Electronic, optical, Magnetic and Thermal Properties of Materials

Syllabus

Fall 2025

Course details:

4 credits

Course code:	MTEN 309
Course title:	Electronic, Optical, Magnetic and Thermal Properties of Materials
Course location:	FMH 309/TIER 007A
Course time:	Monday 1:00 pm-3:05 pm, Tuesday/Thursdays 10:00 - 11:20 am.
Pre-requisite:	MTEN 201

Course Instructor and Office Hours:

Instructor: Dr.Irina Molodetsky, T350, B007-A
Email address: irina.molodetsky@njit.edu
Office number: 973-596-3599
Office hours: Tuesday, 3:00 pm-5:00 pm. Additional time can be scheduled upon request.

Virtual office hours
Virtual meeting times can be arranged, subject to the instructor's availability week by week. To make these arrangements, please email the instructor to find a mutually convenient time. Once the time, date and mode (in-person or virtually) has been confirmed, the instructor will provide you with the Zoom meeting link and details (if applicable).

Course Description:

This course will cover theoretical concepts and applications of the electronic, optical, magnetic and thermal properties of materials. It is intended for engineers/scientists who want to gain a fundamental understanding of metals, alloys, semiconductors, magnetic materials, ceramics, polymers among other materials based on their electrical, thermal, optical and magnetic functionalities. The course will use an integrated approach to present the relationship between the structure, characteristics, properties and performance of all major classes of materials. Some topics covered include free electron theory, electrical conductivity, semi-conductors and energy bands, magnetism, etc. Course includes hands-on laboratory experience.

Course organization:

The course is organized as 3-hour weekly discussions, problem solving and 2 - hour weekly laboratory component to compliment and support the material learned in this class. Lecture slides and auxiliary notes will be available on CANVAS. Taking notes is strongly encouraged. Each class will be accompanied by a Page on Canvas that is retrospectively summarizes "lessons learned", what worked best and needs improvement.

Required software:

Microsoft Word, Excel and PowerPoint software will be required. These are available for download from NJIT software webpage: https://ist.njit.edu/software-available-download#v

Required text(s):

1. Callister, W. & Rethwisch, D. *Materials Science and Engineering: An Integrated Approach*, John Wiley & Sons, USA, 6th edition

Suggested/supportive texts:

1. Hummel, R., *Electronic Properties of Materials* 4th Ed. Springer, (2011)
2. Kasap, S.O. *Principles of Electronic Materials and Devices* 4th Ed. McGraw Hill
3. Cengel, Y. & Ghajar, A. *Heat and Mass Transfer: Fundamentals and Applications* 6th Ed. McGraw Hill (practical examples for thermal conduction and thermal resistance of materials)

Educational objectives:

The student will be able to:

- Apply heat resistance model to optimize heat transfer in a steady state
- Design a composite with improved thermal management property for assigned application
- Identify the role of each material in the main passive and active electronic components
- Apply energy gap theory to describe electrical properties of conductors, dielectrics, semiconductors
- Analyze the absorbance spectrum of a given sample material and construct a Tauc plot to determine the energy gap
- Predict polarization in a ABO3 perovskite and measure d33 for a given piezoelectric sample
- Apply acquired knowledge on properties of materials in a simple product design
- Review existing literature and technology focusing on magnetic properties of materials in solving environmental problems
- Analyze and present experimental data
- Work in teams, to assess and improve collaborative environment

Assignments and Grading Policies:

Table 1. Grade breakdown

Exit Questions	Extra Credit
Quizzes	25
Participation (Assignments)	25
Lab Reports	50
Presentation (paper review)	10

Table 2. Grade scale assignment (changes may apply)

Above 90	A
85-90	B+
80-85	B
70-80	C+
60-70	C
50-60	D
<50	F
Incomplete	I

Weekly Exit Questions (Extra Credit)

A single question relevant to the topic taught or discussed in class for that week can be submitted by each student on Thursday (0.2 %; Canvas submission). Extra credit (2 %) will be awarded to three best questions (instructor and students' choice) at the end of the semester

Quizzes (25%)

Quizzes will be administered after specific sections of the course, which include Thermal, Electrical, Optical, and Magnetic properties. The questions and problems in the quizzes would require your understanding of the material rather than memorization. You will be allowed to use course textbook(s) and your own notes. No electronic devices to be used during quizzes.

