UC Berkeley Departments of Mechanical Engineering and Bioengineering ME C176 and BIOE C119 (4 units) Spring 2019 "Orthopaedic Biomechanics"

Professor Tony M. Keaveny, 5124 Etcheverry Hall tonykeaveny@berkeley.edu Office Hours: TUE AND THUR 1:30–3:00 PM

Graduate Student Instructor: Tongge Wu wutongge@berkeley.edu Office Hours: WED 1:00–2:00 PM AND FRI 4:00–5:00 PM, 1171 ETCHEVERRY HALL

Prerequisites:	ME C85 (or CEE C30) or BIOE 102; or equivalent.		
	Working knowledge of MATLAB is required. Prior knowledge of biology or anatomy is not assumed. Open for undergraduate students only.		
Lectures:	TUE and THUR 9:30 AM –11:00 AM, 60 BARROWS HALL		
Discussion:	WED 10:00–11:00 AM, 10 JACOBS HALL; FRI 9:00–10:00 AM, 10 JACOBS HALL		
Computer Lab:	1171 Etcheverry Hall		
Textbook:	Bartel DL, Davy DT, and Keaveny TM: <i>"Orthopaedic Biomechanics: Mechanics and Design in Musculoskeletal Systems"</i> Pearson Prentice Hall, New Jersey, 2006.		
Other:	Please check bCourses regularly for weekly homeworks and any other assignments or		

COURSE DESCRIPTION

From a biomechanical perspective, the healthy human skeleton is an optimal structure that has adapted its form in response to its function. Studying the mechanics of the skeleton therefore provides information that can be used not only to design artificial prostheses and materials — and thus address specific health care issues — but also to aid in the design of more traditional engineering structures by understanding the behavior and underlying design features of this complex biodynamic structure. Also, by addressing design and analysis principles as applied to orthopaedics, we will encounter fundamental issues — biological heterogeneity, uncertainty, and regulatory constraints — that play a critical role in designing any type of medical device. Thus, the purpose of this course is threefold:

• develop expertise in orthopaedic biomechanics;

announcements.

- learn core principles for the design and analysis of any biomedical implant;
- enhance fundamental skills in engineering design and analysis.

Specific examples of mechanical engineering concepts that will be used include statics, dynamics, optimization theory, composite beam theory, beam-on-elastic-foundation theory, Hertz contact theory, and viscoelasticity. The course has three main themes: Skeletal Forces and Motion; Tissue and Organ Mechanics; and Implant Design and Analysis. Specific biomechanics topics will include loads on human joints; dynamic analysis of human motion; mechanical properties of musculoskeletal tissues including bone, cartilage, tendon, ligament, and muscle; osteoporosis and bone strength assessment; composition and mechanical behavior of orthopaedic biomaterials; and design/analysis of artificial joint, spine, and fracture fixation prostheses; vehicular safety biomechanics. All students will present briefly in class on an application topic of their choice, and an individualized mid-term oral examination will provide students with the opportunity for individualized feedback on their progress. Students will be challenged with a MATLAB-based course project to integrate the course material in an attempt to gain insight into contemporary design/analysis problems; this project will be prefaced by two simpler MATLAB-based mini-project assignments and further complemented by weekly analytical biomechanics assignments.

The course is ideal for undergraduate students interested in biomechanical engineering, those wishing to further develop technical skills in design and analysis of mechanical systems and in using MATLAB, and those interested in addressing contemporary engineering problems directly related to human healthcare.

