UC Berkeley Departments of Mechanical Engineering and Bioengineering
ME C176 and BIOE C119 (4 units) Fall 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: Shannon Emerzian semerzian@berkeley.edu
Office Hours: MON 2:00–3:00 PM AND WED 10:00–11:00 AM, 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 5:00 –6:30 PM, 3108 ETCHEVERRY HALL

Discussion: WED 9:00–10:00 AM, 10 JACOBS HALL

Computer Lab: 1171/2107 ETCHEVERRY HALL

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

Other: *Please check **bCourses** regularly for weekly homeworks and any other assignments or announcements.*

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;
- 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. 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.

DATE	LECTURE TOPIC	MATLAB PROJECTS	READING*
Skeletal Forces and Motion			
Aug. 29	Introduction; basic anatomy		2–21
Sep. 3	Static analysis of skeletal systems I		23–35
Sep. 5	Static analysis of skeletal systems II		23–35
Sep. 10	The force distribution problem †		35–44
Sep. 12	Joint stability †	**MINI MATLAB 1 (due 10/3)**	58–64
Sep. 17	Kinematics and dynamics I	[FYI: Add-drop deadline = Sep 18]	44–58
Sep. 19	Kinematics and dynamics II **		64–65
Tissue Biomechanics and Materials			
Sep. 24	Impact biomechanics		Notes
Sep. 26	Viscoelasticity		154–163
Oct. 1	Tissue mechanics I		71–116
Oct. 3	Tissue mechanics II†		121–147
Oct. 8	Muscle mechanics	**MINI MATLAB 2 (due 10/31)**	147–153; 163–164
Oct. 10	**NO CLASS — PG&E FIASCO**		
Oct. 10	Composite beam theory		168–176
Oct. 17	**MID-TERM EXAM**† *(all course material through Sep 19; closed-book; formulae provided)*		
Oct. 22	Unsymmetrical beams		177–182
Oct. 24	Case studies: whole-bone biomechanics		183–198
Implant Design and Analysis			
Oct. 29	Orthopaedic implant materials		235–24
Oct. 31	Design principles, optimal design	**FINAL MATLAB PROJECT PART A (due 11/19)**	245–259
Nov. 5	Beam-on-elastic-foundation theory I		203–213
Nov. 7	Beam-on-elastic-foundation theory II		304–310
Nov. 12	Contact stresses		223–231; 335–349
Nov. 14	Design of knee prostheses		314–332
Nov. 19	Design of hip prostheses	**FINAL MATLAB PROJECT PART B (due 12/05)**	290–304; 310
Nov. 21	Design of spine prostheses		Notes
Nov. 26	Design of fracture-fixation prostheses		261–28
Nov. 28	**THANKSGIVING HOLIDAY**		
Dec 3.	Current hot topics in orthopaedic biomechanics research		
Dec. 5	Patents & clinical translation		Notes
Dec. 10	Reading, Review, and Recitation		
Dec. 12	Reading, Review, and Recitation		
Dec. 19	**FINAL EXAM**, 11:30 AM –2:30 PM, Location TBA *(all course material; closed-book; formulae provided)*		

* *Reading assignments refer to the course textbook unless specified otherwise.*
** *Professor Keaveny out of town*
† *GSI out of town*

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