinson
	2/16	J-integral,	Rice, Hutchinson
Week 7	2/21	HRR	Anderson, Hutchinson
	2/23	J-CTOD, Microvoid Coalescence	Anderson, Gurson
Week 8	2/28	Experimental Methods	Ewalds and Wanhill
	3/2	DISCUSSION - Metallic Glass and HEA	Ritchie et al.
Week 9	3/14	Stress Corrosion	Anderson, Hutchinson
	2/16	Fracture in Energy Materials	Greer et al.
Week 10	3/21	Cyclic Deformation and Fatigue intro	Anderson, Suresh
	3/23	Fatigue Crack Initiation and Phenomenological approaches	Suresh
Week 11	3/28	Fatigue Crack in ductivle solids, constant amplitude	Suresh
	3/30	Stress Concentration and Small fatigue cracks	Suresh
Week 12	4/4	DISCUSSION - microscale fatigue in Ni, graphene	Pierron
	4/6	Micromechanisms of Fracture Soft Materials	Suo
Week 13	4/11	DISCUSSION - Bone, Cartilage, Hydrogels	Rithie, Suo, Ateshian
	4/13	Dynamic and Time Dependant Fracture	Anderson, Fruend, Finnberg
Week 14	4/18	Dynamic and Time Dependant Fracture	Anderson, Fruend, Finnberg
	4/20	Dynamic and Time Dependant Fracture	Anderson, Fruend, Finnberg
Week 15	4/27	DISCUSSION - Dynamic Crack Propagation	Anderson, Fruend, Finnberg
	4/30	Project Presentations	-

Table 1: Tentative Course Schedule. References to be updated with specified readings