Skeletal Forces and Motion Jan. 22Introduction; basic anatomy static analysis of skeletal systems2-2-35Jan. 29Static analysis of skeletal systems I Jan. 31Califormal Systems I The force distribution problemMINI MATLAB I (due 2/21)33-44Feb. 5Joint stability Kinematics and dynamics I8-6-43Feb. 7Kinematics and dynamics I64-63Feb. 12Kinematics and dynamics I144-58Feb. 13Viscoelasticity121-147Feb. 26Tissue mechanics II Issue mechanics II121-147Feb. 28Muscle mechanics II Muscle mechanics II121-147Feb. 29Composite beam theory Muscle mechanics147-153; IG3-164Mar. 5MD-TLRM EXAM (dl course material through Feb 14; closed-book; formulae provided) Mar. 7168-176Mar. 12Unsymmetrical beams Composite beam theory177-182Mar. 14Case studies; whole-bone biomechanics187-182Mar. 21Design and Analysis Mar. 10235-245Mar. 26SPRINC BREAK235-245Apr. 2Beam-on-elastic-foundation theory I Apr. 4203-213 304-310Apr. 9Contact stresses Carrent provided in phoneshees23-243Apr. 19Design of knee prostheesesFINAL MATLAB PROJECT PART B (due 5/02) 304-310Apr. 23Design of pipme prostheesesFINAL MATLAB PROJECT PART B (due 5/02) 304-310Apr. 23Design of pipme prostheesesFINAL MATLAB PROJECT PART B (due 5/02) 304-310Apr. 23Design of pipme prostheesesFINAL MATLAB PROJ	DATE	LECTURE TOPIC	MATLAB PROJECTS	R EADING*
Jan. 31The force distribution problemMINI MATLAB 1 (due 2/21)35-44Feb. 5Joint stability Kinematics and dynamics I58-64Feb. 12Kinematics and dynamics I64-65Tissue Biomechanics71-116Feb. 12Tissue mechanics I71-116Feb. 21Tissue mechanics I71-116Feb. 26Tissue mechanics I121-147Feb. 26Tissue mechanics I121-147Feb. 27Composite beam theoryMINI MATLAB 2 (due 3/21)Mar. 5MID-TERM EXAM (all course material brough Eeb 14; closed-book; formulae provided)Mar. 7Composite beam theoryMINI MATLAB 2 (due 3/21)Mar. 12Unsymmetrical beams177-182Mar. 14Case studies: whole-bone biomechanics183-198Implant Design and Analysis Mar. 26SPRING BREAKMar. 26SPRING BREAK203-213 304-310Apr. 2Beam-on-elastic-foundation theory I203-213 304-310Apr. 9Contact stresses Design of knee prosthesesFINAL MATLAB PROJECT PART B (due 5/02) 304-310Apr. 16Design of hip prosthesesFINAL MATLAB PROJECT PART B (due 5/02) 314-332Apr. 16Design of spine prosthesesFINAL MATLAB PROJECT PART B (due 5/02) 304-310Apr. 30Ceurse summary, closure261-287 Apr. 23Apr. 30Design of knee prosthesesFINAL MATLAB PROJECT PART B (due 5/02) 304-310Apr. 30Design of knee with opposite isomechanics research261-287 Apr. 30Apr. 31Design of knee with opposite score	Jan. 22	Introduction; basic anatomy		
Feb. 7Kinematics and dynamics I44–58Feb. 12Kinematics and dynamics II64–65Feb. 14Impact biomechanicsNotesTissue Biomechanics and Materials71–116Feb. 19Viscoelasticity71–116Feb. 26Tissue mechanics II121–147Feb. 28Muscle mechanics147–153; 163–164Mar. 5MID-TERM EXAM (all course material through Feb 14; closed-book; formulae provided)Mar. 7Composite beam theoryMINI MATLAB 2 (due 3/21)Mar. 12Unsymmetrical beams177–182Mar. 12Unsymmetrical beams235–245Mar. 14Case studies: whole-bone biomechanics235–245Mar. 21Design principles, optimal designFINAL MATLAB PROJECT PART A (due 4/16)245–259Mar. 28SPRING BREAK243–231Apr. 2Beam-on-elastic-foundation theory I203–213Apr. 3Contact stresses223–231; 335–349Apr. 16Design of hip prosthesesFINAL MATLAB PROJECT PART B (due 5/02)200–304; 310Apr. 16Design of spine prosthesesFINAL MATLAB PROJECT PART B (due 5/02)200–304; 310Apr. 30Clinical translation and patents261–287May 7Reading, Review, and Recitation261–287May 7Reading, Review, and Recitation261–287				
