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

Syllabus, Spring 2014

**Information**

<table>
<thead>
<tr>
<th>Class Hours:</th>
<th>Tuesday, Friday 10:20 - 11:40 am, SEC-203</th>
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<tbody>
<tr>
<td>Instructor:</td>
<td>Professor M. John Matthewson</td>
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<td>Office:</td>
<td>Engineering A133</td>
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<td>Telephone:</td>
<td>848-445-5933</td>
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<td>E-mail:</td>
<td>to mjm: <a href="mailto:mjochnm@fracture.rutgers.edu">mjochnm@fracture.rutgers.edu</a></td>
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<td>to entire class: <a href="mailto:eom@sakai.rutgers.edu">eom@sakai.rutgers.edu</a>†</td>
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<tr>
<td>Web:</td>
<td>sakai.rutgers.edu</td>
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<tr>
<td>Schedule:</td>
<td>The schedule is available on sakai.rutgers.edu.</td>
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<tr>
<td>Office Hours:</td>
<td>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 Monday, Thursday 2:00-3:00 pm; Tuesday 1:00-2:00 pm. In addition, you can arrange an appointment by e-mail to meet me. Please avoid coming to my office in the half hour or hour before a class.</td>
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**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 about $180 compared with $60 for Hummel) and goes into things somewhat too deeply for our needs.

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 (25%), 1 midterm (25%) and the final exam (50%). 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 mid-term 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 midterm.

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 midterm 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**

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 ($k$) 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.

b. Graduates will be able to design a system, component, or process to meet desired needs.

c. 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, January 2, 2014.