Spring, 2015

ME 612 – Continuum Mechanics

Lecture 1 – Class Overview

Instructor: Prof. Marcial Gonzalez

General information

Instructor:

- Professor Marcial Gonzalez
- ME 3061M, marcial-gonzalez@purdue.edu
- Office hours:

  Monday and Wednesday: 9 a.m. to 10 a.m.
  By appointment, ME 3061M

Lectures:

- Tuesday and Thursday: noon to 1:15 p.m.
- Room: ME 1009

Class website:

- www.itap.purdue.edu/learning/tools/blackboard

General information

Emergency preparedness:

- To report an emergency, **call 911**. To obtain updates regarding an ongoing emergency, **sign up for Purdue Alert text messages**, www.purdue.edu/ea
- There are nearly 300 **Emergency Telephones** outdoors across campus and in parking garages that connect directly to the PUPD. If you feel threatened or need help, push the button and you will be connected immediately.
- If we hear a **fire alarm** during class we will immediately suspend class, evacuate the building, and proceed outdoors. Do not use the elevator.
- If we are notified during class of a **Shelter in Place requirement for a tornado** warning, we will suspend class and shelter as indicated--take a look after class.
- If we are notified during class of a **Shelter in Place requirement for a hazardous materials release, or a civil disturbance**, including a shooting or other use of weapons, we will suspend class and shelter in the classroom, shutting the door and turning off the lights.
- Please **review the Emergency Preparedness website** for additional information. www.purdue.edu/ehps/emergency_preparedness/index.html

General information

Getting to know each other:

- Please note that the questionnaire is anonymous and data will only be used in aggregate form.

ME 612 – Continuum Mechanics
Spring Prof. Marcial Gonzalez

FRIST DAY OF CLASS QUESTIONNAIRE

This questionnaire is anonymous and data will only be used in aggregate form.

1. What is your background?

- ☐ Aeronautical/Aerospace Engineering
- ☐ Biological/Biomedical Engineering
- ☐ Chemical Engineering
- ☐ Civil Engineering
- ☐ Mechanical Engineering
- ☐ Materials Engineering
- ☐ Other _____

2. What is your current status in the graduate program?

☐ _____ year M.S. student ☐ _____ year Ph.D. student

Department: _____

3. What is your background in continuum mechanics?

(none) 1 2 3 4 5 (strong)

Provide a short description (e.g., took classes, taught classes, conducted research):

4. Why are you taking this class?

General information

Homework:

- Biweekly homework sets.
- Posted online every other Friday by 5 p.m.
- Due to every other Friday by 5 p.m. in ME 3061.
- You can discuss homework problems with others, including me, but the work has to be an <u>individual</u> work.
- Late homework won't be accepted.
  In case of illness or conference travel, arrange extensions with me in advance.

Academic integrity:

- Purdue 'Statement of Integrity and Code of Conduct':
  www.purdue.edu/purdue/about/integrity_statement.html
- Please take the time to read it carefully and talk with me if you have any questions.

General information

Exams:

- One in-class midterm exam, April 2nd, closed book, closed notes.
- No final exam.

Project:

- Research oriented.
- You will be evaluated based on your weekly progress, a final presentation and a final written report.
- Details will be given during the semester.

Grading:

