MS&E 456 Fall 2015: Electronic, Optical, and Magnetic Properties of Materials

Instructor:

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Office Hours: Monday, 4:00-4:30 PM, or by appointment. Also, please feel free to drop in or email.

Grader:

Youngjun Ahn email: yahn23@wisc.edu

Course Meetings:

TR 11:00 AM-12:15 PM, 265 Materials Science and Engineering

Optional Review and Discussion Meeting:

M 2:30-3:30 PM, MS&E 265.

Course Homepage:

Handouts, readings, assignments, and solutions are available on the course web page at the University of Wisconsin Moodle site: https://ay15-16.moodle.wisc.edu/prod/course/view.php?id=341

Course emails will come from mse456-1-f15@lists.wisc.edu.

Course Description

MS&E 456 will cover the fundamental physical phenomena that define the electronic, optical, and magnetic properties of materials, and show how these properties can be manipulated for a wide range of applications. We will focus on principles that are applicable across metal, organic, and ceramic systems, beginning from a quantum-mechanical description of the energy levels and population statistics of electrons. Discussions of applications will include magnetic devices, lasers, superconductors, and semiconductor electronics.

Course Requirements

Exams

Two midterm exams: Tentatively scheduled for October 15 and November 17.

Final exam: 10:05 AM to 12:05 PM, Wednesday December 23, 2015. The final exam will focus material from the later part of the class.

Please let me know right away if you will not be able to be present for these exams.

Homework

We will have 11 homework assignments. The best 10 homework grades will be counted towards the homework fraction of the final grade.

Grading

Homework	30%
Midterm Exam 1	20
Midterm Exam 2	20
Final Exam	30

Lecture Capture

Many of the lectures for MS&E 456 will be captured for later use by video cameras and microphones. Possible uses for the recordings are to offer students the chance to review material after class this semester and before class in future semesters.

Resources

Course Text

Rolf Hummel, *Electronic Properties of Materials*, 4th Ed., Springer (2011), ISBN 978-1-4419-8163-9.

Wendt Library Reserve Call Number: QC176 H86 2011

Books on Reserve (Wendt Library)

Library course homepage: https://www.library.wisc.edu/course-pages/viewer/show/13862

1. L. Solymar and D. Walsh, *Electrical Properties of Materials*, 7th Ed., Oxford (2004). QC176.8 E35 S64 2004
2. J. D. Livingston, *Electronic Properties of Engineering Materials*, Wiley (1999). TK 7871 L58 1999
3. C. Kittel, *Introduction to Solid State Physics*, 8th Ed. Wiley (2005). QC176 K5 2005
4. J. I. Gersten and F. W. Smith, *Physics and Chemistry of Materials*, Wiley (2001). QD478 G47 2001
5. A. P. Sutton, *Electronic Structure of Materials*, Oxford (1993). QC176.8 E4 S875 1993
6. N. Spaldin, *Magnetic Materials: Fundamentals and Device Applications*, Cambridge (2003). TK7872 M25 H54 2003
7. E. Kaxiras, *Atomic and Electronic Structure of Solids*, Cambridge (2003). QC176.5 K39 2003
8. U. Mizutani, *Introduction to the Electron Theory of Metals*, Cambridge (2001). QC176.8 F74 M5913 2001
9. P. Fulay, *Electronic, Magnetic, and Optical Materials*, CRC Press (2010). TK7871 F85 2010
10. S. H. Simon, *The Oxford Solid State Basics*, Oxford Univeristy Press (2013). Electronic Resource, link at library website.

Other resources

1. University of Wisconsin Writing Center (writing.wisc.edu) and Writer's Handbook (http://writing.wisc.edu/Handbook/index.html)

Lecture Schedule

Week	Meeting Number	Date		Topic
1	1	9/3		Introduction: Electronic properties of materials, Drude model
2	2	9/8		Optical properties, limitations of classical models
	3	9/10		Quantum mechanics: Schrodinger equation, free electrons
3	4	9/15		Particle-in-a-box, hydrogen atom energy levels, atomic structure
	5	9/17		Electrons in periodic potentials
4	6	9/22		Real and reciprocal lattices, Brillouin zones
	7	9/24		Band structures of real materials, effective mass
5	8	9/29		Density of states, Fermi distribution, Fermi surfaces
	9	10/1		Quantum mechanical picture of transport properties
6	10	10/6		Properties of metals revisited, metallic glasses
	11	10/8		Other "electronic" properties: specific heat, thermal transport
7	12	10/13		Semiconductors: Band structure and conduction, mobility
	13	10/15		**Exam 1: Covers class meetings 1-12**
8	14	10/20		Statistics of doped semiconductors
	15	10/22		Organic semiconductors, 2D, and 1D materials
9	16	10/27		Semiconductor devices: p-n junctions, Schottky diodes, BJTs and FETs
	17	10/29		Thermoelectrics
10	18	11/3		Quantum mechanical picture of optical properties
	19	11/5		Bose statistics in optics: stimulated emission, lasers
11	20	11/10		Collective optical excitations: plasmons and related phenomena
	21	11/12		Dielectrics, electrical properties of insulators
12	22	11/17		**Exam 2: Covers class meetings 14-21**
	23	11/19		Ordered magnetic and electrical polarization in solids
13	24	11/24		Ferroelectricity, electronic effects in structural phase transitions
		11/26		**Thanksgiving Recess: No class**
14	25	12/1		Magnetism: electron spin, para- and diamagnetism, ferromagnets
	26	12/3		Origins of magnetism: Heisenberg model, magnetic exchange
15	27	12/8		Applications of magnetic materials: information storage, transformers
	28	12/10		Superconductivity: Thermodynamic Models
	29	12/15		Superconductivity and superconducting materials, BCS theory
		12/23		Final Exam: 10:05 AM, location to be announced