Course Registration Numbers: 15939 (Mdlg Dmg&Strnth Mchsm In Mtrls)

Schedule: Tuesdays and Thursdays at 10:30 – 11:45 am in 3115 ARMS

Instructor: Michael D. Sangid; Email: msangid@purdue.edu
Office: 3329 ARMS; Telephone: 494-0146
Office Hours: Tuesdays and Thursdays, immediately after class and Wednesdays 3 – 4 pm in 3329 ARMS.

Please note: To ensure that everyone has the same access to questions/answers, please ask questions about the HW/projects during class or office hours. Emailing questions should be avoided. Also, please do not ask general/vague questions, such as 'how do I do #X (while showing up with no prior work)?', 'can you find the bug in my code', or 'is this right?'

Prerequisites: An entry-level class in solid mechanics (such as elasticity or continuum mechanics) that covers indicial notation and basic equilibrium/ compatibility conditions.

Required Text: None
Will supply journal papers / book chapters as hand-outs

Recommended Text: *Micromechanics of Defects in Solids*, by T. Mura, Springer, 2nd Edition, ISBN – 9024732565

Supplemental Texts:

The Mechanics of Crystals and Textured Polycrystals, William F. Hosford, Oxford
Micromechanics: Overall Properties of Heterogeneous Materials, by S. Nemat-Nasser, M. Hori, Elsevier
Crystals, Defects, and Microstructure, Rob Phillips, Cambridge
The Mathematical Theory of Plasticity, R. Hill, Oxford
Introduction to Texture Analysis, O. Engler, V Randle, CRC Press
Strengthening Mechanisms in Crystal Plasticity, A.S. Argon, Oxford
Mechanical Behaviour of Engineering Materials: Metals, Ceramics, Polymers, and Composite, Roesler, Joachim, Harders, Harald, Baeker, Martin; Springer, http://www.springer.com/materials/mechanics/book/978-3-540-73446-8
Theory of Elasticity, S.P. Timoshenko, N. Goodier, McGraw

Grading: 3 Credit Hours – HW (25%), Project 1 (25%), Project 2 (25%), and Project 3 (25%). In general, we will have a 90%|80%|70%|60% grade scale with +/- grades. Depending on how the class performs on its assignments and projects, the instructor reserves the right to curve the scale in the favor of the class, if necessary, based on his discretion. Grades will never be curved downward.

Exams: There will be no exam or finals, as part of this class.

Homework: There will be roughly 5 HW assignments given during the semester. You may work in teams of 1 to 3 on the HW. Please write each of your names on the HW assignment that you turn in.

The HW is for your own benefit and is necessary to properly learn the material. It is expect that each student put forward an honest effort in solving each problem. Working together is not a means to 'divide up' the work. If you turn in an assignment with more than one name on it; each person must have put forth their best effort on every problem and discussed this problem with the group. Any abuse of this policy and we will go back to individual assignments.

Project: Each student is expected to turn in his/her own project, containing a written report with figures, tables, equations, codes, references, etc. For Projects 1 and 2, the entire class will work toward the same project: (i) Mori-Tanaka implementation of the Eshelby inclusion model and (ii) Bishop and Hill implementation of a Taylor crystal plasticity model. For the third project, each student must choose his/her own topic, which must be relevant to this class and discussed with the instructor. Additionally, for the third project, students are required to give a class presentation (7 min – but this may be variable based on class size). Although it is helpful to choose a topic relevant to your research, this work cannot be completed prior to this semester or used to satisfy another requirement.

Course Description: This course is intended to be a graduate level course, which focuses on modeling at the microstructure level of primarily metals but also composites. The course topics and modules are defined as follows:

I. Eshelby inclusion problem (1/4 Class)
   - Advanced micromechanics analysis of modern engineering materials with emphasis on relating elastic microstructural phenomena to the mechanics of material behavior.

Project 1: Application to fiber reinforced composites – Mori-Tanaka implementation

II. Overview of classical plasticity (1/4 Class)
   - Phenomenological and mathematical formulation of the constitutive laws of plasticity.
   - Yielding, yield surface; von Mises, Tresca yield criteria; Drucker's stability postulate; strain or work hardening, normality rule, perfect plasticity, and stress-strain law

III. Crystal plasticity (1/4 Class)
   - Physical and mathematical foundation for plasticity in crystalline materials, with application to deformation processes.

Project 2: Bishop and Hill implementation in Taylor problem for deformation of polycrystals

IV. Concepts of dislocations leading to strengthening mechanisms in metals (1/4 class)
   - Study of anisotropy of material and elastoplastic properties at crystal level, microstructural basis for deformation in metals, polymers, and ceramics.
   - Failure mechanisms and toughening in metals, with primary emphasis on work/strain hardening, solid solution hardening, precipitate hardening, and grain boundaries.

