Fall 2021


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MTEN 610 Syllabus – New Jersey Institute of Technology

MTEN 610 – Foundations of Materials Science and Engineering

**Instructor:** Dr. Joshua Young  
- email: joshua.a.young@njit.edu  
- office: York 322

**Office Hours:** Tuesdays, 1 to 3 pm via Webex (or by appointment)

**Date, Time, and Location:** Wednesdays, 6 to 9 pm, Kupfrian 203


This will also be supplemented with material from other textbooks and peer-reviewed literature. These books are not required, and any supplemental material will be provided to you. Additional material will primarily come from:


The VESTA crystal structure visualization software will be used during this class; a tutorial will be posted on Canvas. Please let Prof. Young know if you have issues with it. It can be downloaded for Windows, Mac, and Linux OS here: https://jp-minerals.org/vesta/en/download.html

**Course Overview:** This is an introductory course for Materials Engineering graduate students. This course will introduce materials from an atomistic point of view and describe the relationship between their underlying structure and properties. We will first cover chemical bonding and crystal structure, and how this results in differences between families of materials (metals, ceramics, and polymers). We will then discuss phase transformations and use phase diagrams to describe the compositions and microstructure of solid solutions and discuss the thermodynamics of solid-state phase transitions. Finally, we will discuss important properties of materials (electronic, magnetic, optical, and thermal), how they are measured, how they arise, how they are influenced by crystal structure, and how the appropriate properties and materials are selected and used in various modern engineering applications.

**Prerequisites:** graduate standing

**Course Objectives:** During this course, students will:

1. analyze the fundamental link between materials’ atomistic structure, processing, and properties
2. represent the crystal structures of materials using crystallographic points, directions, and planes
3. understand the differences between families of materials (metals, ceramics, and polymers)
4. utilize phase diagrams to describe transformations and microstructure of solid solutions
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(5) predict elastic and plastic behavior and failure using fundamental relationships between stress and strain
(6) calculate and understand the origin of electrical, thermal, magnetic, and optical properties of materials
(7) understand how these are applied in modern areas of materials engineering research
(8) read and analyze modern scientific papers regarding recent materials engineering developments
(9) write a report and give an oral presentation detailing materials issues facing a specific area of engineering

Delivery Mode: This course will be delivered face-to-face. The MTEN 610 Canvas page will be the primary hub for class information. All homework, lecture notes, final paper and presentation details, and correspondence will take place through it.

Attendance Policy: Attendance is expected at all classes.

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 that is found at: http://www5.njit.edu/policies/sites/policies/files/academic-integrity-code.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.

Grading: The final grade for the course is divided as follows:
- Homework Problem Sets = 25% of grade
- Midterm Report = 20% of grade
- Final Written Report = 30% of grade
- Final Presentation = 25% of grade

Grades will be assigned with the following rubric:

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Grade</th>
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<tbody>
<tr>
<td>90% and above</td>
<td>A</td>
</tr>
<tr>
<td>85-89%</td>
<td>B+</td>
</tr>
<tr>
<td>80-84%</td>
<td>B</td>
</tr>
<tr>
<td>75-79%</td>
<td>C+</td>
</tr>
<tr>
<td>70-74%</td>
<td>C</td>
</tr>
<tr>
<td>60-69%</td>
<td>D</td>
</tr>
<tr>
<td>Below 60%</td>
<td>F</td>
</tr>
</tbody>
</table>

Homework:
- Students will be assigned 10 homework sets of exercises, each equally weighted.
- **In the problem sets you will practice calculations and analyze materials crystal structures in VESTA.**
- Homework sets should be turned in by uploading an electronically formatted or legibly handwritten and scanned document to Canvas before class begins. Homework turned in after 6 pm on the due date will be automatically reduced by 20%, with an additional 10% reduction per day late. You should begin problem sets early. **Homework sets should be turned in by uploading an electronically formatted or legibly handwritten and scanned document to Canvas before class begins. Homework turned in after 6 pm on the due date will be automatically reduced by 20%, with an additional 10% reduction per day late. You should begin problem sets early.**
- Working with your peers on the homework is allowed and encouraged. You should acknowledge your collaborators when submitting your assignments. Each student must provide their own solutions to problems and submit their own assignment, with their own written answers to the questions. It is not acceptable (and a violation of course policies) to use the same written answers as your collaborators.