Participation (25%)

Your participation is "measured" by assignments completed in class and at home. Since there is no "make up" for in-class assignments, your attendance is critical. Laboratory classes attendance is mandatory.

Laboratory experiments (50%)

There are two types of laboratory experiments. The first type of experiment is based on measurements of the materials properties using state-of-the art materials characterization. The second type of experiment is exploratory experiments, where your attention to details, creativity and resourcefulness (with the instructor's support) are essential keys to a successful experiment.

Presentation (10%)

The course instructor will provide a list of research papers. You choose one of the paper for review and presentation of the review. This assignment will include the use of assistance of AI.

Late Work Policy:

Marks will be deducted for late submission of assignments. An improvement of a satisfactory (~ 75% or higher) draft laboratory report will be granted to students, with a final submission within one week after the instructor's feedback.

Make-up Policy:

There are no-make ups for class assignments, quizzes or laboratory experiments.

University Policies:

Accommodation

If you need accommodations due to a disability or challenge please contact Scott Janz, Associate Director of Office of Accessibility Resources & Services (OARS), Kupfrian Hall 201 to discuss your specific needs. A Letter of Accommodation Eligibility from the OARS authorizing your accommodations will be required. Other resources for special support services can be found here: https://www.njit.edu/studentsuccess/support-services-and-accommodations

Academic Integrity

Academic Integrity is the cornerstone of higher education and is central to the ideals of this course and the university. Cheating is strictly prohibited and devalues the degree that you are working on. As a member of the NJIT community, it is your responsibility to protect your educational investment by knowing and following the code of Academic Integrity policy that is found at: NJIT Academic Integrity Code.

Please note that it is my professional obligation and responsibility to report any academic misconduct to the Office of the Dean of Students. Any student found in violation of the code by cheating, plagiarizing, or using any online software inappropriately will result in disciplinary action. This may include a failing grade of F, and/or suspension or dismissal from the university. If you have any questions about the code of Academic Integrity, please contact the Office of the Dean of Students at dos@njit.edu.

Generative AI

Please, use AI usage link to a guidance on how to use Generative AI to improve your skills. Some of the assignments will use generative AI.

Attendance Policy

All students are required to attend all classes. If a student is unable to attend a class session, the instructor should be informed via email of your absence prior to the start of the class since it would greatly affect the mode of planned instruction.

COURSE SCHEDULE (Tentative)

Week 1(9/2)	Introduction Syllabus, Course structure,
Week 1	**Vibrations and Waves.** Periodic motions. Vectors diagrams Superposition of periodic motions Free vibrations (harmonic oscillator) Normal modes in the continuum. Coupled oscillators and normal modes. De Broglie equation

Week 2-4	**Thermal Properties** Sensible Heat. Heat capacity Heat transfer: mechanisms. Modeling of resistance to heat transfer Thermal conductivity. Lab 1 Quiz
Week 5-6	**Electrical properties** Electrical conduction -the Drude Model. Ohm's Law Energy band structures in solids Carrier mobility in metals, semiconductors, and ionic conductors. Theory, examples and measurements. Lab 2 Quiz
Week 7- 8	**Dielectrics** Electrical field. Interaction between the charges. Dielectric strength Dipole structure of the dielectrics. Polarization Principles of engineering dielectric materials -example of perovskite-like structures Lab 3 Quiz
Week 9 -10	**Magnetic Properties** Basic Concepts in Magnetism, Diamagnetism, Para-magnetism, Ferromagnetism, Anti-ferromagnetism, Ferrimagnetism, Langevin Theory of Diamagnetism, Influence of temperature on Magnetic Behavior, Domains and Hysteresis, Magnetic Anisotropy, Soft vs Hard Magnetic Materials, Magnetic Storage, Superconductivity
Week 11-13	**Optical Properties** Electromagnetic Radiation Light interaction with Solids, Atomic and Electronic Interactions Optical Properties of Metals/Non-Metals Refraction, Reflection, Absorption, Emission and Scattering Luminescence Lab 4 Quiz
Week 14	Presentation