Feb. 14Impact biomechanicsNotesTissue Biomechanics and Materials Feb. 19Viscoelasticity Tissue mechanics I71–116Feb. 21Tissue mechanics I121–147Feb. 26Tissue mechanics I121–147Feb. 26Tissue mechanics121–147Feb. 27Muscle mechanics121–147Feb. 28Muscle mechanics121–147Feb. 28Muscle mechanics121–147Feb. 28Muscle mechanics121–147Feb. 29Mar. 5Muscle mechanics168–176Mar. 7Composite beam theoryMINI MATLAB 2 (due 3/21)168–176Mar. 12Unsymmetrical beams Case studies: whole-bone biomechanics183–198Implant Design and Analysis Mar. 190rthopaedic implant materials235–245Mar. 21Design principles, optimal designFINAL MATLAB PROJECT PART A (due 4/16)245–259Mar. 28SPRING BREAK203–213Apr. 2Beam-on-elastic-foundation theory I203–213Apr. 4Beam-on-elastic-foundation theory II203–213Apr. 10Design of knee prostheses223–231; 335–349Apr. 11Design of spine prosthesesFINAL MATLAB PROJECT PART B (due 5/02)290–304; 310Apr. 16Design of spine prosthesesFINAL MATLAB PROJECT PART B (due 5/02)290–304; 310Apr. 16Design of spine prosthesesCurrent hot topics in orthopaedic biomechanics research261–287Apr. 30Clinical translation and patents May 2Course summary, closure261–287M				
Feb. 19Viscoelasticity Tissue mechanics I71–116Feb. 26Tissue mechanics II Muscle mechanics121–147 147–153; 163–164Mar. 5Mub-TERM EXAM (all course material through Feb 14; closed-book; formulae provided) Mar. 7168–176Mar. 5Composite beam theoryMINI MATLAB 2 (due 3/21)168–176Mar. 12Unsymmetrical beams Crase utdies: whole-bone biomechanics183–198Mar. 12Unsymmetrical beams Orthopaedic implant materials235–245Mar. 21Design principles, optimal designFINAL MATLAB PROJECT PART A (due 4/16)245–259Mar. 28SPRING BREAK203–213 304-310Apr. 2Beam-on-elastic-foundation theory I Design of knee prostheses203–213 304-310Apr. 9Contact stresses Design of knee prostheses223–231; 335–349 314-332Apr. 16 Apr. 18Design of hip prostheses Current hot topics in orthopaedic biomechanics research290–304; 310Apr. 23 Apr. 23 Apr. 24Design of fracture-fixation prostheses Current hot topics in orthopaedic biomechanics research261–287 21–287Apr. 30 Apr. 30Clinical translation and patents Kay 2Course summary, closure261–287May 7 May 7 May 7Reading, Review, and RecitationKeitagin AKeitagin A				
Feb. 28Muscle mechanics147–153; 163–164Mar. 5MID-TERM EXAM (all course material through Feb 14; closed-book; formulae provided) MINI MATLAB 2 (due 3/21)168–176Mar. 12Unsymmetrical beams Case studies: whole-bone biomechanics177–182 183–198Implant Design and Analysis Mar. 19Case studies: whole-bone biomechanics235–245Mar. 21Design principles, optimal designFINAL MATLAB PROJECT PART A (due 4/16)245–259Mar. 26SPRING BREAK SPRING BREAK203–213 304–310Apr. 2Beam-on-elastic-foundation theory I Design of knee prostheses203–213 314–332Apr. 16Design of hip prostheses Design of spine prosthesesFINAL MATLAB PROJECT PART B (due 5/02)209–304; 310Apr. 23Design of fracture-fixation prostheses Current hot topics in orthopaedic biomechanics research261–287Apr. 30Clinical translation and patents Kay 2Course summary, closure261–287Apr. 30Reading, Review, and Recitation Reeding, Review, and RecitationFinal Matlab Project Part B (due 5/02)290–304; 310	Feb. 19	Viscoelasticity		71–116
Mar. 7Composite beam theoryMINI MATLAB 2 (due 3/21)168–176Mar. 12Unsymmetrical beams Case studies: whole-bone biomechanics177–182Mar. 14Case studies: whole-bone biomechanics183–198Implant Design and Analysis Mar. 19235–245Mar. 21Design principles, optimal designFINAL MATLAB PROJECT PART A (due 4/16)245–259Mar. 26SPRING BREAK Mar. 28203–213 304–310Apr. 2Beam-on-elastic-foundation theory I Design of knee prostheses203–213 304–310Apr. 9Contact stresses Design of knee prostheses223–231; 335–349 314–332Apr. 16Design of hip prosthesesFINAL MATLAB PROJECT PART B (due 5/02) 290–304; 310290–304; 310Apr. 23Design of fracture-fixation prostheses Apr. 25Current hot topics in orthopaedic biomechanics research261–287Apr. 30Clinical translation and patents May 2Course summary, closure261–287May 7Reading, Review, and Recitation May 9Reading, Review, and Recitation261–287				
Mar. 12Unsymmetrical beams Case studies: whole-bone biomechanics177-182 183-198Implant Design and Analysis Mar. 19Orthopaedic implant materials235-245Mar. 21Design principles, optimal designFINAL MATLAB PROJECT PART A (due 4/16)245-259Mar. 26SPRING BREAK Mar. 28SPRING BREAK203-213 304-310Apr. 2Beam-on-elastic-foundation theory I Beam-on-elastic-foundation theory II203-213 304-310Apr. 9Contact stresses Design of hip prostheses223-231; 335-349 314-332Apr. 16Design of hip prosthesesFINAL MATLAB PROJECT PART B (due 5/02)290-304; 310 290-304; 310Apr. 23Design of fracture-fixation prostheses Apr. 25Current hot topics in orthopaedic biomechanics research261-287 Apr. 30Apr. 30Clinical translation and patents May 2Course summary, closure261-287May 7Reading, Review, and Recitation Review, and Recitation261-287				