Project 3: The topic of this project must be relevant to this class and discussed with the instructor. Students are required to give a class presentation (see note above concerning projects) and turn in a report. Although it is helpful to choose a topic relevant to your research, this work cannot be completed prior to this semester or used to satisfy another requirement.

CS&E Program: This class is listed as a Relevant Course to count towards the requirements of the CS&E Program.

Approach: Active learning – classes are a mixture of lecture and discussion
Students are expected to be present and prompt for class, to keep up with the materials and homework assignments, and to live up to the highest standards of honesty and integrity. Students are encouraged and expected to be lively and participate with the lectures. The class notes will be given on the blackboard with figures shown on the overhead (the figures will be made available through the class website). It is expected that the students come to class and take notes. If a student cannot make it to class, they should arrange to get the notes from one of their classmates.

In general, notes and handouts are "considered to be 'derivative works' of the instructor's presentations and materials, and they are thus subject to the instructor's copyright in such presentations and materials."

Definition of Academic Dishonesty: Purdue prohibits "dishonesty in connection with any University activity. Cheating, plagiarism, or knowingly furnishing false information to the University are examples of dishonesty" (*University Regulations*, Part 5, Section III, B, 2, a). Furthermore, the University Senate has stipulated that "the commitment of acts of cheating, lying, and deceit in any of their diverse forms is dishonest and must not be tolerated. Moreover, knowingly to aid and abet, directly or indirectly, other parties in committing dishonest acts is in itself dishonest" (University Senate Document 72-18, December 15, 1972).

Academic Integrity: "Purdue University values intellectual integrity and the highest standards of academic conduct. To be prepared to meet societal needs as leaders and role models, students must be educated in an ethical learning environment that promotes a high standard of honor in scholastic work. Academic dishonesty undermines institutional integrity and threatens the academic fabric of Purdue University. Dishonesty is not an acceptable avenue to success. It diminishes the quality of a Purdue education which is valued because of Purdue's high academic standards" (S. Akers, *Academic Integrity, A Guide for Students*, 1995, revised 1999). Also, see PURDUE UNIVERSITY CODE OF HONOR

Students with Disabilities: Students with disabilities requiring additional assistance should make themselves known to the instructor.

Campus Emergency: In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control.

Additional Information: This class will uphold Purdue University's policies on 'Attendance and Grief Absence', 'Adverse Weather', 'Campus Emergency', etc. Please consult purdue.edu for more information.

			Topic	Handouts	Assignments	Due Dates
	Week	**1**				
1	Tues	12-Jan	Class Introductions			
2	***TBD***		Review: Indicial Notation			
3	Thur	14-Jan	Elasticity Fundamentals			
	Week	**2**				
4	Tues	19-Jan	Eshelby Analysis	Eshelby / Han		
5	Thur	21-Jan	Interior of Inclusion	Ellipse Formulation		
	Week	**3**				
6	Tues	26-Jan	Spherical Inclusion Example		HW1	
7	Thur	28-Jan	External to Inclusion			
8	***TBD***		Mori-Tanaka Implementation	Tucker		
	Week	**4**				
9	Tues	2-Feb	Project I Description		P1	HW1
10	Thur	4-Feb	Inclusion Energy			
	Week	**5**				
11	Tues	9-Feb	Plasticity Introduction			
12	Thur	11-Feb	Pi-Plane	Hill		
	Week	**6**				
	Tues	16-Feb	*No Class - TMS*			
	Thur	18-Feb	*No Class - TMS*			
	Week	**7**				
13	Tues	23-Feb	Yield Condition		HW2	
14	Thur	25-Feb	Flow Rule			P1
	Week	**8**				
15	Tues	1-Mar	Normality / Convexity			
16	Thur	3-Mar	Texture Introduction	Hosford / Rollett	HW3	HW2
17	***TBD***		Single Crystal Deformation	Dawson		
	Week	**9**				
18	Tues	8-Mar	Polycrystalline Deformation I	Kocks		
19	Thur	10-Mar	Polycrystalline Deformation II			HW3
	Week	**10**				
	Tues	15-Mar	*No class - Spring Break*			
	Thur	17-Mar	*No class - Spring Break*			
	Week	**11**				
20	Tues	22-Mar	Exponetial Mapping	Crystal Rotation	HW4	
21	Thur	24-Mar	Bishop-Hill Algorithm	Bishop-Hill		
22	***TBD***		Project II & III Description		P2 & P3	
	Week	**12**				
23	Tues	29-Mar	Kinetics I	McDowell		
24	Thur	31-Mar	Kinetics II			HW4
	Week	**13**				
25	Tues	5-Apr	Work Hardening	Mecking / Beaudoin		
26	Thur	7-Apr	Incompatibility I		HW5	P3 Abstracts
	Week	**14**				
27	Tues	12-Apr	Incompatibility II			
28	Thur	14-Apr	Grain Boundaries	Hirth / Sangid / Rittner		P2
	Week	**15**				
29	Tues	19-Apr	Self Consistent Approaches	Lebensohn & Tome		
30	Thur	21-Apr	X-Ray Diffraction			HW5
	Week	**16**				
31	Tues	26-Apr	Project III Consultation			
32	Thur	28-Apr	Project III Consultation			
	Week	**17**				
33	***TBD***		Project III Presenations			P3

