New Course EFD Template

PURDUE UNIVERSITY | College of Engineering

Engineering Faculty Document No.:
24-25
July 17, 2024

TO: The Engineering Faculty

FROM: The Faculty of the School of Mechanical Engineering

RE: New graduate course – ME 59600 Solid Mechanics II

The Faculty of the School of Mechanical Engineering has approved the following new graduate course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

FROM (IF ALREADY OFFERED WITH TEMPORARY NUMBER):

ME 59700, Solid Mechanics II

Spring semesters

3 total credits; 3 lecture-based

No Pre-req required. Solid Mechanics I (ME 59300 pending) is recommended, but not required

Previous Semesters Offered: Spring 2024—17 Residential, Spring 2022-23 Residential

TO:

ME 59600 Solid Mechanics II

Semesters Offered: Spring

3 total credits; 3 lecture-based

No Pre-req required. Solid Mechanics I (ME 593 pending) is recommended, but not required.

Course description: The design of modern engineering structures is intrinsically linked to the understanding and analysis of materials and structures. This course is a foundational course on graduate level knowledge in this area of engineering.

RATIONALE:

The course serves as a foundation and complements existing graduate courses in Mechanical Engineering, such as those which address Continuum Mechanics (ME 612), Wave Propagation in Solids (ME 597), Theory of Vibrations (ME 563, ME 664), Contact Mechanics (ME 556), Fracture Mechanics (ME 650), Composite Materials (ME 559). It is also the natural progression of the Mechanical Engineering course 'Solid Mechanics I' (ME 593 pending), providing a natural sequence of courses to build a strong foundation in solid mechanics to graduate students in Mechanical Engineering, and Engineering in general.

Eckhard A. Groll
William E. and Florence E Perry Head of Mechanical Engineering

Link to Curriculog entry: https://purdue.curriculog.com/proposal:28736/form

ME __5XX____
Solid Mechanics II

Course Outcomes

1. Select the most appropriate theory for modeling a particular material and structure in a given application, and outline the variables and general parameters needed, as well as the limitations of the chosen theory. [1, 2, 7]
2. Comprehend the response of nonlinear elastic materials (hyperelasticity), rate-dependent materials (viscoelasticity), and path-dependent materials (plasticity), and the corresponding material properties involved in their characterization. Specific outcomes are defined by the instructor. [1, 2, 7]
3. Comprehend the formulation of structural elements (beams, plates, shells) as the analytical upscaling of continuum solids under kinematic assumptions. Specific outcomes are defined by the instructor. [1, 2, 7]
4. Comprehend the formulation of solid-solid and solid-fluid interactions as the analytical upscaling of continuum solids under kinematic assumptions and specific boundary conditions. Specific outcomes are defined by the instructor. [1, 2, 7]
5. Develop the skill to analyze problems in mechanics of materials, interpret technical literature, and write technical report about a problem in this field. [1,2,3]

1. Review of Elasticity (2 wks)

1. Course introduction.
2. Kinematics for large deformation.
3. Conservation and balance laws.
4. Cauchy stress and other definitions.
5. Constitutive relationships.

2. Hyperelasticity (2-3 wks)

1. Strain energy density.
2. Objectivity. Material-frame indifference, Isotropy and anisotropic elastic solids.
3. Hyperelastic and incompressible solids.
4. Examples: soft tissues, polymers.

3. Viscoelasticity (1-3 wks)

1. Linear viscoelasticity (relaxation, creep)
2. Constitutive equations in integral and differential forms.
3. Maxell and Voigt models, three-dimensional constitutive models.
4. Nonlinear models.
5. Examples: soft tissues, polymers.

4. Plasticity (2-3 wks)

1. Phenomenological observations.
2. Rate independent plasticity.
3. Additive decomposition of incremental strains. Multiplicative decomposition of deformation gradient.
4. Yield criteria, flow rules, hardening rules.
5. J2 or von Mises, Mohr-Coulomb, and Drucker-Prager plasticity models.
6. Examples.

5. Structural Elements and Structural Instabilities (1-3 wks)

1. Beam, plates and shells.
2. Displacement field and constitutive relationships of elastic structures (internal resultants and kinematic variables).
3. Structural instabilities. Buckling.
4. Examples: instabilities in columns, cylindrical shells, thin films on elastic foundations (among others).

6. Solid-Solid and Fluid-Solid Interactions (2-3 wks)

1. Contact between smooth non-conforming surfaces of deformable solids.
2. Elastic, strain-rate dependent, and plastic spherical solids in contact.
3. Indentation problems (interaction between rigid and deformable solids)
4. Boundary conditions at fluid-solid interfaces. Fluid flow equations.

