

**Properties of Materials II (Mechanical Properties of Materials), Spring 2009**  
**Prof Linda S. Schadler**

**Class Hours:** **Monday**      **10:00-11:50**                      **Office Hours: Mon, Thurs 9-10am**  
**Lab, Wed**      **10:00-2:00**                      **Teaching Assistant: Steve Mayott**  
**Thursday**      **10:00-11:50**                      **TA Office Hours: TBA**

**Text:** "Mechanical Behavior of Materials" Meyers and Chawla  
My expectation is that you will have read the textbook before coming to class. This is difficult material to learn and some repetition is a good thing! I will only assign the most relevant reading, but there is lots of good supplemental reading in this book.

**Format:** The course will have ~3 hours of lecture per week and 2 hours of laboratory = 4 credits. I'm not sure why they always schedule the 4 hours of lecture, but I try not to use it! That means, I am usually available from 11:30 -12:00 for questions and it is a time when the lab groups can meet to compare data, etc.

I will "lecture" on a topic for the day, but this will be broken up with class discussion, and problem solving

**Tests:** There will be three two-hour exams during the term (and now and then a lab quiz to make sure you are reading the labs before coming to class!)

**Laboratory:** There will also be a teaching assistant to help during laboratory sessions. A laboratory schedule and discussion of grading policy / plagiarism / safety is attached. The reports will be handed in individually. If you don't understand the format of the report, please clarify that early in the semester. At the end of the term you will work with a team on a four-five week problem. You will be asked to choose a material from the pile of materials I have. Then you will be asked to strengthen the material. The results of this work will be an oral presentation to the class during the last two classes and a group written report.

**Homework:** You will receive several homework assignments (about one every other week). They can be completed collaboratively, but each student should hand in one set of answers. If you collaborate with people please list their names on your homework. Each student should understand every question that they hand in even if they have received help on it.

<b>Grading:</b>	Laboratory Reports	20%
	Strengthening Experiments	20%
	Homework	10%
	Three two-Hour exams	30%
	Final Exam (3 hour mandatory)	20%

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**Syllabus and Reading Assignments – MORE FINELY DIVIDE READING ASSIGNMENTS!**

<b>Date</b>	<b>Topic</b>	<b>Reading</b>	<b>Outcomes – Students should be able to</b>
<b>Jan 25</b>	1. Introduction to Mechanical Properties Review of Material from ENGR 1600 2a. Tensile Testing at the macroscale	Text 1.3.1-1.3.5 required. whole chapter is helpful,	<ul style="list-style-type: none"> <li>• Complete tensile tests according to ASTM standards and understand sources of error</li> </ul>
<b>Lab-Jan 27</b>	Lab Safety and Procedures <b>Lab #1 - Tensile Testing of Metals and Polymers (FULL REPORT DUE Feb 10)</b> <b>First Data uploaded by Feb 4</b>	Text 2.1, 2.2	<ul style="list-style-type: none"> <li>• Calculate Young's modulus, yield stress, ultimate strength, ductility, strain to failure from tensile test results.</li> </ul>
<b>Jan 28</b>	2. Analyzing Data from the Instron HOMEWORK #1 DUE	Lab Manual Text 3.1, 3.2	<ul style="list-style-type: none"> <li>• Understand the difference between engineering stress and true stress.</li> </ul>
<b>Feb 1</b>	3. Definition of 3D Stress and Strain Transformation of Stresses	Text 2.2-2.8	<ul style="list-style-type: none"> <li>• Determine engineering stress and strain from force and displacement</li> <li>• Have observed in an optical microscope tensile fracture surfaces of a metal and two polymers.</li> </ul>
<b>Lab Feb 3</b>	– <b>Part 2 of Lab #1 – Finish any testing and Microscopy of samples. Data upload by Feb 4!!!</b>	Lab Manual	
<b>Feb 4</b>	4. Hooke's Law for anisotropic materials Anisotropic moduli	Text 2.9, 2.10 + Handout	<ul style="list-style-type: none"> <li>• Understand that stress is 3D and that there are stress invariants</li> </ul>
<b>Feb 8</b>	5. Atomic view of elasticity 3 and 4 point bending HOMEWORK #2 DUE	Text 2.17	<ul style="list-style-type: none"> <li>• Be able to use Young's modulus, bulk modulus, Poisson's ratio to relate stress to strain</li> </ul>
<b>Feb 10</b>	<b>Lab #2 - Tensor Transformations</b> (Worksheet Due Feb 17)	Lab Manual	<ul style="list-style-type: none"> <li>• Be able to transform a stress matrix using Mohr's circle and tensors</li> <li>• Differentiate between hydrostatic and deviatoric stress and calculate dilatational strain</li> <li>• Apply Hooke's Law for a 3D stress and strain state</li> <li>• Find the stress in a plane of a single crystal</li> <li>• Predict Young's modulus,</li> </ul>

