Syllabus for ME 753: Bone Biomechanics

Introduction
Bone Biomechanics is an upper level undergraduate and graduate level course that will allow the student to gain an in-depth knowledge of bone as a living mechanical system. Knowledge of basic mechanics of materials is required, and a knowledge of finite element analysis will be helpful. Class time will be split between instructor lectures and student presentation of reading material (with discussion by all students). Students will be assigned stress analysis homework, will perform basic finite element analyses, and will develop bone remodeling simulations.

Course Rationale
While the topic of bone biomechanics may seem relatively narrow, there is much to learn about bone mechanics that can be applied to other tissues as well. Students will study the microstructure, biology, mechanical properties, and the adaptation of bone to the mechanical environment. Through these studies and mechanical modeling of these systems, the student will gain an appreciation for the intricate design of the human body, and will develop tools that can be applied to the analysis of other tissues.

This class is appropriate for all engineering graduate students, even those outside the field of orthopaedics, who have an interest in biomechanics.

Class Meeting Times and Activities
Tuesdays and Thursdays, 9:30-10:50 AM, Learned Hall, Room 3015

The coursework will consist of readings, lectures, in-class group and collaborative learning exercises, homework assignments, finite element analysis laboratories, poster presentations by each student, and exams.

Instructor Office Hours
Mondays 1-2 PM, Tuesdays 11 AM - Noon, and Thursday: 11 AM - Noon, Learned Hall 3011

Course Goals
After active participation in this course and an effort to learn the material, students will be able to:

1. Recall and appreciate the general characteristics, hierarchical structure, material properties, appropriate constitutive models, and adaptation potential for bone as a tissue and organ.
2. Understand relationships between structure and function in bone as a tissue and organ.
3. Determine key strengths and weaknesses of a bone implant, determine potential adaptation to the implant, and suggest improvements for a biomedical implant.
4. Develop and run simulations of bone adaptation.
5. Apply appropriate theoretical, analytical and computational techniques to determine realistic stresses and strains in bones.
6. Understand the interactions with of bone with the chemical and nutritional state of the body, and the manifestations of disease (osteoarthritis and osteoporosis).
7. Identify the factors affecting the mechanical properties of bone tissue.
8. Select an appropriate experimental method to determine the properties of cancellous or cortical bone.

Course Materials
One primary text will be used in this course:

Two secondary (supplemental) text will be used in this course:
   Structure, Function, and Adaptation of Compact Bone, by R. Bruce Martin and David B. Burr (1989)

In addition, students will be provided selected research papers and will be assigned to study certain topics and locate other relevant past and current research articles.
Course Outline

Day 1:
Course Introduction ("prerequisites"), Policies,
Introduction to Blackboard Software,
Historical perspectives on bone structure, function and remodeling (Martin & Burr: Chapter 1)

Weeks 1-3: Bone Biology (Cell, Tissue and Organ) and Composition and Structure
Biology and composition overview (Cowin: Chapter 1)
Bone and cartilage growth (Martin, Burr & Sharkey: Chapter 2)
Analysis of bone remodeling (Martin, Burr & Sharkey: Chapter 3)

Weeks 4-8: Mechanical Properties of Bone, Fracture and Fatigue
Determinants of Strength (Martin, Burr & Sharkey: Chapter 4)
Experimental determination of properties (Cowin: Chapter 5)
Properties of cortical and cancellous bone (Martin, Burr & Sharkey: Chapter 4)
Anisotropy and composite models for bone (Cowin: Chapter 7,9)
Fatigue and fracture resistance of bone (Martin, Burr & Sharkey: Chapter 5)

Weeks 9-11: Finite Element Modeling of Bone and Implants [Related Laboratories]
Basics of Finite Element Modeling (Cowin: Chapter 4)
Fracture Healing and Fixation
Total Joint Replacements (Cowin: Chapter 8)

Weeks 12-15: Bone Adaptation to Mechanical Environment (Concepts and Simulations)
Experimentation and current concepts (Martin, Burr & Sharkey: Chapter 6 and Cowin: Chapter 10)
Computational Techniques for Bone Remodeling Simulations
   Tulane (Hart/Cowin) Simulations (Cowin: Chapter 12)
   Nijmegen (Huiskes et al.) Simulations (Huiskes et al, 1989)
   Stanford (Carter et al.) Simulations (Beaupre, Orr and Carter, 1990) [Related Take-Home Final]

Week 15-16: Disease States in Bone
Osteoporosis (Wark, 1993)
Osteoarthritis

Course Requirements and Grading
The grading scheme is subject to change. Current plans are as follows:

   Class discussion/participation (5%)
   Homework (15%)
   Labs (10%)
   Poster Presentation (10%)
   Midterm 1 (20%)
   Midterm 2 (20%)
   Take-Home Final (20%)

Homework is due at the beginning of class time on the due date. Homework will be accepted up to 1 week late, with a 10% reduction in score for each day late. For instance a homework turned in 3 days late would be graded normally, but the final score would be reduced by 30 percent. Problems for which the solution has been discussed in class after the due date will receive a zero score, but other problems will be scored normally under the 1 week late homework policy.

Exam dates are provided in the detailed schedule handed out in class and available from the course webpage. Anyone missing the exam without informing the instructor of a conflict at least one week prior to the exam will receive a zero score for the exam. By contacting the instructor in advance, arrangements can be made for an alternate exam day and/or time.

Attendance is not required, but since class participation, discussion, and presentations are graded, poor attendance will almost certainly result in a poor grade in the course.
**Course Policies (G-Grades)**
For this course, a G-Grade will be granted if the student has taken one exam. The G-Grade allows two additional terms to complete course work.

**Course Policies (Academic Integrity)**
Students in this course will be expected to comply with the University of Kansas Policy on Academic Integrity. Any student suspected of violating this obligation for any reason during the semester will be required to participate in the procedural process, initiated at the instructor level, as outlined in the University Guidelines on Academic Integrity. This may include, but is not limited to, the confiscation of the examination of any individual suspected of violating University Policy. Furthermore, no student may bring any unauthorized materials to an examination, including dictionaries and programmable calculators.

**Course Policies (Disabilities)**
If you have a disability that requires special testing accommodations or other classroom modifications, you need to notify both the instructor and the Disability Resources and Services no later than the 2nd week of the term. You may be asked to provide documentation of your disability to determine the appropriateness of accommodations.