Mar. 19Orthopaedic implant materials235-245Mar. 21Design principles, optimal designFINAL MATLAB PROJECT PART A (due 4/16)245-259Mar. 26SPRING BREAKSPRING BREAK203-213Mar. 28SPRING BREAK203-213Apr. 2Beam-on-elastic-foundation theory I203-213Apr. 4Beam-on-elastic-foundation theory II304-310Apr. 9Contact stresses223-231; 335-349Apr. 11Design of knee prostheses314-332Apr. 16Design of hip prosthesesFINAL MATLAB PROJECT PART B (due 5/02)290-304; 310Apr. 23Design of fracture-fixation prostheses261-287Apr. 30Clinical translation and patents Course summary, closure261-287May 7Reading, Review, and Recitation Reading, Review, and Recitation261-287	Mar. 12	Unsymmetrical beams		177–182
Mar. 26 Mar. 28SPRING BREAK SPRING BREAKApr. 2 Apr. 4Beam-on-elastic-foundation theory I Beam-on-elastic-foundation theory II203–213 304–310Apr. 9 Apr. 9 Contact stressesContact stresses 314–332Apr. 16 Apr. 18Design of hip prostheses Design of spine prosthesesFINAL MATLAB PROJECT PART B (due 5/02) 290–304; 310Apr. 23 Apr. 23 Apr. 25Design of fracture-fixation prostheses Current hot topics in orthopaedic biomechanics research261–287 Apr. 30 Clinical translation and patents May 2May 7 May 9 Reading, Review, and Recitation May 9Reading, Review, and Recitation Review, and Recitation				235–245
Mar. 28SPRING BREAKApr. 2 Apr. 4Beam-on-elastic-foundation theory I Beam-on-elastic-foundation theory II203-213 304-310Apr. 9 Apr. 11Contact stresses Design of knee prostheses223-231; 335-349 314-332Apr. 16 Apr. 18Design of hip prostheses Design of spine prosthesesFINAL MATLAB PROJECT PART B (due 5/02) 290-304; 310Apr. 23 Apr. 25Design of fracture-fixation prostheses Current hot topics in orthopaedic biomechanics research261-287 Current hot topics in orthopaedic biomechanics researchApr. 30 May 2Clinical translation and patents Course summary, closure261-287	Mar. 21	Design principles, optimal design	FINAL MATLAB PROJECT PART A (due 4/16)	245–259
Apr. 4Beam-on-elastic-foundation theory II304–310Apr. 9Contact stresses223–231; 335–349Apr. 11Design of knee prostheses314–332Apr. 16Design of hip prostheses FINAL MATLAB PROJECT PART B (due 5/02) 290–304; 310Apr. 18Design of spine prostheses261–287Apr. 23Design of fracture-fixation prostheses261–287Apr. 30Clinical translation and patents Course summary, closure201–287May 7Reading, Review, and Recitation Reading, Review, and Recitation201–201				
Apr. 11Design of knee prostheses314–332Apr. 16Design of hip prosthesesFINAL MATLAB PROJECT PART B (due 5/02)290–304; 310Apr. 18Design of spine prostheses261–287Apr. 23Design of fracture-fixation prostheses Current hot topics in orthopaedic biomechanics research261–287Apr. 30Clinical translation and patents Course summary, closure261–287May 7Reading, Review, and Recitation Reading, Review, and Recitation261–200				
Apr. 18Design of spine prosthesesApr. 23Design of fracture-fixation prostheses261–287Apr. 25Current hot topics in orthopaedic biomechanics research261–287Apr. 30Clinical translation and patents Course summary, closure261–287May 7Reading, Review, and Recitation May 9Reading, Review, and Recitation	-			
Apr. 25Current hot topics in orthopaedic biomechanics researchApr. 30Clinical translation and patentsMay 2Course summary, closureMay 7Reading, Review, and RecitationMay 9Reading, Review, and Recitation			FINAL MATLAB PROJECT PART B (due 5/02)	290–304; 310
May 2Course summary, closureMay 7Reading, Review, and RecitationMay 9Reading, Review, and Recitation				261–287
May 9 Reading, Review, and Recitation	-	-		
May 15 FINAL EXAM , 11:30 AM – 2:30 PM, Location TBA (<i>all course material; closed-book; formulae provided</i>)	2	0		
	May 15	FINAL EXAM , 11:30 AM –2:30 PM, LO	cation TBA (all course material; closed-book; for	mulae provided)