			melting temperature, coefficient of thermal expansion differences based on crystal potential energy curves.
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<b>Feb 11</b>	6. Viscoelasticity and Rubber Elasticity	Text 2.12-2.14	<ul style="list-style-type: none"> <li>Develop the equations for a small combination of springs and dashpots and predict the model behavior</li> </ul>
<b>Lab – Feb 16</b>	<b>Scanning Electron Microscopy and Metallography Training</b>		
<b>Lab-Feb 17</b>	<b>Lab #3 - Strain Rate Effects in Polymers (FULL REPORT Due Mar 3) Data uploaded FEB 24</b>	Lab Manual + Book	<ul style="list-style-type: none"> <li>Describe the limitations of Hooke's law for some materials</li> <li>Describe the role of entropy in the deformation of rubbers</li> <li>Determine Tg from DMA data</li> </ul>
<b>Feb 18</b>	7. Plastic deformation and criteria	Text 3.1-3.2, 3.5, 3.7.1-3.7.4, 3.7.6	<ul style="list-style-type: none"> <li>Predict plastic deformation for complex stress states.</li> <li>Be able to apply craze criteria</li> <li>Apply power law work hardening and calculate n</li> <li>Understand why the yield stress can be different in tension and compression</li> <li>Describe hardness tests and their limitations</li> <li>Predict the effect of temperature on yield stress</li> <li>Predict the effect of pressure on yield stress</li> </ul>
<b>Feb 22</b>	8. Hardness Testing, compression testing	Text 3.3, 3.4, 3.8	
<b>Lab-Feb 24</b>	<b>Lab #4 Compression Testing of Composites (SHORT REPORT Due March 17) Data uploaded by March 3</b>	Lab Manual	
<b>Feb 25</b>	9. Dislocations HOMEWORK #3 DUE	Text 4.1, 4.2, 4.4	<ul style="list-style-type: none"> <li>Calculate the shear stress on a slip system and compare it to the critical shear stress</li> <li>Describe the slip systems for FCC and BCC</li> <li>Describe why 5 independent slips systems are required for ductility</li> <li>Describe the difference between edge and screw dislocations</li> </ul>
<b>March 1</b>	EXAM #1 (Chapters 1-3)		
<b>Lab-Mar 3</b>	<b>Lab #5 Four Point Bending (SHORT REPORT DUE March 24) DATA UPLOADED BY Mar 17</b>	Lab Manual Text 9.6, 8.3, 7.10 Weibull Analysis in text	
<b>Mar 4</b>	10. Dislocations SPRING BREAK	Text 4.4	
<b>Mar 15</b>	11. Martensite and other Steel Structures Snowdate....12. Dislocations	11.2, 11.4 and handout	
<b>Lab-</b>	<b>Lab #6 Jominy End Quench</b>	Lab Manual	<ul style="list-style-type: none"> <li>Determine if the interaction</li> </ul>

<b>Mar 17</b>	(FULL REPORT Due March 31)	Callister 10.6, 10.7 – handouts	between two dislocations will be favorable
<b>Mar 18</b>	12. Dislocations	Text 4.4	<ul style="list-style-type: none"> <li>• Predict the distance between partial dislocations from the stacking fault energy</li> <li>• Calculate line tension for a curve dislocation</li> <li>• Describe a Lomer-Cottrell Lock</li> <li>• Calculate dislocation energy and stress</li> </ul>
<b>March 22</b>	13. Volumetric Defects HOMEWORK #4 DUE	Text Chapter 5 Not 5.4.3, 5.4.4, 5.7, 5.8	<ul style="list-style-type: none"> <li>• ASTM Grain size measurement methods</li> <li>• Structure of a grain boundary</li> <li>• Grain Boundary Energy</li> <li>• Effect of grain size on yield stress</li> <li>• Dislocation pileup – g.b. as obstacles</li> </ul>
<b>Lab-Mar 24</b>	Intro to <u>strengthening team</u> experiments Read and Plan processing Precipitation Kinetics Reviewed		(Draft Plan due to Mr. VanSteel due Mar 29 for what processing you will be doing)
<b>March 25</b>	14. Work Hardening	Text Chapter 6 NOT 6.3.2, 6.4	<ul style="list-style-type: none"> <li>• Suggest several ways to strengthen a metal or metal alloy</li> </ul>
<b>March 29</b>	15. Strengthening in Metals	Text Chap 10 NOT 10.3.4-10.3.6, 10.6, 10.7	<ul style="list-style-type: none"> <li>• Describe the mechanisms behind work hardening in single crystals</li> <li>• Predict the increase in yield stress due to solutes and precipitates,</li> <li>• Predict the effect of grain size on hardening (strengthening)</li> </ul>
<b>Lab-Mar 31</b>	<b>Strengthening - Team Experiments</b> Modify Materials	Lab Manual + books	Draft plan to Dr. S. describing your hypothesis of how your processing will affect microstructure and therefore properties
<b>Apr 1</b>	16. Fracture – Macroscopic	Text Chapter 7.1-7.6	<ul style="list-style-type: none"> <li>• Differentiate ductile and brittle fracture surfaces</li> </ul>
<b>Apr 5</b>	17. Fracture - Testing	Text Chapter 9.1-9.3	<ul style="list-style-type: none"> <li>• Calculate the stress</li> </ul>

