Electronic, optical, Magnetic and Thermal Properties of Materials

Syllabus

Fall 2024

Course details:

4 credits

Course code:	MTEN 309
Course title:	Electronic, optical, Magnetic and Thermal Properties of Materials
Course location:	FMH 108/TIER 007A
Course time:	Tuesdays, Thursdays 10:00 11:20 am; Monday 1:00-3:05 pm
Pre-requisite:	MTEN 205, MTEN 201

Course Instructor and Office Hours:

Instructor: Dr.Irina Molodetsky, T350
Email address: irina.molodetsky@njit.edu
Office number:973-596-3599
Office hours: Thursdays 1:15 – 5:00 pm

Laboratory Instructor: Dr.Irina Molodetsky, T350
Email address: irina.molodetsky@njit.edu
Office number:973-596-3599

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 will include a written and oral presentation and a critical assessment of the latest development of the field.

Course organization:

The course is organized as a 3-hour lecture with in-class discussion and problem solving and 2- hour laboratory component. Lecture slides and auxiliary notes (book chapters, journal articles, review papers, practice problem sheet, lab manuals, etc.) will be available on CANVAS. Solutions for the assignment/ in-

class practice problems will be posted after in-class discussion/tutorial session. Resources provided should be used as a guide for studying. Taking notes is strongly encouraged.

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:

- Integrate the understanding of the scientific and engineering principles underlying the four major elements of materials engineering (structure, properties, processing, and performance) for metals, ceramics and polymers in light of their electrical, optical, magnetic and thermal properties
- Apply free electron theory, atomic structure and crystals to describe electrical, optical, magnetic and thermal properties in materials
- Identify, describe, and compare relationships between microstructure/atomic structure on electrical, optical, magnetic, and thermal properties
- Review existing literature and technology, identify and critically assess key material design principles considering a selected material function and electrical, optical, thermal or magnetic properties and performance
- Analyze and present experimental data
- Work in teams, to assess and improve collaborative environment

Assignments and Grading Policies:

Table 1. Grade breakdown

Class Participation/Exit Questions	10
Quizzes	10
Assignments	15
Lab Reports	25
Test 1	10
Test 2	10
Final Project	30

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 (5%)

A single question relevant to the topic taught or discussed in class for that week should be submitted by each student at the end of every lecture. The exit question should be submitted online (Canvas) and will be reviewed the following week in class. The questions can be related to theoretical concepts covered by instructor, in-class discussions or papers reviewed in preparation for the final project. The top exit question will be voted on and an extra credit will be awarded.

Quizzes (10%)

A 10-15-minute quiz will be administered to evaluate concepts taught from the prior week. Quizzes will be modeled like in-class practice problems. Solution for quizzes will be discussed in class the following week.

Assignments (15%)

Assignments will be a compilation of questions/problems to cover the major sub-topics discussed throughout the class. There will be 4 major assignments; 1 on each property completed- Electrical, Optical, Magnetic and Thermal.

Tests (20%)

There will be 2 tests administered. Each will be a 2-hour long written test assessing student problem solving and application of knowledge of topics covered on electrical, optical and magnetic properties. The tests will be conducted in-class following the schedule outlined in the syllabus. The test will be open book/open notes. Students will be assigned 3-4 problems to complete. More details on the exam format and procedure will be provided in-class.

Final Project (30%)

The course instructor will provide a list of current devices/materials related to electrical, optical and thermal properties for students to select a project topic from. Students will be placed in teams (team size will be dependent on class size) using CANVAS. Each team will be required to select a material/topic and conduct a brief review on the development of the selected material in light of its property. Research papers (published within the last 10 years), textbooks, and other printed resources must be relevant to the topics covered throughout the course. The team will prepare a 15-minute presentation and a written review with a summary of the basis of selection of the material, the structure, synthesis and processing of the material and relationship to its property and performance/application. The team should also compare performance of material to other existing technology, its advantages and limitations- resulting in a constructive criticism of the selected material for at least one specific application. A copy of the reviewed resources (articles,

etc.), the review and the power point presentation should be submitted.

Late Work Policy:

Marks will be deducted for assignments and final project reports and presentations that are submitted late without an extenuating circumstance, which is documented through the Dean of Students' office. For every day that the item is submitted late, 5% marks will be deducted. Material submitted later than a week will not be accepted.

Re-grade/Make-up Policy:

For discrepancies or questions related to grades received during the semester, you have the opportunity to discuss and request a regrade or makeup for quizzes/critiques, assignments, and mid-semester tests within 1 week after the material was graded and returned to you. The new grade will be the final grade. If there are concerns with your final overall course grade and a grade change is requested, this will be done following University guidelines as outlined in the catalog: https://catalog.njit.edu/undergraduate/academic-policies-procedures/.

Opportunities to improve grade score or complete assignments to improve overall grade can be discussed with the instructor on a case-by-case basis.

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 **academic code of integrity policy.** More details on this is provided at the following link: https://www5.njit.edu/policies/sites/policies/files/NJIT-University-Policy-on-Academic-Integrity.pdf

Please note that it is my professional obligation and responsibility to report any academic misconduct to the Dean of Students Office. 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 Dean of Students Office at dos@njit.edu

COVID policy:

Based on the NJIT memo regarding Course Requirements and Expectations for Spring 2023, dated January 11, 2023 from the Interim Provost and Senior Executive Vice President: "Although not mandated, both

students and instructors are free to wear facemasks in the classroom, if they so desire. Instructors are not allowed to set their own rules on this issue. The university will be actively monitoring the situation and if the conditions call for it, the policy may be changed."
If you are feeling unwell and experiencing any of the COVID- like symptoms, please follow University guidelines as stipulated at the following website: https://www.njit.edu/healthservices/. Any student who has tested positive, should inform the relevant University authorities at **covid.notify@njit.edu** so that proper contact tracing and COVID recovery measures can be completed. If he/she is unable to attend class sessions, measures for making up or conducting the presentations at a later date will be discussed on a case-by-case basis. This should be reported to the Dean of Students. More resources: https://www.njit.edu/counseling/c-caps-covid-19-bulletin

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. Class attendance will also be recorded by instructor and/or TA.

Withdrawal

Student requests for withdrawals after the deadline *(end of the 10th week of classes)* will not be permitted unless extenuating circumstances are documented **through the Office of the Dean of Students**. If you are considering withdrawing, please contact the course instructor and the Dean of Students

COURSE SCHEDULE (Tentative)

Week 1	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.
Week 2-3	**Thermal Properties** Heat capacity Thermal conductivity Modeling of resistance to heat transfer Lab 1
Week 4-5	**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. Hands on – energy storage devices Lab 2
Week 6-7	**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 Hands-on – energy storage devices Lab 3
Week 8-9	**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 10-11	**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 Hands-on – Filters Lab 4
Week 12-14	Final project