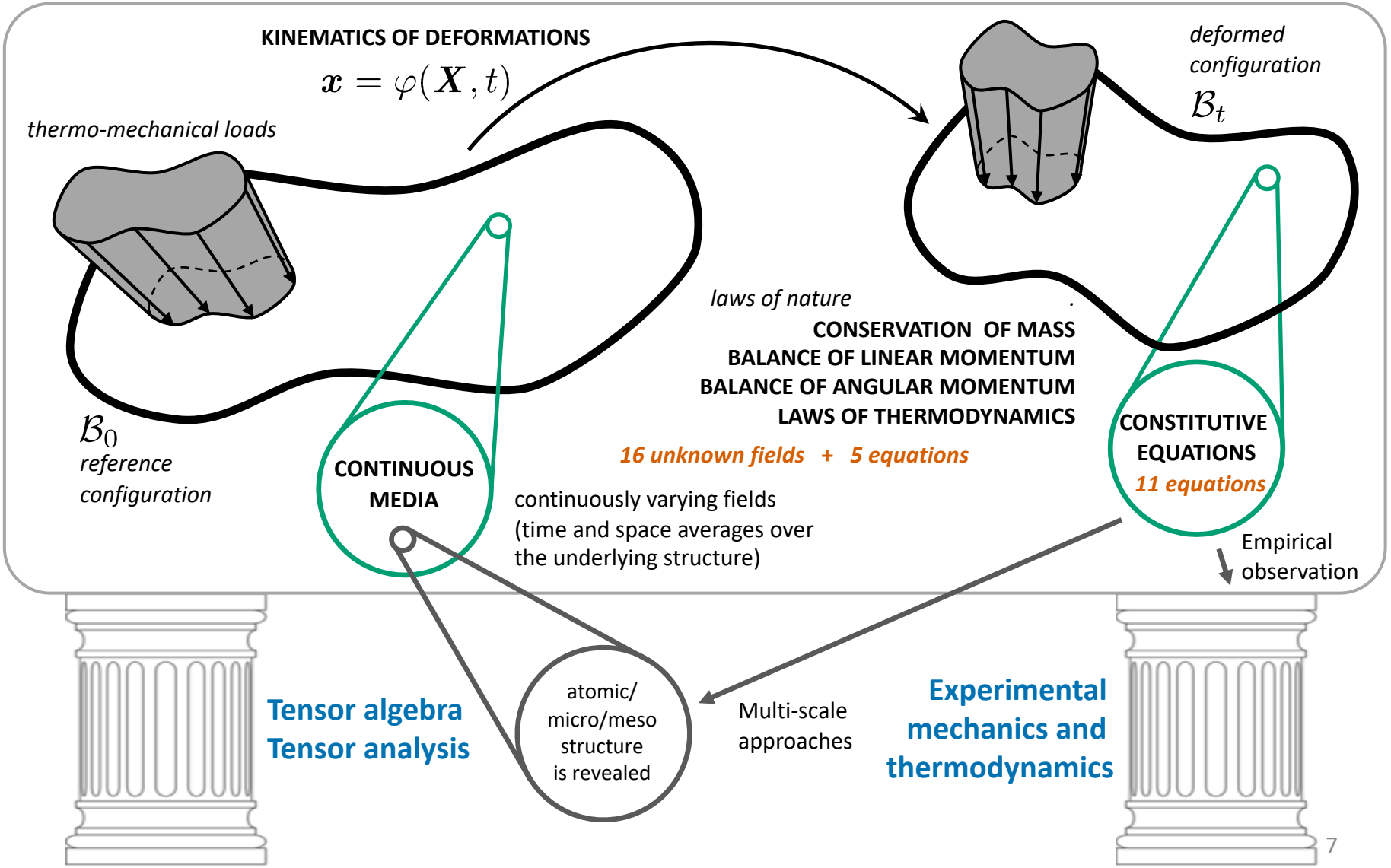
- Homework (30%), midterm exam (40%), final project (30%)

  Note: 5 HWs, 6 pts. each.

- Grades are not curved.