<b>Lab- Apr 7</b>	<b>Lab #7 Fracture Toughness Charpy Impact Test (SHORT REPORT Due April 21) Data uploaded April 14</b>		<p>concentration at a crack tip</p> <ul style="list-style-type: none"> <li>Describe the logic behind the Griffith Criteria</li> <li>Be able to apply failure criteria to predict failure</li> <li>Be able to describe several toughening mechanisms</li> <li>Describe fracture toughness testing methods and calculate fracture toughness from data</li> </ul>
<b>Apr 8</b>	18. Fracture - Microscopic HOMEWORK #5 DUE	Chapter 8 NOT 8.3	
<b>Apr 12</b>	EXAM #2 (Chapters 4-7)		
<b>Lab- April 14</b>	NO SCHEDULED LAB BECAUSE NO CLASSES – BUT YOU ARE WELCOME TO COME IN		
<b>April 15</b>	19. Creep Metals	Text Chapter 13.1-13.9	<ul style="list-style-type: none"> <li>Describe the three stages of creep</li> </ul>
<b>April 19</b>	20. Creep Polymers	Text 13.11	<ul style="list-style-type: none"> <li>Predict steady state creep using Nabarro-Herring and Coble Creep laws</li> <li>Calculate activation energy</li> <li>Use the Larson-Miller parameter and data to predict remaining lifetime.</li> <li>Apply Time-Temp-Superposition</li> <li>Molecular and atomic mechanisms of creep</li> </ul> <p>Deformation Maps</p>
<b>Lab- April 21</b>	<b>Strengthening - Team Experiments</b> Modify Materials / Test Materials	Lab Manual	
<b>April 22</b>	21. Fatigue	Text Chapter 14.1-14.8	<ul style="list-style-type: none"> <li>Read an S-N curve</li> <li>Use the Palmer-Mindquist relationship</li> </ul>
<b>Apr 26</b>	22. Fatigue HOMEWORK #6 DUE	Text Chapter 14.1-14.8	<ul style="list-style-type: none"> <li>Predict lifetime using Paris Law or Coffin Law</li> <li>Apply Goodman Diagrams</li> </ul>
<b>Lab – April 28</b>	<b>Strengthening - Team Experiments</b> Testing Materials	Lab Manual	<ul style="list-style-type: none"> <li>Apply Goodman Diagrams</li> <li>Be able to characterize fracture surfaces</li> <li>Describe methods used to improve fatigue resistance</li> </ul>

<b>April 29</b>	23. Composites	Text Chapter 15.1-15.6 NOT 15.5.4, 15.5.5	<ul style="list-style-type: none"> <li>• Be able to define the types of composites</li> <li>• Understand the load transfer from low modulus to high modulus filler and the predict the resulting composite modulus</li> </ul>
<b>May 3</b>	EXAM #3 (Chapters 9-14)		
<b>May 5</b>	<b>Strengthening - Team Experiments</b> Microscopy – other unfinished tests	Lab Manual	
<b>May 6</b>	Final Laboratory Presentations		
<b>May 10</b>	Final Laboratory Presentations		

#### Overall Course Outcomes

- (1) *Students should have a basic understanding of several mechanical properties tests and the use of ASTM standards to complete valid tests.*
- (2) *Students should be able to use quantitative equations to describe observed mechanical behavior of materials (such as hardening laws) and predict failure (Von Mises Criteria, Paris Law)*
- (3) *Students should have a basic understanding of the relationship between atomic, and microscale structure and mechanical properties.*
- (4) *Students should have a basic understanding of strengthening mechanisms in metals and the role of dislocation motion and structure as a result of strengthening processing.*
- (5) *Students should have a basic understanding time and temperature dependent behavior in all materials with an emphasis on polymers.*
- (6) *Students should have a basic understanding of stress tensors and transformation of stress.*