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: *"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, 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.

DATE	LECTURE TOPIC	MATLAB PROJECTS	READING*
Skeletal Forces and Motion			
Jan. 22	Introduction; basic anatomy		2–21
Jan. 24	Static analysis of skeletal systems		23–35
Jan. 29	Static analysis of skeletal systems I		23–35
Jan. 31	The force distribution problem	**MINI MATLAB 1 (due 2/21)**	35–44
Feb. 5	Joint stability		58–64
Feb. 7	Kinematics and dynamics I		44–58
Feb. 12	Kinematics and dynamics II		64–65
Feb. 14	Impact biomechanics		Notes
Tissue Biomechanics and Materials			
Feb. 19	Viscoelasticity		
Feb. 21	Tissue mechanics I		71–116
Feb. 26	Tissue mechanics II		121–147
Feb. 28	Muscle mechanics		147–153; 163–164
Mar. 5	**MID-TERM EXAM** *(all course material through Feb 14; closed-book; formulae provided)*		
Mar. 7	Composite beam theory	**MINI MATLAB 2 (due 3/21)**	168–176
Mar. 12	Unsymmetrical beams		177–182
Mar. 14	Case studies: whole-bone biomechanics		183–198
Implant Design and Analysis			
Mar. 19	Orthopaedic implant materials		235–245
Mar. 21	Design principles, optimal design	**FINAL MATLAB PROJECT PART A (due 4/16)**	245–259
Mar. 26	**SPRING BREAK**		
Mar. 28	**SPRING BREAK**		
Apr. 2	Beam-on-elastic-foundation theory I		203–213
Apr. 4	Beam-on-elastic-foundation theory II		304–310
Apr. 9	Contact stresses		223–231; 335–349
Apr. 11	Design of knee prostheses		314–332
Apr. 16	Design of hip prostheses	**FINAL MATLAB PROJECT PART B (due 5/02)**	290–304; 310
Apr. 18	Design of spine prostheses		
Apr. 23	Design of fracture-fixation prostheses		261–287
Apr. 25	Current hot topics in orthopaedic biomechanics research		
Apr. 30	Clinical translation and patents		
May 2	Course summary, closure		
May 7	Reading, Review, and Recitation		
May 9	Reading, Review, and Recitation		
May 15	**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.*

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