  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

Continuum mechanics and thermodynamics

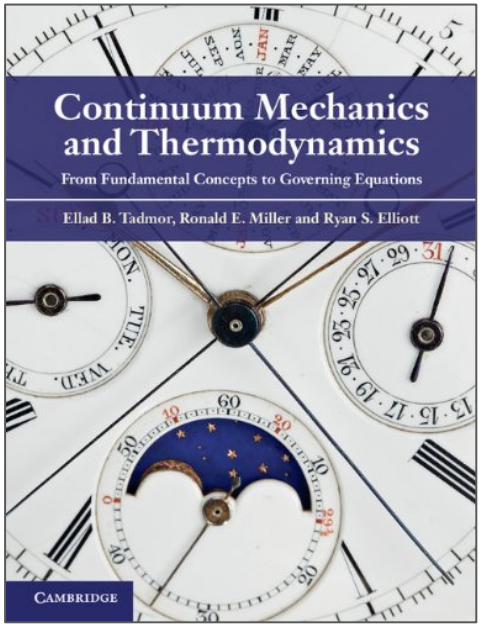


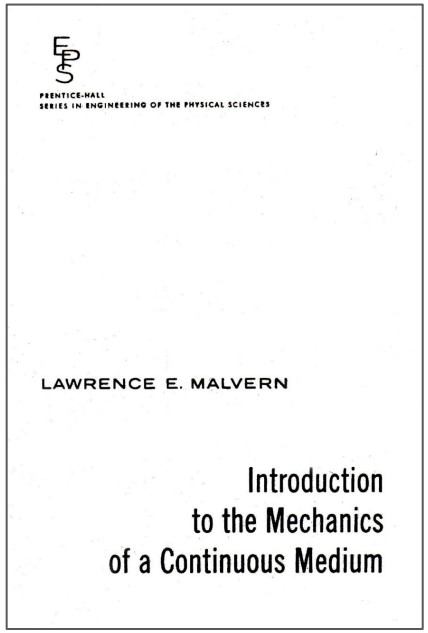
ME 612 – Course outline - Syllabus

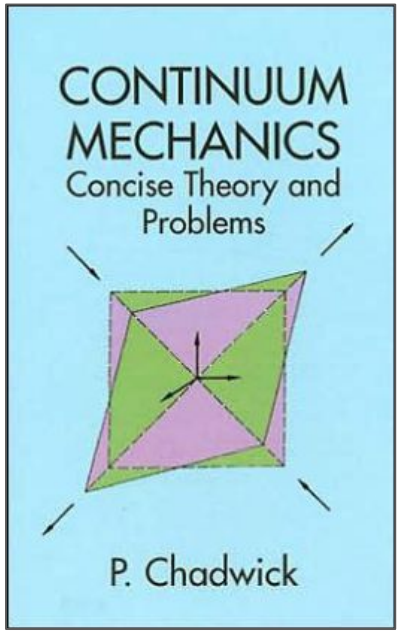
- Tensor algebra and tensor analysis
- Kinematics of deformations
- Mechanical conservation and balance laws
- Thermodynamics
- Constitutive relations
- Energy principles and stability

