Fall 2019

ME 614-101: Continuum Mechanics

I. Joga Rao

ME-614
Continuum Mechanics
Fall 2019

Course Instructor

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Office Hours: Tue, Thur 11:00AM to 12PM

Course Content

This course is designed to provide first year graduate students with a general introduction to the fundamentals of the mechanics of continuous media. The specific topics covered will include vector and tensor analysis, kinematics associated with finite deformation, the stress tensor, the balance laws of mechanics, i.e., the conservation of mass, linear momentum, angular momentum and energy. In addition, the course will discuss constitutive equations for linear and non-linear elastic solids and Newtonian fluids. The role of material invariance under superposed rigid body motion will be emphasized.

Course Audience

The course is for graduate students in Mechanical, Civil and Biomedical Engineering and students of Applied Mathematics.

Course Objectives

At the end of the course, the student should be proficient in the following

1. Able to use Cartesian tensors and vectors in three dimensions, using both index and bold face notation.
2. Understand the relationship between the surface tractions and the stress tensor.
3. Be able to derive and use the basic kinematics relationships associated with a body undergoing large deformations.
4. Grasp the importance of the basic conservation laws and their use to solve practical problems.
5. Understand the concept of a constitutive equation and know the assumptions made in connecting the stress to the appropriate kinematic quantities.
6. Be able to use invariance requirements to achieve restrictions of the constitutive equations.

Prerequisites

Undergraduate mechanics, mathematics (linear algebra, differential equations and vector calculus) and familiarity with elementary theories of fluids and solids that are typically covered in undergraduate fluids and solid mechanics courses.

Recommended Text

Hozapfel, G. A., *Nonlinear Solid Mechanics: A Continuum Approach for Engineering*, John Wiley & Sons, New York, 2000.

Reference

Chadwick, *Continuum Mechanics*, Dover, New York, (1999).
Spencer, *Continuum Mechanics*, Dover, New York (1980)
Malvern, *Introduction to the Mechanics of a Continuous Media*, Prentice Hall, NJ, 1977.
Bowen, *Introduction to Continuum Mechanics for Engineers* (Mathematical Concepts and Methods in Science and Engineering, 39), New York: Plenum Press (1989), revised 2007. Available for free at the following website: http://rbowen.tamu.edu/

Grading

Two in semester exams 25% each. Group Homework (assigned weekly) (15%) and a final (35%).

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Course Outline

1. Introduction

2. Mathematical Preliminaries (2 weeks)
   - Vectors and vector spaces.
   - Tensors in a three-dimensional Euclidean space, relationship between matrices and tensors.
   - Index notation, Einstein's summation convention.
   - Review of eigenvalues and eigenvectors. Polar decompostions.
   - Vector and tensor calculus.

3. Kinematics (4 weeks)
   - Bodies, configurations and motions.
   - Material time derivative, Eulerian and Lagrangian representation of velocities and accelerations.
   - Displacement, deformation gradient, polar decomposition of deformation gradient: stretch and rotation.
   - Transformation of line elements, area elements and volume elements. Material time derivatives of area and volume elements.
   - Eulerian and Lagrangian measures of strain, linearized measures of strain, rigid body motions.
   - Stretch, shear and spin, velocity gradient tensor.

Exam 1 (25%)

4. Conservation Principles (3 weeks)
   - Reynolds transport theorem
   - Conservation of mass
   - The concept of stress, Euler's axioms, existence of the stress tensor.
   - Conservation of linear and angular momentum
   - Balance laws and stresses in the reference configuration
   - Conservation of energy.

Exam 2 (25%)

5. Constitutive Theories (3 weeks)
   - Invariance requirements due to superposed rigid body motions.
   - Transformation of kinematic quantities, tractions and stresses under superposed rigid body motions.
   - Inviscid Fluids.
   - Viscous Fluids.
   - Non linear elastic solids.
   - Linear elastic solids.

6. Review. (Last class)

Final Exam (35%)

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POLICIES AND PROCEDURES

- **Homework** will be assigned weekly and is due a week later before class. *Unless the assignment specifies otherwise, you must work in teams of three or four, handing in one team solution per assignment.* The instructor will designate the teams.
- **Team Roles**. On each group assignment, your team should designate a coordinator to organize work sessions, make sure everyone knows where and when to meet and understands who is supposed to be doing what. A *recorder* to prepare and turn in the final solution set, and one or two *checkers* to check the solution for correctness and verify that everyone in the group understands both the solutions and strategies used to obtain them. The team roles must rotate on every assignment—once a team member has carried out a role, he/she may not do it again until everyone else on the team has done it.
- **Homework format**. Each completed homework should be in one person's handwriting (the recorder's). Put the names and roles (coordinator, recorder, checker) of *participating* group members and the problem set number and date on the outside. *If a student's name appears on a solution set, it certifies that he/she has participated in solving the problems*.
- **Late homework**. Completed assignments should be turned in at the beginning of class on the due date. Solution sets will be accepted up to one week after the due date. Late assignments will receive a maximum grade of 50%. *However, once a group hands in several late assignments, they will no longer be accepted.*
- **Posted solutions.** *Problem set solutions will not be posted*. The burden is on you to make sure you find out how to solve the problems by getting help before they are due and/or asking about them in class after they have been handed in.
- **Individual effort assessments for team homework**. All students will be periodically asked to submit evaluations of how well they and their teammates performed as team members (see hand out). These evaluations will be incorporated into the assignment of homework grades. *If repeated efforts to improve team functioning (including faculty intervention) fail, a non-participant may be fired by unanimous consent of the rest of the team, similarly a team member essentially doing all the work of the team may quit.* Individuals who quit or are fired must find a team of three unanimously willing to accept them; otherwise they will receive zeros for the remainder of the homework.
- **Tests**. There will be two in semester exams and a comprehensive final exam. You can only miss an exam with either a certified medical excuse (through the office of the Dean of Students) or prior instructor approval. Exams missed with certified medical excuses or prior instructor approval will be dealt with individually. If you miss any test without a valid excuse, a zero will be averaged into your grade.
- **Calculation of course grade.** A weighted average grade will be calculated as follows: Two in semester exams-25%; each (50% total), final examination-35%; homework-15%. **A weighted grade of 88 or above is guaranteed a course grade of A, 78 or above = B+, 70 or above = B, 60 or above = C+, 50 or above = C**
  Note: The grades will not be curved in this course. It is theoretically possible for everyone in the class to get an A (or an F). Your performance depends only on how you do, not on how everyone else in the class does. It is therefore in your best interests to help your classmates in every legal way possible.

Consulting with faculty. You are strongly encouraged to discuss academic matters with the course instructor during office hours, by email or by appointment.

NJIT Honor Code and Professional Conduct will be Strictly Enforced.

"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"*