14:635:212 Physics of Materials

Department of Materials Science and Engineering
Rutgers University

Syllabus, Spring 2021

Information

Class Hours:	Tuesday/Thursday 3:20 - 4:40 pm EDT on Zoom (via Canvas)
Course Index:	14347
Instructor:	Professor Ryan Sills
Office:	Center for Ceramics Research (CCR)-108
Telephone:	(848) 445-4942
Email:	*ryan.sills@rutgers.edu*
Web:	*canvas.rutgers.edu*[†]
Exams:	*Exam 1:* Thursday March 4 (format TBD) *Exam 2:* Thursday April 1 (format TBD) *Final Exam:* TBD
Office Hours:	1:00 pm - 2:00 pm, Tuesdays and Thursdays In addition, you can schedule an appointment with me by email.

Course Description

This course focuses on the physics of materials necessary for an understanding of *material properties* and *material processing*. Specifically, we will focus on:

- Mechanical behaviors (viscoelasticity, plasticity)
- Chemical behaviors (reaction kinetics, mass transport)
- Thermal behaviors (thermal properties, heat transfer)

We will not cover optical, magnetic, or electrical behaviors (these are covered in 14:635:316 Electronic, Optical and Magnetic Properties of Materials).

The high-level goals of the course are to develop *physical models* which provide:

- Understanding of the physical origin of material behaviors
- Scaling behaviors of different properties (e.g., temperature dependence)

[†] 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.

- Techniques for designing materials and materials production processes

Prerequisites

There are no prerequisites. However, the course is quite mathematical so it is useful to be up-to-date with your mathematics courses (mostly calculus).

Textbooks

There is no required textbook for this course. A collection of notes and example problems for this course will be posted on Canvas on the "Files" page. Chapters in the following books are useful reading:

- *The Production of Inorganic Materials* by Evans and De Jonghe (Macmillan, 1991)
- *Fundamentals of Ceramics* by Barsoum (McGraw-Hill, 1997)
- *Physical Ceramics* by Chiang, Bernie, and Kingery (Wiley, 1997)
- *Introduction to Ceramics* by Kingery, Bowen, and Uhlmann (Wiley, 1975)
- *Polymer Engineering Science and Viscoelasticity* by Brinson and Brinson (Springer, 2015)

The exams will only cover material covered in class so lecture notes are the students' primary source of information – students should make sure their notes are neat.

Grading

The grade for this course is made up of 5 problem sets (10% each – half of your grade is the homeworks!), 2 midterm exams (15% each), and the final exam (20%). Problem sets will be due at the beginning of class on the specified day. Late problem sets will be deducted 25 points for each day it is late. Problem sets should be individual efforts but students are encouraged to work in teams. Handing in any work copied from other students (past or present) is ***not*** acceptable and will be treated as cheating. Exam 2 covers material not examined in Exam 1. The final exam is cumulative but emphasizes course content not examined in Exam 1 or Exam 2.

For problem sets, ***I have the following expectations***:

- When I ask for a "plot," you must *use a computer to produce the plot*. You must properly label the axes and datasets (with units), and the plot must be clear. I suggest getting good at using plotting software of your choice (Excel, MATLAB, Python, etc.).
- Whenever I ask you to fit a linear model to a dataset, I expect you to use a *linear regression*.
- Your units and the orders of magnitude of your answers must make sense.
- If I ask for you to *explain* something, then you need to give a clear, thorough explanation that adds content (e.g., don't just describe in words what is already obvious).

If one of these four criteria is not met on a homework assignment, a score of 1 or less will be given (see below).

For problem sets, I will grade each problem on a coarse scale from 0 to 3. These numbers have the following meaning:

0 = You put no or very little effort in the problem
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). After the resubmission window closes, I will post the homework solutions so that students can identify what they did correctly/incorrectly.

Attendance

Lectures will be held live via Zoom on Canvas at the scheduled time. Lectures will also be recorded, in case it is not possible to attend a lecture. Each lecture will be uploaded the day it is recorded for viewing. ***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 take-home exams. For midterm exams, I hope to limit the duration to 4 hours, but this depends on student availability and technological constraints. The final exam duration will be 24 hours. 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.

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.

Respect of Copyright

Much of the material for this course posted on Canvas is copyrighted by the authors (including Prof. Mathewson). Students are expected to respect copyright. Any material copyrighted by Prof. Mathewson may be retained after the course ends for your own personal use. Scanned pages from other textbooks must be deleted at the end of the course. One of the textbooks (*Polymer Engineering Science and Viscoelasticity*) is freely available through the library.

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*).

Contents

General Concepts

Definition of physical model, types of models, dimensional analysis, role of microstructure, balance laws, constitutive laws, mathematics primer

Viscoelasticity and Plasticity

Elasticity: stress, strain, linear elastic behavior, elastic moduli, stress waves. Plasticity: plastic strain, mechanisms. Viscosity: definition, temperature dependence, Newtonian and non-Newtonian fluids, derivations of classic solutions (Poiseuille flow, Stokes flow), dimensional analysis, solution by elastic analogy. Viscoelasticity: relaxation and creep, Maxwell and Kelvin models.

Reaction Kinetics and Corrosion

Homogeneous and heterogeneous reactions, definition of reaction rate, dependencies, Rate equations: reaction order, heterogeneous rates, reversible reactions, Langmuir-Hinshelwood, temperature effects. Mass transport: diffusion, convection, mass transfer coefficient, transport during a reaction, rate controlling step.

Thermal Properties

Heat capacity & specific heat: equipartition theorem, Einstein model, Debye model. Thermal expansion: relation to heat capacity, anharmonicity, anisotropy, composites. Thermal conductivity: phonon, electron, photon contributions, composites.

Heat Transfer

Conduction: Fourier's laws, heat equation, steady state solutions, solution in one dimension, plane wall, radial conduction, lumped capacitance. Convection: forced & free, solution by dimensional analysis, heat transfer correlations for cylinders, walls, plates, pipes. Radiation: black body radiation, emissivity and absorptivity, gray surface, view factors.