Suggested reading

Let me know if you want to leaf through a book before buying it



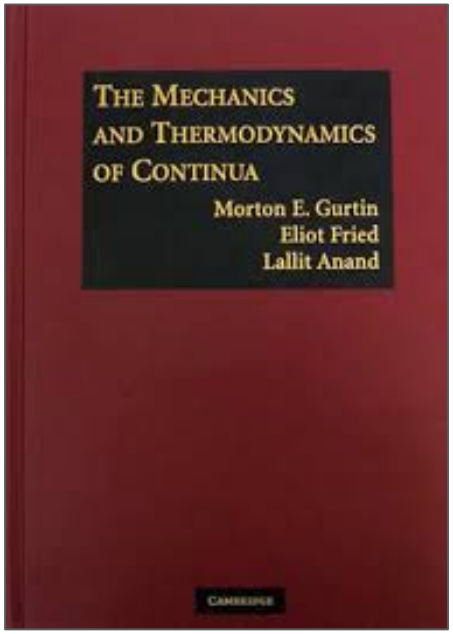


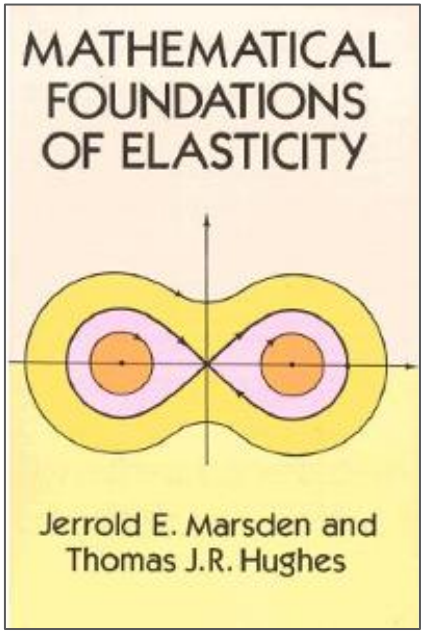


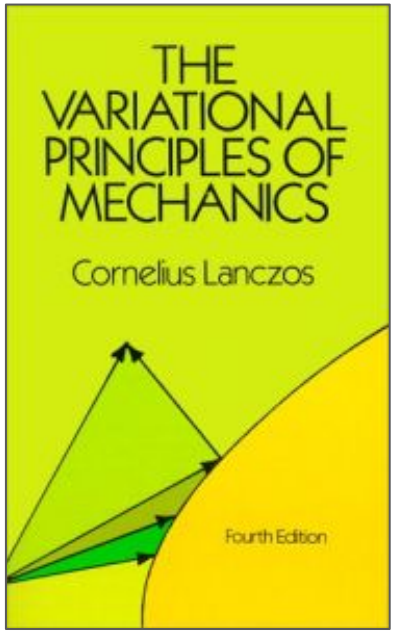
- Tadmor E.B., Miller R.E., Elliot R.S., "Continuum Mechanics and Thermodynamics", Cambridge University Press, 2012. → *This book will be on reserve under ME 612 at the Engineering Library*
- Malvern L.E., "Introduction to the Mechanics of a Continuous Medium", Prentice Hall, 1969.
- Chadwick P., "Continuum Mechanics - Concise Theory and Problems", Dover Reprint, 1976.