* Reading assignments refer to the course textbook unless specified otherwise.

Grading

All homeworks and projects are to be uploaded on *bCourses* by 2 pm of the assigned day. By 6 pm of the due day, solutions to the homeworks will be posted on *bCourses*. As a result of this fixed schedule, **late homeworks or projects will not be accepted without prior approval from Professor Keaveny**.

Homework grading:

Successful completion of homeworks is essential to prepare for the exams.

Per homework, full marks are awarded if the student *reasonably attempts* all questions.

Per semester, homework grades will be based on the average grade for all but one homework, *i.e.* students are permitted to miss one homework without it impacting their overall homework grade.

Class participation is based on active involvement in class activities and discussions. Default score is 3%, which is moved up or down depending on degree of participation — so participate!

The topic of the Final Project is the same for all students.

All exams are closed book, closed notes. A comprehensive "cheat-sheet" will be provided for all exams, containing all formulae required. Thus, there is no need to memorize any formulae.

For this upper division 4-unit elective class, the grading scheme is designed to ensure that if you do well on the homeworks, participation, and project, you should not fail:

Grading:	Weekly homeworks Class participation Matlab assignments (2 mini + final project) Mid-term exam	5% 5% 40% (5+10+25) 15%
	Mid-term exam	15%
	Final exam	35%