**Class Project:**
- The class project makes up the bulk of the grade for this class and is intended to help bridge the gap between what is expected at undergraduate versus graduate level.
- **For this project, you will select a scientific or engineering application and compose a literature review detailing the materials used for it.**
- This will involve determining the properties required for the application, what materials were used in the past and why, what materials constitute cutting edge technology in this area, and how these improvements were made.
- This is an individual project.

The project consists of three parts:

1. **Midterm Report:** The first part is to (1) decide on a topic, (2) justify the choice, (3) describe why it is important, and (4) do a cursory background literature review. During week 6, you will receive details about the report and a list of potential topics; you do not have to choose a topic from the list, but it would be best to discuss the topic beforehand with Prof. Young. The midterm report is a minimum of 4 pages (not including references). The report should cover the 4 topics listed above.

2. **Final Report:** The final report is an extension of the midterm report. It is a minimum of 10 pages (not including references). In addition to the points listed above, the final report should detail (1) what material properties are needed for the application, (2) state-of-the-art materials used in the application, and (3) why these materials are used (in terms of crystal structure, properties, etc.).

3. **Final Presentation:** The final presentation will be 15 minutes to the class describing your selected topics and your findings. The presentation will be in the style of a Materials Research Society meeting, with 12 minutes for the presentation and 3 minutes for questions.

- A rubric for each part will be provided to you before the assignments are due. Both reports will be graded not only on content, but also style, clarity, organization, and formatting. The presentation will be graded on content, organization, time, and question answering.
**Schedule of Topics:**

<table>
<thead>
<tr>
<th>Week</th>
<th>Topics</th>
<th>Assignment</th>
</tr>
</thead>
</table>
| 1 – Sep. 1, 2021 | - Course Objectives  
- Introduction to Materials Engineering  
- Atomic Structure and Bonding | Download VESTA |
| 2 – Sep. 8, 2021 | **NO CLASS – MONDAY CLASSES MEET** |                       |
| 3 – Sep. 15, 2021 | - Atomic Structure and Bonding  
- Crystal Structure Basics | HW1 assigned |
| 4 – Sep. 22, 2021 | - Advanced Crystal Structure Topics  
- Symmetry and Tensor Properties | HW1 due  
HW2 assigned |
| 5 – Sep. 29, 2021 | - Metals and Ceramics  
- Electronic Structure (band gaps, etc.) | HW2 due  
HW3 assigned |
| 6 – Oct. 6, 2021 | - Defects  
- Diffusion  
- Midterm report details and project topics | HW3 due  
HW4 assigned |
| 7 – Oct. 13, 2021 | - Polymers  
- Molecular Solids | HW4 due |
| 8 – Oct. 20, 2021 | - Phase Transformations I: Phase Diagrams and Microstructure | Midterm Report due  
HW5 assigned |
| 9 – Oct. 27, 2021 | - Phase Transformations II: Solidification, Nucleation and Growth | HW5 due  
HW6 assigned |
| 10 – Nov. 3, 2021 | - Mechanical Properties  
- Dislocations  
- Failure | HW6 due  
HW7 assigned |
| 11 – Nov. 10, 2021 | - Electronic Properties  
- Electronic Devices | HW7 due  
HW8 assigned |
| 12 – Nov. 17, 2021 | - Magnetic Properties  
- Optical Properties | HW8 due  
HW9 assigned |
| 13 – Nov. 24, 2021 | - Thermal Properties  
- Corrosion and Degradation of Materials | HW 9 due  
HW10 assigned |
| 14 – Dec. 1, 2021 | - Modern materials engineering research areas | HW 10 due |
| 15 – Dec. 8, 2021 | **FINAL PRESENTATIONS** |                       |
| 16 – Dec. 15, 2021 | **NO CLASS – FINAL EXAM WEEK** | Final Report due |