University Of California, Berkeley
Department of Mechanical Engineering

ME C210 /Bio Eng C209: Advanced Orthopedic Biomechanics (4 units)

Graduate Course

Syllabus

CATALOG DESCRIPTION

Students will learn the application of engineering concepts including statics, dynamics, optimization theory, composite beam theory, beam-on-elastic foundation theory, Hertz contact theory and materials behavior. Topics will include forces and moments acting on human joints; composition and mechanical behavior of orthopedic biomaterials; design/analysis of artificial joint, spine, and fracture fixation prostheses; musculoskeletal tissues including bone, cartilage, tendon, ligament, and muscle; osteoporosis and fracture-risk predication of bones; and bone adaptation. Students will be challenged in a MATLAB-based project to integrate the course material in an attempt to gain insight into contemporary design/analysis/problems. Also listed as Bioengineering C209.

COURSE PREREQUISITES

ME C85/CE C30 or Bio Eng 102; concurrent enrollment OK. Proficiency in MatLab or equivalent. Prior knowledge of biology or anatomy is not assumed.

TEXTBOOK(S) AND/OR OTHER REQUIRED MATERIAL

Bartel DL, Davy DT, and Keaveny TM: *"Orthopaedic Biomechanics: Mechanics and Design in Musculoskeletal Systems"* Pearson Prentice Hall, New Jersey, 2006.

COURSE OBJECTIVES

The purpose of this course is twofold:

- to learn the fundamental concepts of orthopaedic biomechanics;
- to enhance skills in mechanical engineering and bioengineering by analyzing the mechanical behavior of various complex biomedical problems.

DESIRED COURSE OUTCOMES

Working knowledge of various engineering concepts such as composite beam theory, beam-on-elastic-foundation theory, Hertz contact theory and MATLAB-based optimization design analysis. Understanding of basic concepts in orthopaedic biomechanics and the ability to apply the appropriate engineering concepts to solve realistic biomechanical problems, knowing clearly the assumptions involved.

TOPICS COVERED

Basic anatomy, Static analysis of skeletal systems, Kinematics and dynamics, Viscoelasticity, Tissue Mechanics, Muscle Mechanics, Composite beam theory, Whole Bone Structural Analysis, Mechanics of aging, disease, drug treatment; Implant Design: Orthopaedic implant materials, Design objectives of orthopaedic

prostheses, Design of hip prostheses, Beam-on-elastic-foundation theory, Contact stresses and wear, Design of knee prostheses, Fracture fixation and spinal implants, Bone adaptation and implant design.

CLASS/LABORATORY SCHEDULE

Three hours lecture, one hour discussion and computer workshop.

CONTRIBUTION OF THE COURSE TO MEETING THE PROFESSIONAL COMPONENT

Emphasis on interpretation of results from analytical and computational models, in light of economic, ethical and safety issues provides students with substantial professional component. Students are also required to write professional-type short reports summarizing their computational analyses.

ASSESSMENT OF STUDENT PROGRESS TOWARD COURSE OBJECTIVES

The students' progress is assessed via Weekly homework, three Matlab assignments which involves computer programming, one Mid-term exam and a Final exam 40%

Literature Review paper 5%
Weekly homeworks and assignments 10%
Matlab assignments (2 mini + final project) 25% (2.5+7.5+20.0)
Mid-term exam 20%
Final exam 40%

TOPICS COVERED/WEEKLY AGENDA

Please see attached.

ROOM SHARE AND GRADUATE CONTENT

In the graduate level version of Orthopaedic Biomechanics, graduate students will review current work in the literature that applies the principles and techniques described in class. There will be a separate discussion section for the graduate students to discuss these papers. Also, these sessions will provide the students with a broad understanding of the cutting edge research being performed in this area. By the end of the semester, it is expected that the students will not only be able to read and understand the literature, but will be able to critically assess the limitations, strengths and weaknesses in a study.

A second major component difference between the undergraduate and graduate level course work will be a written assignment with an oral presentation. The graduate students will be expected to provide an oral presentation to the class (groups of 3). Students will describe an anatomical feature and a condition or disease associated with the feature. In addition, the group will be required to write a short summary report of the anatomical region with the focus of expressing to a lay reader why it is important to know about the feature/condition, what's being done research-wise or clinically, and what future treatments may be coming. It is expected that this assignment will allow them to apply the critical thinking skills learned during the discussion sections, described above. The purpose of this assignment is not for the students to feel like they need to solve these big issues in one assignment, but more to focus on communicating these ideas to people that may not know the topic area (i.e. general public or other engineers).