Further reading

Let me know if you want to leaf through a book before buying it

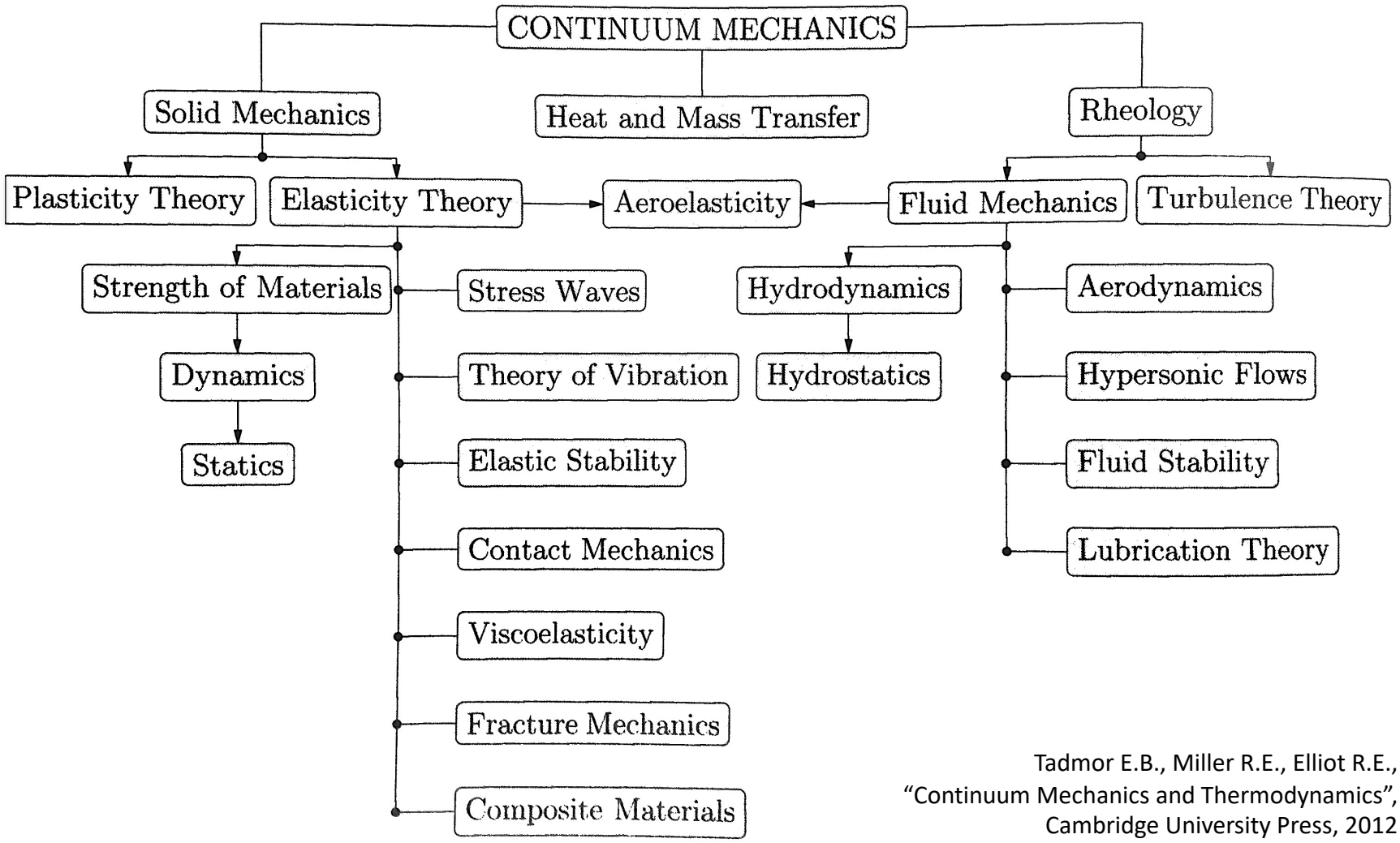






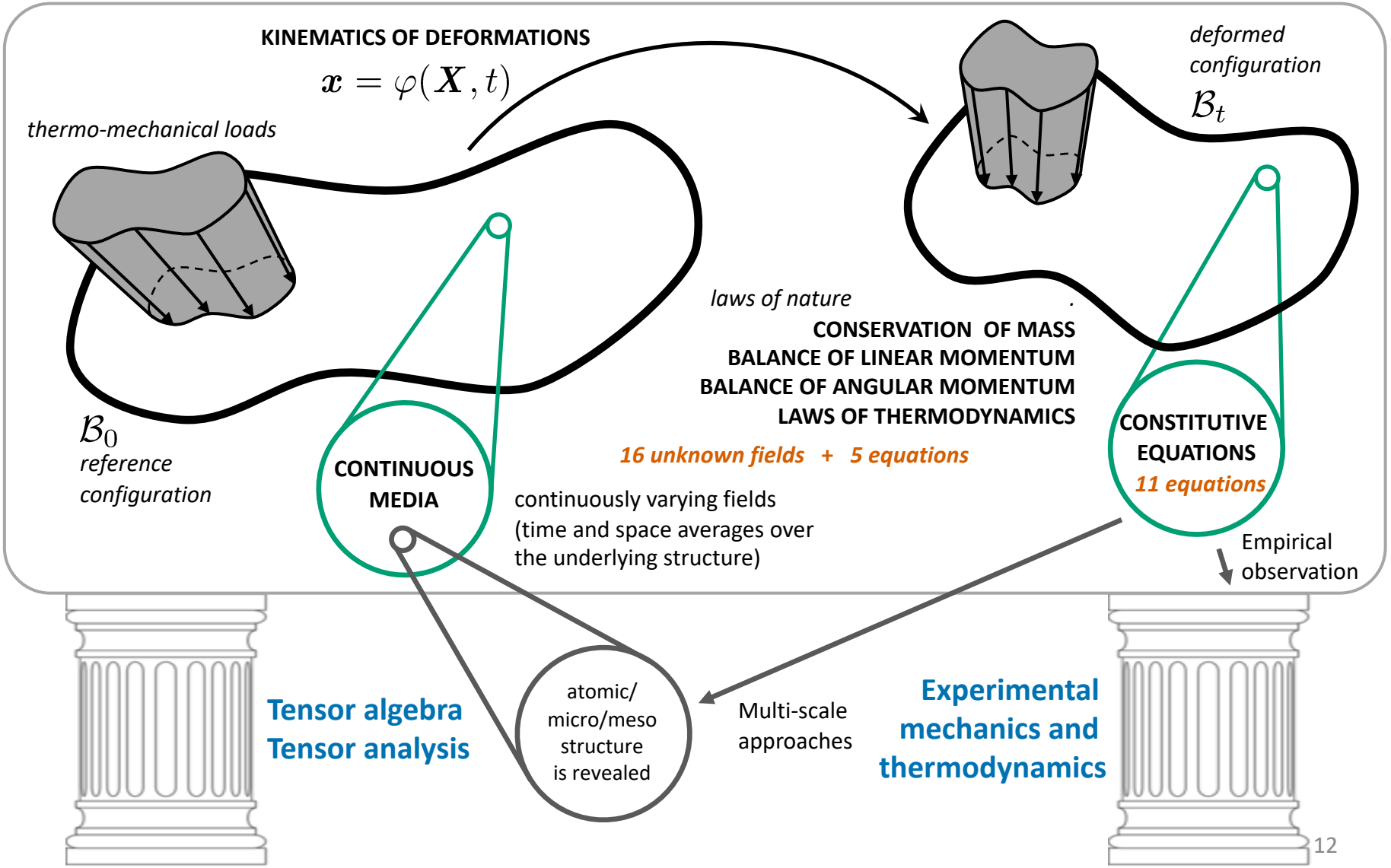
- Gurtin M.E., Fried E., Anand L., “The Mechanics and Thermodynamics of Continua”, Cambridge University Press, 2010.
- Marsden J.E., Hughes T.J.R., “Mathematical Foundations of Elasticity”, Dover Reprint, 1983.
- Lanczos C., “The Variational Principles of Mechanics”, Dover Reprint, 1970.

