14:635:212 Physics of Materials

Syllabus, Spring 2013

Information

Class Hours:	Tuesday, Thursday 3:20 - 4:40 pm, SEC-208
Instructor:	Professor M. John Matthewson
Office:	Engineering A133
Telephone:	848-445-5933
E-mail:	to mjm: *mjohnm@fracture.rutgers.edu* to entire class: *pom@sakai.rutgers.edu*†
Web:	*sakai.rutgers.edu*
Schedule:	The schedule is available on *sakai.rutgers.edu*.
Office Hours:	I operate an open door policy - if I am in I will be glad to talk to you. However, I also have formal office hours after class. In addition, you can arrange an appointment to meet me by e-mail. Please avoid coming to my office in the half hour or hour before a class.

Course Description

This course covers several materials properties including elasticity, viscosity and rheological behavior, reaction kinetics, thermal properties (specific heat, expansion, conductivity), thermoelectricity and temperature measurement. Physical models are described that explain the various behaviors of different materials.

Course Objective

The primary aim of this course is to introduce students to the fundamentals of various aspects of the physical properties of materials. Understanding these properties will help the student with issues such as the design of material production processes, materials selection and materials performance.

Prerequisites

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

† I frequently need to communicate with the entire class. To do that I send email to *pom@sakai.rutgers.edu*. If I send a message, I will assume you have read it. It is therefore your responsibility to check your email regularly, to make sure communications from *sakai* are not treated as spam, and that *sakai* has the best email address for contacting you.

Textbooks

There is no required textbook for this course. A collection of notes and example problems for this course will be posted on *sakai.rutgers.edu*. 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). 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 and should get copies of the notes from a colleague if a class is missed.

Attendance

Class attendance is mandatory. If you can not attend class for any reason, please report it ***in advance*** using the Rutgers online absence reporting system. However, doing this does ***not*** automatically excuse your absence. ***Unexcused absences may result in loss of credit***.

Grading

The grade for this course is made up of 4 problem sets (20%), 2 period exams (40%) and the final exam (40%). Problem sets should be individual efforts but students are encouraged to help each other with hints. Handing in any work copied from other students is unacceptable and will be treated as cheating. The period exams and the final exam are all closed book. Equation sheets will be handed out with the exams – copies can be found on *sakai.rutgers.edu*. Equation sheets should be closely studied as part of your preparation for the exams. Quiz 2 covers work not examined in Quiz 1. The final exam is cumulative but emphasizes course content not examined in Quiz 1 or Quiz 2.

Read the Rubric!

Follow all instructions on problem sets and exams. I reserve the right to ***deduct credit*** if instructions are not followed

Calculator Policy

Calculators will be provided for quizzes and the final – if students want to use their own calculator, they must demonstrate clearing the calculator's memory at the start of the exam - ***please come early if you chose to do this***. Students should ***always*** ***bring graph paper and a ruler*** to the quizzes and final exam.

Respect of Copyright

Much of the material for this course that I post on *sakai* is copyrighted; and much of the copyright belongs to me. Students are expected to respect copyright. Specifically, copyrighted material made available to you for this course is for your own personal use for this course only. In particular, questions and solutions are for your own use and are intended to help you and you alone. Passing on any of this material to others is a ***violation of my copyright***. Receiving any of this material from other students without my express permission is a ***violation of my copyright***. Further, since old questions and solutions might give you an unfair advantage over your colleagues, receiving this material without my permission is a ***violation of student ethics*** and will be treated as ***cheating***. At the end of the course, any material you receive that is copyrighted but not owned by me should be ***destroyed***. However, any material for which I own copyright may be retained for your own personal use at the end of the course.

Student Feedback

I take the comments made by students on the teaching assessment survey very seriously so that I can improve the quality of this course. Please be sure to complete the survey at the end of the semester. Below I address issues raised by students the last few of times I have taught this class:

More worked example problems:
I plan to give at least one worked example problem in class for each major section of the course. However, my philosophy is that the best worked examples are worked by the students on their own. For this purpose, example problems are posted on *sakai* at the start of the semester – they are almost all old exam or homework questions. I can provide hints if you get stuck on any of them. In addition, I will post solutions to these problems on *sakai* a few days before the relevant exams.

