BE 521, Continuum Mechanics for Biomedical Engineers

AM 521, Continuum Mechanics

Fall 2009, Tue/Thu, 2–4 pm

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 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.

Prerequisites

EK 424 or AM 308 and either BE 420, BE 436, AM 420, AM 422, EK 304 or consent of instructor.

Textbooks

- Holzapfel, G.A. 2000 *Nonlinear Solid Mechanics*, John Wiley & Sons, Inc.
- Panton, R.L. 2005 *Incompressible Flow*, John Wiley & Sons, Inc.
- Aris, R. 1989 *Vectors, Tensors, and the Basic Equations of Fluid Mechanics*, Dover.
- Batchelor, G.K. 2000 *An Introduction to Fluid Dynamics*, Cambridge University Press.

Grading

The final grade for the course will be based on homework problems and oral discussions of homeworks. There will be three sets of homework problems (approximately 15 problems per set). Each set will be discussed in a 15–20-minute oral format. The homeworks and the oral discussions will contribute 50% each to the final grade. *Collaboration between students in solving homework problems is NOT recommended!*

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 one of the dates of an oral discussion, please let us know in advance so that it can be rescheduled on an individual basis.

Topics

1. **Vectors and tensors (1.5 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 (4 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-Kirchoff stress)
4. **Field equations (2 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 (3 weeks):** basic principles (determinism, local action, material frame indifference, isotropy), Hookean solids and Newtonian fluids

Instructors

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