CM as a 'grand unifying theory' of engineering science



Tadmor E.B., Miller R.E., Elliot R.E.,
"Continuum Mechanics and Thermodynamics",
Cambridge University Press, 2012

CM as a 'contextual framework' for current research



Content and structure of the lectures

Before class:

- It is recommended that you read the suggested material.
- Lecture slides will be posted online on *Blackboard.*

During class:

- Bring a printout of the slides with you.
- Lecture notes are not self-explanatory.
- We will work out some problems and derivations together …

  DIY "Do It Yourself"

  …. 'we will work out the solutions and derivations together'

DIY

$$\nabla s = \frac{\partial s(\underline{x})}{\partial x_j} \underline{e}_j$$

$$\nabla \underline{v} = \frac{\partial \underline{v}}{\partial x_j} \otimes \underline{e}_j = \frac{\partial (v_i \underline{e}_i)}{\partial x_j} \otimes \underline{e}_j = \frac{\partial v_i}{\partial x_j} \underline{e}_i \otimes \underline{e}_j$$

$$\nabla \underline{\underline{T}} = \frac{\partial \underline{\underline{T}}}{\partial x_k} \otimes \underline{e}_k = \frac{\partial \left[T_{ij} (\underline{e}_i \otimes \underline{e}_j) \right]}{\partial x_k} \otimes \underline{e}_k =$$

$$= \frac{\partial T_{ij}}{\partial x_k} (\underline{e}_i \otimes \underline{e}_j \otimes \underline{e}_k)$$

$$\operatorname{div} \underline{v} = \frac{\partial \underline{v}(\underline{x})}{\partial x_k} \cdot \underline{e}_k \overset{?}{=} \left(\nabla \underline{v}(\underline{x}) \right) : \underline{\underline{I}} =$$

$$= \frac{\partial v_i}{\partial x_j} (\underline{e}_i \otimes \underline{e}_j) : \left(\delta_{mn} \underline{e}_m \otimes \underline{e}_n \right)$$

$$= \frac{\partial v_i}{\partial x_j} \cdot \delta_{mn} \delta_{im} \delta_{jn} = \frac{\partial v_j}{\partial x_i}$$

- Most importantly: **Actively participate in class!**

Goal and structure of the homework sets

Goal:

- Facilitate a deeper understanding of the course material.
- Give you feedback on your learning and help prepare you for the exam.
- Give *me* feedback on your learning and help *me* better prepare you for the exam.
  Another good reason for enforcing individual work on homework assignments.

Structure:

- A mix of theoretical (proof-based problems) and practical problems (algebra-based problems).
- Provide reasoning and justification for each step in your solution (regardless the type of problem).
  You will be graded on the quality of these steps.
- Advice: start working on the homework set as soon as it is posted!

