ME 521, Continuum Mechanics
BE 521, Continuum Mechanics for Biomedical Engineers
Fall 2019, MW, 12:20-2:05 pm (PSY B51)

Instructor:

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EMA 220
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Office hours: Thurs 12:30-1:30pm, or by appointment

Course Description:

The main goal of this course is to present a unified, mathematically rigorous approach to two classical branches of mechanics: the mechanics of fluids and the mechanics of solids. Topics will include kinematics, stress analysis, balance laws (mass, momentum, and energy), the entropy inequality, and constitutive equations in the framework of Cartesian vectors and tensors. Emphasis will be placed on mechanical principles that apply to all materials by using the unifying mathematical framework of Cartesian vectors and tensors. Illustrative examples from materials, biology and physiology will be used to describe basic concepts in continuum mechanics. The course will end at the point from which specialized courses devoted to problems in fluid mechanics (e.g. biotransport) and solid mechanics (e.g. cellular biomechanics) could logically proceed. 4 credits.

Textbook: Lai, Rubin, & Krempl. 2009 Introduction to Continuum Mechanics, 4th Edition, Elsevier. [This book was selected because it is (1) well written and (2) **available for free** online from our library].

Prerequisites:

1) Two semesters of undergraduate mechanics of solids and/or fluids.
2) Advanced calculus and vectors. Familiarity with linear algebra is very useful.

Grading:

The final grade for the course is based on written homework solutions, a few short quizzes, a lab report, participation in class, and a final paper (12-15 pages) with a very short in-class presentation. Collaboration between students in discussing homework problems is okay, but students must turn in their own individual work. Final papers should integrate theory and empirical research in a topic of your choice related to continuum mechanics.

Incompletes and Withdrawals:

Incompletes will be given to students making good academic progress (C or better) who have a compelling reason for being unable to complete the course schedule. Students may withdraw from the course prior to the University's deadline for doing so. After the last day of class, no student will be allowed either an incomplete or the right to withdraw. Students who observe special religious holidays or who may have a conflict with the discussions or lectures, please let me know in advance in order to reschedule the discussions. You will be assessed on the accurate representation of literature, evidence of analyzing the literature rather than merely describing it, and the clarity of presentation of your thoughts. Proposal will be due end of October, and final paper/presentation will be due on the penultimate and final days of class, respectively.

Topics:
1. Vectors and tensors (2 weeks): algebra of vectors and tensors (index notation, products, calculus of vectors and tensors). These concepts will be explained using Cartesian coordinates

2. Kinematics of deformation and motion (3 weeks): deformation gradient, stretch, strain, rotation, shear, rigid motion, local and global length, area and volume changes, principal strains and principal directions, strain deviators, material and spatial time derivatives, flow-lines, stretching, vorticity, transport theorems, circulation

3. Stress analysis (2.5 weeks): surface and body forces, traction and stress (Cauchy theorems, normal and shear stress, hydrostatic and deviatoric stress, principal stresses, Piola-Kirchhoff stress)

4. Field equations (3 weeks): conservation of mass, balance of linear and angular momenta, balance of energy, principle of virtual work, entropy inequality. Some of these concepts will be illustrated through examples (e.g. stress distribution in solids due to gravity, hydrostatic stress distribution in fluids, etc.)

5. Constitutive equations (2.5 weeks): basic principles (determinism, local action, material frame indifference); material symmetry (isotropy); Hookean solids and Newtonian fluids. Thermomechanics and viscoelasticity.