COURSE NUMBER: ME _5XX_____ **COURSE TITLE:** Solid Mechanics II

REQUIRED COURSE OR ELECTIVE COURSE: Elective

TERMS OFFERED: Spring

TEXTBOOK/REQUIRED MATERIAL: None, but several references will be recommended

- Elasticity: Theory, Applications, and Numerics. 4th Edition. Sadd M.H. Elsevier, 2010.
- Nonlinear Solid Mechanics. Holzapfel. Wiley, 2000.
- Continuum Mechanics and Thermodynamics. Tadmor E.B., Miller R.E., Elliot R.S. Cambridge University Press, 2012.
- An Introduction to Continuum Mechanics. M.E. Gurtin. Academic Press, 2003.
- Creep and Relaxation of Nonlinear Viscoelastic Materials. Findley W.N., Lai J.S., Onaran K. Dover Publications, 1989.
- The Theory of Viscoelasticity. Christensen R.M. Dover Publications, 2003.
- Contact Mechanics, Johson K.L. Cambridge University Press, 2012.
- Beams, plates, and shells. Donnell L.H. McGraw-Hill Book Co, 1976.
- Computational Inelasticity. Simo J.C. and Hughes T.J.R. Springer, 1998.

PRE-REQUISITES: Graduate student standing, Second Semester Senior Standing, Solid Mechanics I (or equivalent course in elasticity)

COORDINATING FACULTY: Solid Mechanics Area Faculty

COURSE OUTCOMES:

1. Select the most appropriate theory for modeling a particular material and structure in a given application and outline the variables and general parameters needed, as well as limitations of the chosen theory. [1, 2, 7]
2. Depending on instructor, more advanced outcomes are expected in particular subjects, for example [1, 2, 7]:
   - Formulate and evaluate the stress-strain response of a (i) hyperelastic material, (ii) a viscoelastic material, (iii) a plastic material.
   - Formulate and evaluate the internal resultant versus kinematic variable response of (i) beams, (ii) plates, and (iii) shells.
   - Formulate and evaluate the contact force (pressure) between (i) smooth non-conforming deformable surfaces (e.g., spherical objects), (ii) a rigid object on a deformable substrate (e.g., indentation), (iii) fluid-solid interfaces, for elastic solids (and/or rate-dependent solids and/or plastic solids).
3. Use solid mechanics principles to interpret and analyze the mechanical behavior of advanced engineering structures. [1,2,3,7]

COURSE DESCRIPTION: The design of modern engineering structures is intrinsically linked to the understanding and analysis of materials and structures. This course is a foundational course on graduate level knowledge in this area of engineering.

ASSESSMENTS TOOLS:

1. Biweekly homework.
2. One 2-hour mid-term exam.
3. Final project.

RELATED ME PROGRAM OUTCOMES:

1. Engineering fundamentals
2. Engineering design
3. Communication skills
4. Ethical/Prof. responsibilities
5. Teamwork skills
6. Experimental skills
7. Knowledge acquisition

PROFESSIONAL COMPONENT:

1. Engineering Topics: Engineering Science – 3 credits (100%)

NATURE OF DESIGN CONTENT: Comprehend on how to realize engineering systems by use of analysis tools in advanced solid mechanics

COMPUTER USAGE: Students are expected to appropriately choose from spreadsheets, symbolic math packages.

COURSE STRUCTURE/SCHEDULE:

1. Lecture – 2 days per week at 75 minutes.

PREPARED BY: Solid Mechanics Area Faculty **REVISION DATE:** September, 2021

ME 597 – SOLID MECHANICS II

INSTRUCTOR

Prof. Marcial Gonzalez
e-mail: marcial-gonzalez@purdue.edu
Office hours by appointment.
Room: WANG 4048

LECTURES

Tuesday and Thursday: 10:30 to 11:45 a.m.
Room: PHYS 201

COURSE INFORMATION

All relevant materials (i.e., course syllabus, homework assignments, lecture slides, homework solutions) will be posted on Brightspace.

GRADING

Homework assignment: 30% Exam: 40% Final project: 30%

Your course grade will be based on a straight grading scale: 97-100% A+; 93-97% A; 90-93% A-; 87-90% B+; 83-87% B; 80-83% B-; 77-80% C+; 73-77% C; 70-73% C-; 67-70% D+; 63-67% D; 60-63% D-; <60% F. It is possible that, depending on the class averages at the end of the semester, the grade cutoffs can be adjusted *slightly downward*. However, the grades in this course are *not curved* with intent of satisfying particular preset grade distribution goals.

