ENG BE 533 Biorheology

Dimitrije Stamenović
Tuesday & Thursday, 12 – 2 pm

This is an introductory course whose main goal is to acquaint students with basic concepts of elasticity, viscoelasticity, plasticity, viscoplasticity, poroelasticity and related phenomena that often characterize mechanical behavior of biomaterials. In studying these phenomena, different approaches have been utilized, including methods of continuum mechanics, phenomenological approaches, mathematical modeling and microstructural approaches that relate structural features with the overall behavior. Illustrative examples of application of these methods to studies of various biological solids at the system, organ, tissue, cellular and subcellular levels will be presented. The course provides good foundations for further studies in the areas of rheology, material science, mechanics of solids and cellular and tissue mechanics.

Prerequisites: Knowledge of basic principles in mechanics of solids (BE 420) and fluids (BE 436, ME 303), or continuum mechanics (BE 419, BE/ME 521), or equivalent is required.

Literature (bold texts are closely related to the course topics):

1. **Fung, Y. C. *Biomechanics – Mechanical Properties of Living Tissues*, 2nd edition, Springer: New York, 1993.**
2. Fung, Y. C. Biomechanics – *Motion, Flow and Growth*, Springer: New York, 1990.
3. Fung, Y. C. *Biodynamics – Circulation*, Springer, 1984.
4. Fung, Y. C., N. Perrone, and M. Anliker (editors). *Biomechanics – Its Foundations and Objectives*, Prentice-Hall: Englewood Cliffs, NJ, 1972.
5. Mow, V. C., F. Guilak, R. Tran-Son-Tay, and R. Hochmuth (editors). *Cell Mechanics and Cellular Engineering*, Springer: New York, 1994.
6. **Mofrad, M. R. K., and R. D. Kamm (editors). *Cytoskeletal Mechanics: Models and Measurements*. Cambridge University Press: New York 2006.**
7. M. R. King (editor). *Principles of Cellular Engineering: Understanding the Biomolecular Interface*. Elsevier Academic Press, 2006.
8. Abé, H., K. Hayashi, and M. Sato (editors). *Data Book on Mechanical Properties of Living Cells, Tissues, and Organs*, Springer: Tokyo, 1996.
9. Silver, H. F. *Biological Materials: Structure, Mechanical Properties, and Modeling of Soft Tissues*, New York University Press: New York, 1987.
10. **Ward, I. M. *Mechanical Properties of Solid Polymers*, 2nd edition, Wiley: Chicester, 1983.**
11. Turner, A., Jr. *Mechanical Behavior of High Polymers*, Interscience: New York, 1984.
12. Erich, F. R. (editor). *Rheology – Theory and Applications*, Vol. 1 -, Academic Press, 1956-.

13. Malvern, L. E. *Introduction to Mechanics of a Continuous Medium*, Prentice-Hall: Englewood Cliffs, NJ, 1969.
14. Lazan, B. J. *Damping of Materials and Members in Structural Mechanics*, Pergamon Press: Oxford, 1986.

Lecture Topics:

1. Introduction to rheology.
2. Recap of basic equations of continuum mechanics (kinematics of deformation and stress analysis).
3. Constitutive equations: general theory.
4. Tissue and cell elasticity: continuum approach (linear theory, nonlinear theory, strain energy function, prestress; examples).
5. Tissue and cell elasticity: microstructural approach (microstructural models of living tissues), statistical approach (thermodynamics of elastic deformation, rubber elasticity), examples.
6. Tissue and cell viscoelasticity: phenomenological approach (stress relaxation, creep, hysteresis, frequency and temperature effects), examples.
7. Linear viscoelasticity: continuum approach, lumped models, empirical models (power law, fractional calculus), structural damping, examples.
8. Linear viscoelasticity: microstructural and molecular approach, polymer chain dynamics, examples.
9. Elements of nonlinear viscoelasticity: examples of empirical, semi-empirical and molecular approaches in studies of living tissues.
10. Elements of tissue plasticity and viscoplasticity (permanent deformation, hysteresis, yield stress), empirical and lumped models of plastic and viscopalstic behavior of living tissues.
11. Elements of linear poroelasticity (application to cartilage and cells).

Texting and web surfing during lectures and discussions is prohibited!!!

Course Grade: Based on homework problems and oral defense of homeworks. There will be three sets of homework problems (approximately 15-20 problems per set). Each set is defended in a 20-30 min oral exam. The homeworks and the oral exam contribute 40% each to the final grade. Students will be asked to discuss papers in the class form the literature related to specific topics in the class (20% of the grade).

Incompletes & 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 classes, no student will be allowed either an incomplete or the right to withdrawal. Students who observe special religious holidays or have which may conflict with the oral exams, please let me know in advance in order to reschedule the exams.

Office Hours: Friday 11 am -12 pm.

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