Use a Textbook / More notes:
Since this class covers a variety of topics not typically covered in one textbook, there is no single class text. However, handouts are made available on *sakai* for most of the material covered, but there are a few small gaps. I will continue to increase the number of handouts to more fully cover all the class material.

Please give me feedback on how I am doing with these improvements. Please do not wait until the end of the semester for the teaching assessment survey if you think I can usefully make changes immediately. Any and all constructive criticism will be gratefully received!

Syllabus

Viscous Flow

Elasticity: stress, strain, linear elastic behavior, elastic moduli. Viscosity: definition, temperature dependence, turbulence. Viscosity measurement: derivations from first principals, Poiseuille flow, Stokes flow, dimensional analysis, rotational viscometer, cone-plate viscometer, measurement by elastic analogy. Rheology: categorization of behaviors, example systems, suspensions.

Reaction Kinetics

Homogeneous and heterogeneous reactions, definition of reaction rate, dependencies, rate equations, reaction order, probabilistic interpretation, heterogeneous rates, reversible reactions, Langmuir, Langmuir-Hinshelwood, temperature effects, activated complex theory, Boltzmann distribution. Mass transport, rate controlling step.

Thermal Properties

Heat capacity & specific heat: equipartition theorem, gases, Debye theory. Thermal expansion: relation to heat capacity, reversibility, anisotropy, thermal stress, glazes. Thermal conductivity: phonon, electron, photon contributions, multiphases.

Heat Transfer

Conduction: Fourier's laws, steady state solutions, solution in one dimension, furnace wall, cylindrical symmetry, time dependent solutions, steady rate of heating/cooling, thin film solution, error function solution. Convection: forced & natural, solution by dimensional analysis, example of convection from long cylinders, heat transfer coefficient. Radiation: black body radiation, emissivity and absorptivity, Kirchoff's law, non equilibrium.

Temperature Measurement

Optical pyrometer. Thermoelectricity: Seebeck effect, Peltier effect, Thomson effect, thermoelectric power diagrams, practical temperature measurement.

ABET A-O Requirements

A. Apply knowledge of mathematics, science and engineering

Students learn the fundamental physics that leads to many of the measurable physical properties of materials. They apply their mathematical and scientific knowledge to understand the derivation of key relationships of physical properties to the underlying physical processes controlling those properties.

B. Design and conduct experiments, as well as to analyze and interpret data

Students learn what experiments are needed to measure the physical properties of materials. They learn how to graph real experimental data and interpret the data in terms of the physical models. They learn how to review the data critically and to assess the significance and cause of any deviations from theory.

C. Design a system, component, or process to meet desired needs

The students learn how to apply their understanding of physical properties in order to make simple designs for relevant processes. They apply thermal conductivity principles to design furnace walls.

E. Identify, formulate and solve engineering problems

Students learn not only to understand the origin and nature of physical properties, but also learn how to apply their understanding to solving quantitative problems associated with those physical properties.

L. Use experimental, statistical, and computational methods to analyze the behavior of ceramic systems

Students learn how to determine physical properties of materials by making suitable graphs of experimental data. They learn how to fit a theoretical model to the data and extract values for the physical parameters. Particular emphasis is given to assessing the confidence of the measured values of the physical parameters.

M. Apply advanced science and engineering principles to materials systems

Students learn that the physical properties of materials can be related to their atomic structure, bonding, etc. They also learn how the physical properties affect the performance of a material in typical applications.

N. Understanding of the fundamental principles underlying and connecting structure, properties, processing and performance related to the material systems utilized in ceramic engineering

This course emphasizes that the physical properties of materials are related to fundamental physics. Reference is made to quantum mechanics and statistical mechanics where appropriate and is it shown how these principles provide understanding of why materials behave the way they do. Students learn why different classes of materials have very different physical properties.

O. Apply and integrate knowledge from each of the above four elements of the field to solve material selection and design problems

Throughout students are encouraged to relate all levels of understanding from the very basic physical principles through physical properties to the application of this knowledge to understanding real engineering problems. Students are shown that their understanding of at a fundamental level can help optimize the solution to an engineering problem or predict the behavior of a new material system.

M. J. Matthewson, January 21, 2013.