PERSON(S) WHO PREPARED THIS DESCRIPTION

Professor Grace O'Connell, September 25, 2013

ABBREVIATED TRANSCRIPT TITLE (19 SPACES MAXIMUM): ADV ORTHO BIO MECH
TIE CODE: LECS
GRADING: Letter
SEMESTER OFFERED: Fall and Spring
COURSES THAT WILL RESTRICT CREDIT: ME C176 and BIO E C119, no credit
INSTRUCTORS: Keaveny and O'Connell
DURATION OF COURSE: 14 Weeks
EST. TOTAL NUMBER OF REQUIRED HRS OF STUDENT WORK PER WEEK: 12
IS COURSE REPEATABLE FOR CREDIT? No.
CROSSLIST: Bio Eng C209

DATE	LECTURE TOPIC	MATLAB PROJECTS	READING*
Skeletal Forces and Motion			
Sept. 2	**LABOR DAY HOLIDAY**		
Sept. 4	Introduction; basic anatomy		2-21
Sept. 9	Static analysis of skeletal systems I		23–35
Sept. 11	Static analysis of skeletal systems II		
Sept. 16	The force distribution problem		35–44
Sept. 18	Kinematics and dynamics I		44–58
Sept. 23	Kinematics and dynamics II		64–65
Sept. 25	Joint stability	**MINI MATLAB 1 (due 10/09)**	58–64
Tissue Mechanics and Materials			
Sept. 30	Impact biomechanics		
Oct. 2	Viscoelasticity		154–163
Oct. 7	Tissue mechanics I		71–116
Oct. 9	Tissue mechanics II		121–147
Oct. 14	Muscle mechanics		147–153; 163–164
Oct. 16	**MID-TERM EXAM** *(all course material through Oct 2; closed-book)*		
Oct. 21	Composite beam theory (Symmetric beams)		168–176
Oct. 23	Composite beam theory (Unsymmetrical beams)	**MINI MATLAB 2 (due 11/06)**	177–182
Oct. 28	Case studies: whole bone mechanics		183–198
Oct. 30	Orthopaedic implant materials		235–245
Implant Design and Analysis			
Nov. 4	Design principles, objectives, and constraints		245–25
Nov. 6	Beam-on-elastic-foundation theory I		203–213
Nov. 11	**VETERAN'S DAY HOLIDAY**		
Nov. 13	Beam-on-elastic-foundation theory II		304–310
Nov. 18	Contact stresses	**FINAL PROJECT PART A (due 12/2)**	223–231; 335–349
Nov. 20	Design of knee prostheses	**Review Paper Due**	314–332
Nov. 25	Design of hip prostheses		290–304; 310
Nov. 27	Design of spine prostheses	**FINAL PROJECT PART B (due 12/05)**	
Dec. 2	Design of fracture fixation prostheses		261–287
Dec. 4	Course summary, closure		
Dec. 9	Reading, Review, and Recitation		
Dec. 11	Reading, Review, and Recitation		
Dec. 19	**FINAL EXAM**, 8:00-11:00 AM, Location TBA *(all course material; closed-book)*		

** Reading assignments refer to the course textbook; please try to do reading before class.*

All homeworks and projects are to be uploaded on bspace, by 2 pm of the assigned day. Solutions to the homeworks will be posted on bspace by 6 pm of that day. Late homeworks or projects will not be accepted without prior approval from Professor O'Connell. The topic of the Final Project is the same for all students.

Grading:		
	Literature Review paper	5%
	Weekly homeworks and assignments	10%
	Matlab assignments (2 mini + final project)	25% (2.5+7.5+20.0)
	Mid-term exam	20%
	Final exam	40%

	Lecture topics	Graduate Discussion (all discussions are based on a critical review and analysis of 1-2 papers from the literature)	Assignments/ Mini Projects
Week 1	Introduction; Basic anatomy	early biomechanics studies - gait analysis	
Week 2	Static analysis of skeletal system	biomechanical studies using statics to understand mechanical function of joint loads (cartilage and intervertebral disc)	
Week 3	Force distribution problem; Dynamics		
Week 4	Dynamics II; Joint Stability	Studies that look at the effect of muscle forces on the stability of the joint function (knee and spine)	
Week 5	Impact biomechanics; Viscoelasticity	Studies that measure impact properties of bones and how it relates to fractures	Matlab Project 1
Week 6	Tissue Mechanics	Visocelastic studies on tendons and ligaments	
Week 7	Muscle Mechanics/ Midterm	studies that measure muscle activity and forces during daily activity	
Week 8	Composite Beam Theory	Repair strategies for fracture of long bones with critical defects	
Week 9	Design Principles, objectives and constraints	Studies that look at wear properties of biomaterials used for protheses	Matlab Project 2
Week 10	Beam-on-elastic foundation Theory	Kree prostheses - early studies of efficacy and effect on pain reduction	
Week 11	Contact stresses; Design of Knee Prostheses	Hip prostheses papers - Studies performed for FDA review and approval	Review Paper
Week 12	Design of hip and spine prostheses	Spine prostheses - studies that look at long term effect of prostheses and effect on other neighboring tissues	
Week 13	Designe of fracture fixation prosthesis; course summary	Studies that look at failure of prostheses	Matlab Project 3- part 1
Week 14	Reading, review, and receitation	no discussion	Matlab Project 3-part 2
Week 15	Final Exam		

Grading

Literature Review paper	5%
Weekely Homeworks	10%
Matllab Assignments	25%
Mid-term exam	20%
Final exam	40%