Homework assignments
Typically, one homework set will be due every week, except for weeks during which exams are given or the final project is reviewed. Homework must be submitted by 5 p.m. (EST) on Friday unless otherwise posted. Please post your HW on Gradescope on the appropriate HW link using a **single** PDF file (you will be asked to prescribe which page(s) each problem is on in Gradescope). Late HW will not be accepted without a personalized excuse (i.e., a generic PUSH note is not sufficient). Please review your homework submission after it has been uploaded onto Gradescope to ensure that all work has been properly submitted. If for some reason you have problems posting your HW on Gradescope, please email the instructor the PDF of your HW before the 5 p.m. (EST) deadline with an explanation. Your work needs to be presented with a logical thought process and in a neat, easy-to-read style. Failure to do so can result in a loss of points in your homework grade.

Exam
One in-class midterm exam, closed book, closed notes March 28th, Time/Room (TBD)
No final exam.

Final project
- Research oriented.
- Evaluated based on weekly progress, a final video presentation, and a final written report.
- Details will be given during the semester.

ELECTRONIC DEVICES

You are asked to not use electronic communication devices during class time (this includes reading/sending text messages and using a laptop computer for other than taking class notes). Please turn off cell phones before coming to class and put away your cell phone before the start of class.

ACADEMIC DISHONESTY POLICY

Faculty and students working together can promote a fair and positive academic environment. All students are expected to conduct themselves in an ethical manner. Students are permitted to discuss assignments together but should do their own work when preparing a lab memo (i.e., *copying of an on-line resource, or another student's work, is explicitly prohibited*).

Any student caught cheating on an assignment will receive disciplinary action, up to and including receiving a grade of "F" for the course. In addition, documentation of the infraction will be forwarded to the Office of the Dean of Students (ODOS), which may result in additional disciplinary sanctions, up to and including expulsion from the University. All of us are equally responsible for ensuring a fair and positive environment. If you become aware of any dishonest activities, please report the infractions to the instructors (anonymously if you prefer) and we will investigate the concerns. If there is sufficient evidence of academic dishonesty, we will take disciplinary action. Finally, remember if you are complicit in assisting a peer to cheat, you are equally guilty. Please take to heart Purdue's Honor Pledge:

"As a boilermaker pursuing academic excellence, I pledge to be honest and true in all that I do. Accountable together - we are Purdue."

ATTENDANCE

Attendance is expected for all class meetings. *If you are unable to attend on any day, please contact your instructor prior to the class meeting time via email*. Failure to do so will give you an *unexcused absence* for the day; an unexcused absence will result in a reduction in the points used in calculating your course grade. You are responsible for all course material on any dates that you are absent.

Only the instructor can excuse a student from a course requirement or responsibility. When conflicts can be anticipated, such as for many University-sponsored activities and religious observations, the student should inform the instructor of the situation as far in advance as possible so that alternate arrangements may be made. For unanticipated or emergency conflict, when advance notification to an instructor is not possible, the student should contact the instructor as soon as possible by email. For cases that fall under **excused absence regulations**, you or your representative should contact or go to the Office of the Dean of Students (ODOS) website to complete appropriate forms for instructor notification. Under academic regulations, excused absences may be granted by ODOS for cases of grief/bereavement, military service, jury duty, parenting leave, or emergent medical care. The processes are detailed, so plan ahead.

LEAVING CLASS

You are expected to arrive to class on time and remain in the classroom throughout the class period. If you have a medical condition that requires you to step out of the room during the class period, please see your instructor at the start of the term. Otherwise, please plan ahead so that you do not need to take breaks in the middle of class.

STUDENTS WITH DISABILITIES

If you have a disability that requires special academic accommodation, please make an appointment to speak with your instructor within the first week of the semester to discuss any adjustments and bring your accommodation letter from the Disability Resource Center. *It is important that we are informed about this at the beginning of the semester*. It is the student's responsibility to notify the Disability Resource Center (http://www.purdue.edu/drc) of an impairment/condition that may require accommodations and/or classroom modifications. If a student does not notify their instructor well in advance about the need for accommodations, there may not be time to arrange some accommodations.