EMERGENCY PREPAREDNESS LECTURE

1 *Prior to the first day of class, obtain a copy of the building emergency plan for each building in which you will be teaching. Note the evacuation route and assembly area, as well as the shelter in place locations. BEPs are located on the Emergency Preparedness website http://www.purdue.edu/ehps/emergency_preparedness/*

2 *On the first day of class, the following information is required to be presented to students:*

As we begin this semester I want to take a few minutes and discuss emergency preparedness. Purdue University is a very safe campus and there is a low probability that a serious incident will occur here at Purdue. However, just as we receive a "safety briefing" each time we get on an aircraft, we want to emphasize our emergency procedures for evacuation and shelter in place incidents. Our preparedness will be critical IF an unexpected event occurs!

Emergency preparedness is your personal responsibility. Purdue University is actively preparing for natural disasters or human-caused incidents with the ultimate goal of maintaining a safe and secure campus. Let's review the following procedures:

- For any emergency call 911.
- There are nearly 300 Emergency Telephone Systems throughout campus that connect directly to the Purdue Police Department (PUPD). If you feel threatened or need help, push the button and you will be connected to the PUPD.
- If we hear a fire alarm we will immediately evacuate the building
    - **Do not use the elevator.**
    - Go over evacuation route…see specific Building Emergency Plan.
- If we are notified of a Shelter in Place requirement for a tornado warning we will shelter in the lowest level of this building away from windows and doors. Our preferred location is near the elevators, outside of B119.
- If we are notified of a Shelter in Place requirement for a hazardous materials release we will shelter in our classroom shutting any open doors and windows.
- If we are notified of a Shelter in Place requirement for a civil disturbance such as a shooting we will shelter in a room that is securable preferably without windows.

(NOTE: Each building will have different evacuation & shelter locations. The specific Building Emergency Plan will provide specific locations and procedures)

Attached to the syllabus is an "Emergency Preparedness for Classrooms" sheet that provides additional preparedness information. Please review the sheet and the Emergency Preparedness website for additional emergency preparedness information.

EMERGENCY PREPAREDNESS SYLLABUS ATTACHMENT

EMERGENCY NOTIFICATION PROCEDURES are based on a simple concept – if you hear a fire alarm inside, proceed outside. If you hear a siren outside, proceed inside.

- **Indoor Fire Alarms** mean to stop class or research and immediately **evacuate** the building.
- Proceed to your Emergency Assembly Area away from building doors. **Remain outside** until police, fire, or other emergency response personnel provide additional guidance or tell you it is safe to leave.
- **All Hazards Outdoor Emergency Warning Sirens** mean to immediately seek shelter (**Shelter in Place**) in a safe location within the closest building.
    - "Shelter in place" means seeking immediate shelter inside a building or University residence. This course of action may need to be taken during a tornado, a civil disturbance including a shooting or release of hazardous materials in the outside air. Once safely inside, find out more details about the emergency*. **Remain in place** until police, fire, or other emergency response personnel provide additional guidance or tell you it is safe to leave.

**In both cases, you should seek additional clarifying information by all means possible…Purdue Emergency Status page, text message, Twitter, Desktop Alert, Alertus Beacon, digital signs, email alert, TV, radio, etc…review the Purdue Emergency Warning Notification System multi-communication layers at http://www.purdue.edu/ehps/emergency_preparedness/warning-system.html*

EMERGENCY RESPONSE PROCEDURES:

- Review the **Emergency Procedures Guidelines** https://www.purdue.edu/emergency_preparedness/flipchart/index.html
- Review the **Building Emergency Plan** (available on the Emergency Preparedness website or from the building deputy) for:
    - evacuation routes, exit points, and emergency assembly area
    - when and how to evacuate the building.
    - shelter in place procedures and locations
- additional building specific procedures and requirements.

EMERGENCY PREPAREDNESS AWARENESS VIDEOS

"Shots Fired on Campus: When Lightning Strikes," is a 20-minute active shooter awareness video that illustrates what to look for and how to prepare and react to this type of incident. See: http://www.purdue.edu/securePurdue/news/2010/emergency-preparedness-shots-fired-on-campus-video.cfm (Link is also located on the EP website)

MORE INFORMATION

Reference the Emergency Preparedness web site for additional information: https://www.purdue.edu/ehps/emergency_preparedness/