14:635:316 Electronic, Optical and Magnetic Properties of Materials

Syllabus, Spring 2016, Version 2

Information

Class Hours:	Tuesday, Friday 10:20 - 11:40 am, SEC-203
Instructor:	Professor M. John Matthewson
Office:	Engineering A133
Telephone:	848-445-5933
E-mail:	to mjm: *mjohnm@fracture.rutgers.edu* to entire class: *eom@sakai.rutgers.edu*†
Web:	*sakai.rutgers.edu*
Schedule:	The schedule is available on *sakai.rutgers.edu*.
Office Hours:	Official office hours: **12:30-2:00pm Monday, Tuesday, Thursday and Friday.** I operate an open door policy - if I am in my office I will be glad to talk to you. 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 class.

Course Description

This course will introduce the topic of electrons in solids. Specifically, it will describe how electrons interact with each other, electromagnetic radiation and the crystal lattice to give the material its inherent electrical, optical and magnetic properties. Semiconductors, metals, insulators, polymers and superconductors will be discussed.

Course Objective

The primary aim of this course is to introduce students to the fundamentals underpinning electronic properties of materials. This spans everything from the basics of electron behavior in solids to the design of magnet and optoelectronic devices.

Prerequisites

There are no prerequisites. ***It is strongly suggested*** that students are up-to-date with their mathematics courses, and especially have taken courses covering ***differential equations*** and

† I frequently need to communicate with the entire class. To do that I send email to *eom@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.

complex numbers. While students will not need detailed knowledge of the solution methods for differential equations, most of the course concerns solutions to the Schrödinger equation – perhaps the most famous differential equation. Familiarity with this branch of mathematics will be very helpful. If you have not had a course on differential equations, either delay taking EOM or come to me for advice. Extensive use is made of complex numbers. Students should be familiar with this branch of mathematics before attempting to take this course.

Textbooks

The required textbook is *Electronic Properties of Materials 4th Edition* by Rolf E. Hummel (Springer-Verlag). *Principles of Electronic Materials and Devices 3rd Edition* by S. O. Kasap (McGraw-Hill) has nice illustrations, many worked examples and good questions at the end of the chapters. It is, however, more expensive than Hummel (currently new prices about $234 compared with $66 for Hummel) and goes into things somewhat too deeply for our needs.

Grading

The grade for this course is made up of 5 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 and working in teams is acceptable. Handing in any work copied from other students is ***not*** acceptable and will be treated as cheating. The period exams and the final exam are closed book. Equation sheets will be handed out with the exams. The equation sheets will also be posted on *sakai* and reviewing them is an essential part of your preparation for the exams. The final exam is cumulative but emphasizes course content not examined in the period exams.

Read the Rubric!

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

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***.

Exam Policies

1. A exam can only be missed under exceptional circumstances and only if you have a Dean's note giving permission. A makeup will be given for missed exams which will not be the same as the original exam. The makeup will include an oral component. A makeup will not be given if you miss an exam without permission - you will score zero for the exam.
2. Lack of preparation is not an acceptable excuse for missing/delaying an exam!
3. Exams will be recorded by video to discourage cheating and to help identify and punish any attempts at cheating.
4. During exams students should not wear bulky or loose clothing – no hats and no hoodies. Backpacks should be placed at the front of the classroom. Your desk should be clear except for writing instruments, a ruler and a calculator. One drink in a transparent container is also permitted. You do not need paper of your own copy or the equation sheet – these will be provided.
5. Please use the bathroom before the exams. Bathroom breaks are only for urgent need. If you do have to use the bathroom, your must empty all your pockets. Only one student may be

absent for the bathroom at any time. Bathrooms are carefully checked before and after exams since they are commonly used for cheating.

6. Clear your desks and the surrounding area ***before*** getting your exam from me.
7. Please review Rutgers' academic integrity policy. Ignorance of the rules is no defense.

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 ***by a hard rest*** at the start of the exam - ***please come early if you chose to do this***. Students should ***always*** ***bring a ruler*** to the period and final exams.

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

Students often complain about the textbook – in particular the number of errors. I will therefore compile a list of errors and distribute it to the class. As noted above, despite its drawbacks, Hummel's text is the most appropriate for the level of this class. If you find a text that you think is a possible alternative, please let me know.

Syllabus

The Basics of Electrons in Solids

The electron; Problems with classical description; Wave-particle duality; De Broglie theorem; Bohr model for hydrogen; Born postulate; Schrödinger's equation; Solving the wave equation; Particle in a 1-D box & quantum tunneling; Electrons in a periodic potential; Bloch waves; Energy (E) versus wavevector (k) dispersion plots, energy bands; Brillouin zones; Fermi-Dirac/Bose-Einstein/Boltzmann statistics; Density of states, population density; Effective mass.

Electronic Properties

Classical conductivity; Quantum description of conductivity; Effect of alloying in metals; Intrinsic & extrinsic semiconductor properties; Fermi level & Hall effect in semiconductors; Devices (Diode, Zener diode, Bipolar transistor; FETs, MOSFETS, Ohmic/Schottky junctions); Conductive polymers; Ionic conductors; Superconductors.

Optical Properties

Dielectric properties; Ferroelectrics & piezoelectrics; Snell's law; Maxwell equations; Complex dielectric constant; Transmittance, reflectivity & conductivity; Classical & quantum approach to optical properties; Phonons; I.R. & Raman spectroscopy, luminescence, fluorescence; Devices (LASERs, LEDs & optical data storage).

Magnetic Properties

Types of magnetism (Ferro-, para-, ferri-, dia- and antiferro-); Susceptibility; Quantum description of magnetism; Magnet design

ABET A-O Requirements

Upon completion of the course the students will be equipped with the basic knowledge needed for them to work as materials scientists and engineers in the electronics industry. This will be achieved by a series of lectures and homeworks designed to introduce the theoretical underpinnings of electronic properties as well as practical applications for electronic materials. The following ABET criteria are met by the course:

a. Graduates will be able to apply knowledge of mathematics, science and engineering.
c. Graduates will be able to design a system, component, or process to meet desired needs.
e. Graduates will be able to identify, formulate and solve engineering problems.
h. Graduates will have the broad education necessary to understand the impact of engineering solutions in a global and societal context.
i. Graduates will recognize the need for, and develop the ability to engage in life-long learning.
j. Graduates will have knowledge of contemporary issues.

Relationship of Course to Program Objectives

This is a core course that will help students develop both a quantitative and a qualitative understanding of electronic materials. It builds on the knowledge of materials, physics, chemistry and mathematics that the students have obtained during their preceding years as an undergraduate. The course brings together a range of different topics including crystallography, microstructure and calculus to explain the important electronic, optical and magnetic properties of modern materials.

M. J. Matthewson, February 19, 2016.