16:635:513 Mechanical Behavior of Materials

Department of Materials Science and Engineering
Rutgers University

Fall 2020

Information

Instructor:	Prof. Ryan Sills
Class Hours:	Tuesdays and Thursdays, 8:40-10:00am EDT
Class Location:	Primary location: WebEx (see Canvas for link) Backup location: Zoom (rutgers.zoom.us/my/rbs131)
Course Index:	13145
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Exams:	*Midterm:* Tuesday October 27 (format TBD) *Final:* Tuesday December 15 (format TBD)
Office Hours:	Thursdays, 12:00-1:20pm EDT on WebEx (see Canvas for link)

Course Description

This course is focused on the mechanical behaviors of materials, the physics and materials science that underlies these behaviors, and engineering approaches for prediction of mechanical failure of materials. The first half of the class elaborates the various defects and deformation mechanisms which contribute to mechanical behaviors. The second half of the class focuses on the major mechanical behaviors themselves—including yield, creep, fracture, and fatigue—along with relevant mechanical properties and failure criteria. For each topic, experimental observations, commonly employed physical models, and mechanistic theories will be discussed. A common theme will be the relationship between microstructure, deformation processes, and mechanical properties.

Prerequisites

This course assumes a basic knowledge of physics (mechanics), calculus, and linear algebra. A

† Canvas will be the official communication tool for the course. If I post something on Canvas, it is the student's responsibility to be aware of the posting.

background in crystallography is also helpful, but not essential.

Textbooks

The course is largely derived from these books:

- *Mechanical Behavior of Materials* by Meyers and Chawla (Cambridge, 2009)
    - Available as an eBook (https://ebookcentral.proquest.com/lib/rutgers-ebooks/reader.action?docID=5120008&ppg=9)
- *Imperfections in Crystalline Solids* by Cai and Nix (Cambridge, 2016)

I will provide my written lecture notes as a resource, but also recommend obtaining copies of these books. Meyers and Chawla alone is probably sufficient as a reference for the class, but Cai and Nix covers crystalline defects in much greater depth. For those whose research is focused on ceramics, *Mechanical Properties of Ceramics* by Wachtman, Cannon, and Mathewson (Wiley & Sons, 2009) is a good resource.

Another good resource is *Applied Mechanics of Solids* by Bower, which is freely available online book at www.solidmechanics.org.

Grading

The grade for this course is made up of 5 problem sets (8% each), a midterm exam (25% each) and a final exam (35%). Problem sets will be due at 5pm EDT on the specified day and should be submitted via Canvas. Late problem sets will be deducted 25 points for each day it is late; 1 minute late = 1 day late. Problem sets should be individual efforts but students are encouraged to help each other and working in teams is acceptable. Handing in any work copied from other students (past or present) is ***not*** acceptable and will be treated as cheating. The final exam is cumulative but emphasizes course content not examined in the midterm.

I plan to try something new (to start at least) with homework assignments. I will grade each problem on a scale from 0 to 3. These numbers have the following meaning:

0 = You put no or very little effort in the problem set
1 = You clearly put in effort, but do not understand the content well
2 = You have some understanding of the content
3 = You have mastered the content

I will not mark the problem sets to indicate what was done correctly or incorrectly, and instead will provide commentary on what content needs further study by the student. This is because after problem sets are returned, students will be allowed to resubmit problems where they scored < 3 but > 0 (if you score a 0, you are not allowed to resubmit). The resubmission date will be one week from the day that the problem sets are returned by 5pm EDT. After this additional week, I will post the homework solutions so that students can identify what they did correctly/incorrectly.

Attendance

While all lectures will be pre-recorded and may be viewed by each student on their own time, I hope to present lectures in real-time for those students who are able to attend. Each lecture will be uploaded the day it is recorded for viewing and available for viewing for 1 week; it is the responsibility of each student to view each lecture within this week. After a week, each lecture will be taken down. ***Viewing of lectures is mandatory***, either in-person or by viewing the pre-recorded lecture on Canvas. ***For each lecture that is not viewed in full by a student, I will deduct 1% from their final grade.***

Exam Policies

Exams will be in the style of 24-hour, take-home exams. Students will be given 24 hours to complete and submit their exam. While students may use any written resources (notes, textbooks), students are ***not allowed*** to use the internet (other than the course Canvas page) during their exams. If it is discovered that the internet was used by a student, a score of zero will be given on the exam.

I intend to make exams for this class comprised of “open-ended,” application-focused problems, where there is not really a “right” answer. The intent is that exams are opportunities to students to broadly apply the concepts in the class and think critically about what is and what is not important.

Academic Integrity

Students in this class and in all courses at Rutgers University are expected to uphold the highest standards of academic integrity. Cheating, plagiarism in written work, receiving and providing unauthorized assistance, and sabotaging the work of others are among the behaviors that constitute violations of the Academic Integrity Policy. You are expected to be familiar with this policy. If you have questions about specific assignments, be sure to check with the instructor. The Academic Integrity Policy defines all forms of cheating and the procedures for dealing with violations. You should be familiar with this policy. The trust between the instructor and the class depends on your acceptance of this essential principle of behavior in the University. Do your own work and do not provide unauthorized assistance to others and you will find this course more rewarding.

Special Accomodations

Rutgers University welcomes students with disabilities into all of the University's educational programs. In order to receive consideration for reasonable accommodations, a student with a disability must contact the appropriate disability services office at the campus where you are officially enrolled, participate in an intake interview, and provide documentation: *ods.rutgers.edu/students/documentation-guidelines*. If the documentation supports your request for reasonable accommodations, your campus’s disability services office will provide you with a Letter of Accommodations. Please share this letter with your instructors and discuss the accommodations with them as early in your courses as possible. To begin this process, please complete the Registration form (*webapps.rutgers.edu/student-ods/forms/registration*).

Syllabus

Basic Concepts

Types of materials, stress, strain, tensors, tensor invariants, tensor transformations, Einstein notation, deviatoric vs. hydrostatic, strain energy, thermodynamics, equilibrium, dynamic effects

Viscoelasticity and Plasticity

Hooke’s law, stiffness tensor, anisotropy, storage and loss moduli, phenomenological models, rubber elasticity, nonlinear elasticity, yielding, plastic flow, hardening, necking, yield criteria

Crystal Defects and Deformation Mechanisms

Point defects, dislocations, stacking faults, antiphase boundaries, twins, grain boundaries, precipitates, phase transformations, crazing, shear yielding

Yield and Strengthening Mechanisms

Work hardening, solid solution strengthening, precipitation strengthening, grain refinement (Hall-Petch), nano-structured materials, intermetallics, brittle solids

Creep and Time-Dependent Deformation

Nabarro-Herring creep, Coble creep, Harper-Dorn creep, dislocation creep, grain boundary sliding, heat-resistant materials, polymer creep, electromigration

Fracture Mechanics and Toughening Mechanisms

Stress concentrations, Griffith criterion, linear elastic fracture mechanics, plastic zone, J-integral, intrinsic vs. extrinsic toughening, R-curve, ductile fracture, brittle fracture, stress corrosion cracking

Fatigue

Stress-based approach, fatigue-life, endurance limit, mean stress effects, strain-based approach, crack initiation, fatigue crack growth (Paris law)