MENTAL HEALTH/WELLNESS

If you find yourself beginning to feel some stress, anxiety and/or feeling slightly overwhelmed, try WellTrack**.** Sign in and find information and tools at your fingertips, available to you at any time.
If you need support and information about options and resources, please contact or see the Office of the Dean of Students. Call 765-494-1747. Hours of operation are M-F, 8 am- 5 pm.

If you find yourself struggling to find a healthy balance between academics, social life, stress, etc., sign up for free one-on-one virtual or in-person sessions with a Purdue Wellness Coach at RecWell. Student coaches can help you navigate through barriers and challenges toward your goals throughout the semester. Sign up is free and can be done on BoilerConnect.

If you're struggling and need mental health services: Purdue University is committed to advancing the mental health and well-being of its students. If you or someone you know is feeling overwhelmed, depressed, and/or in need of mental health support, services are available. For help, such individuals should contact Counseling and Psychological Services (CAPS) at 765-494-6995 during and after hours, on weekends and holidays, or by going to the CAPS office on the second floor of the Purdue University Student Health Center (PUSH) during business hours. The CAPS website also offers resources specific to situations such as COVID-19.

CAMPUS EMERGENCIES

In the event of a major campus emergency (e.g., severe weather, active shooter, etc.), course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances. The School of Mechanical Engineering will provide details regarding access to information online and any additional procedures that may be needed as soon as they are available or can be obtained by contacting the instructors or TAs via mail or phone. You are expected to read your @purdue.edu email on a frequent basis.

PURDUE UNIVERSITY | Mechanical Engineering

Prof. Marcial Gonzalez
ME 597 – Solid Mechanics II
Spring 2024

SYLLABUS AND TENTATIVE SCHEDULE

Version: Tuesday, March 19, 2024

Please check the online version
for periodic updates and changes.

Tuesday (10:30 to 11:45 a.m., PHYS 201)	**Thursday** (10:30 to 11:45 a.m., PHYS 201)	**Reading**	**Friday** **5 p.m.**
01/09 (01) Class overview	01/11 (02) Introduction to vectors and tensors	TME-2012 2.1 – 2.6	
01/16 CANCELED	01/18 (03) Kinematics of deformations	TME-2012 3.1 – 3.5	HW1a posted
01/23 (04) Kinematics of deformations	01/25 (05) Conservation and balance laws	TME-2012 4, 5.1, 5.6	HW1a due HW1b posted
01/30 (06) Thermodynamics	02/01 (07) Constitutive relations | Coleman-Noll proc.	TME-2012 6.1 – 6.2	HW1b due
02/06 (08) Hyperelastic solids	02/08 (09) Hyperelastic solids	H-2000 6.2 – 6.4	HW2a posted
02/13 (10) Viscoelastic solids	02/15 (11) Viscoelastic solids | Internal variables	H-2000	HW2a due HW2b posted
02/20 (12) Material parameter estimation	02/22 (13) Plasticity | Internal variables	L-1990 Ch.2-3	HW2b due HW3a posted
02/27 (14) Plasticity | J2 or von Mises	02/29 (15) Plasticity | Mohr-Coulomb, Drucker-Prager	L-1990 Ch.2-3	HW3a due HW3b posted
03/05 (16) Solid-solid interactions | Contact mechanics	03/07 (17) Solid-solid interactions | Contact mechanics	J-2012 Ch. 4	HW3b due HW4a posted
SPRING VACATION	SPRING VACATION		
03/19 (18) Guidelines for special project	03/21 (19) Midterm Prep		HW4a due HW4b posted
03/26 (20) Structural elements | Beams, plates, shells	03/28 EXAM Time/Room: MSEE B010, 6-8PM		
04/02 Project progress report #A1 (presentation)	04/04 Project progress report #A2 (presentation)		HW4b due HW5a posted
04/09 Project progress report #A3 (presentation)	04/11 (21) Structural elements | Beams, plates, shells		HW5a due 4/15 HW5b posted
04/16 Project progress report #C1 (presentation)	04/18 Project progress report #C2 (presentation)		
04/23 Project progress report #C3 (presentation)	04/25 (22) Fluid-solid interactions		HW5b due
Week of 04/29 Time (TBD): Final project report and video submission.			

[TME-2012] Tadmor E.B., Miller R.E., Elliot R.S., "Continuum Mechanics and Thermodynamics", Cambridge University Press, 2012.
[H-2000] Holzapfel G.A., "Nonlinear Solid Mechanics", Wiley, 2000.
[J-2012] Johnson K.L., "Contact Mechanics", Cambridge University Press, 2012.
[L-1990] Lubliner J., "Plasticity Theory", Dover Reprint, 1990.