Tentative schedule

Tuesday (noon to 1:15 p.m., ME 1009)	Thursday (noon to 1:15 p.m., ME 1009)	HW (Friday, 5 p.m., ME 3061)
01/13 - (01) Overview	01/15 - (02) Introduction to vectors and tensors	-
01/20 - (03) Introduction to vectors and tensors	01/22 - (04) Introduction to vectors and tensors	HW1 posted
01/27 - (05) Kinematics of deformations	01/29 - (06) Kinematics of deformations	-
02/03 - (07) Conservation and balance laws	02/05 - (08) Conservation and balance laws	HW1 due - HW2 posted
02/10 - (09) Conservation and balance laws	02/12 - (10) Thermodynamics	-
02/17 - (11) Thermodynamics	02/19 - (12) Discontinuity surfaces	HW2 due - HW3 posted
02/24 - (13) Constitutive relations	02/26 - (14) Constitutive relations	-
03/03 - (15) Constitutive relations	03/05 - (16) Constitutive relations	HW3 due - HW4 posted
03/10 - (17) Constitutive relations	03/12 - (18) Constitutive relations	-
03/17 - (19) Constitutive relations	03/19 - Midterm Prep (noon to 12:45 p.m.)	HW4 due
SPRING VACATION	SPRING VACATION	
03/31 - (20) Guidelines for special project	**04/02 - MIDTERM (noon to 2 p.m.) Room TBD**	-
04/07 - (21) Energy principles and stability	04/08 - Project progress report #1 (presentation)	-
04/14 - (22) Energy principles and stability	04/16 - Project progress report #2 (presentation)	HW5 posted
04/21 - (23) Constitutive relations	04/23 - Project progress report #3 (presentation)	-
04/28 - (24) TBD	04/30 - Project progress report #4 (presentation)	HW5 due
Week of 05/04 - Final project report and presentations		

Class overview

Any questions?

Spring, 2015

ME 612 – Continuum Mechanics

Lecture 1 – Notation and Nomenclature

Instructor: Prof. Marcial Gonzalez

Notation and nomenclature

Direct notation:

- Examples of physical properties

mass (scalar)	velocity (vector)	stress (tensor)
m	$\boldsymbol{v}$	$\boldsymbol{\sigma}$

- Examples of algebraic operations

$$\boldsymbol{a} \cdot \boldsymbol{b} \qquad \boldsymbol{a} \times \boldsymbol{b}$$

DIY

How are we going to follow this nomenclature on the blackboard or in the homework problems?

Notation and nomenclature

Indicial notation:

- Examples of physical properties

mass (scalar)	velocity (vector)	stress (tensor)
m	v_i	σ_{ij}

$i \in \{1, 2, ..., n_\mathrm{d}\}$

- Examples of algebraic operations

$$\boldsymbol{a} \cdot \boldsymbol{b} = \sum_{i=1}^{n_\mathrm{d}} a_i b_i = a_i b_i$$

Einstein's summation convention or summation convention (i is *dummy index*)

- Many times, it is convenient to store the components of a vector or a tensor in a column or a matrix.

DIY

$[\boldsymbol{v}] =$ $[\boldsymbol{\sigma}] =$

Notation and nomenclature

Indicial notation:

- Dummy indices and free indices

$$\sigma_{ij} n_j = t_i$$

i free index

j dummy index

DIY

$$\boldsymbol{\sigma n} = \boldsymbol{t}$$

Notation and nomenclature

Indicial notation:

- Kronecker delta

$$\delta_{ij} = \begin{cases} 1 & \text{if} \quad i = j \\ 0 & \text{if} \quad i \neq j \end{cases}$$

DIY

$a_i \delta_{ij} = a_j$ (index substitution)

Notation and nomenclature

Indicial notation:

- Permutation symbol

$$\epsilon_{ijk} = \begin{cases} 1 & \text{if } i,j,k \text{ form an even permulation of 1,2,3} \\ -1 & \text{if } i,j,k \text{ form an odd permulation of 1,2,3} \\ 0 & \text{if } i,j,k \text{ do not form a permulation of 1,2,3} \end{cases}$$

DIY

$$\boldsymbol{a} \times \boldsymbol{b} = \boldsymbol{c} \quad \text{with} \quad c_k = \epsilon_{ijk} a_i b_j$$

Notation and nomenclature

Any questions?