



## **BME 556: Advanced Biomechanics**

School of Engineering and Science  
Fall 2023

Instructor: Raviraj Nataraj

Canvas Course Address: <https://sit.instructure.com/courses/68642>

Course Schedule: Wednesdays 6:30 pm – 9:00 pm, in-person EAS 329

Contact Info:

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Virtual Office Hours: By appointment, Zoom link: <https://stevens.zoom.us/j/7877229014>

Prerequisite(s): BME 506 Biomechanics, BME 505 Biomaterials, familiarity with Differential Equations, Multivariable Calculus, and Statistics (or equivalents)

Corequisite(s): None

Cross-listed with: N/A

### **COURSE DESCRIPTION**

This course will provide students with a practical foundation to approach current computational and experimental methods used in the field of biomechanics. The goal of the course will be to bridge the gap between the theoretical computations and the practical application of experimental techniques. Topics covered will include cartilage and muscle mechanics, response of bone tissue to loading, cardiovascular biomechanics, and human locomotion. These topics will be covered with review of relevant physiology followed by computational and experimental constructs to test theoretical concepts. Students will be required to use statistical analysis software.

### **STUDENT LEARNING OUTCOMES**

Upon completion of the course students will be able to:

- Outcome 1 – Perform detailed computations involving mechanics applied to biological systems across the cellular, tissue, and locomotion levels.

- Outcome 2 – Design and present a detailed proposal for evaluation of a musculoskeletal problem or device.
- Outcome 3 – Perform statistical computations to elucidate experimental results.
- Outcome 4 – Use software that creates and analyzes three-dimensional anatomical models from patient-specific images.

## COURSE FORMAT AND STRUCTURE

This course is weekly on-campus and in person at the assigned classroom. Occasionally, as needed, class will be online on Zoom at: <https://stevens.zoom.us/j/94916943564>. To access course materials, please visit [stevens.edu/canvas](https://stevens.edu/canvas). For more information about course access or support, contact the Technology Resource and Assistance Center (TRAC) by calling 201-216-5500.

### Course Logistics

Most weeks this course will meet in person in the assigned classroom. Students will generally have observed pre-recorded lecture videos associated with that week's topic. Students will take a quiz on that material to begin that week's class. The professor will then give an abstract version of the lecture material prior to students engaging in workshop activities for the remainder of the class. Deviations from this format include weeks in which there will be an in-class exam (two total) or final project presentations (last week). An approximate time breakdown for each class week is as follows:

- **Each week, pre-recorded lectures (~60 minutes)** to be available online for each student to view on own time *prior* to next in-class session.
- **Wednesday in-class session (<90 minutes)** will involve:
  - Class quiz (graded for participation) on pre-recorded material – *10 minutes*
  - Mini-lecture by Professor for book-keeping (class announcements, explanation of logistics, etc...) and short overview of key points in lecture material – *20 minutes*
  - Class exercises <60 minutes
    - Sample problem(s) – either group or individual; review solution as class (Professor or groups will work problems/answers)
    - Group task(s) – TBD, will be assigned day of...example: group will provide own mini-lecture on assigned module from pre-recorded lecture

### Instructor's Online Hours and Virtual Office Hours

I will be available via email and respond as soon as I am available (generally within 24-48 hours) to answer any class-related questions or make an appointment for meetings as requested. If unable to schedule a requested meeting in person, I will offer the opportunity to make an appointment to have an online meeting via Zoom (see link above).

### Classroom Etiquette Guidelines

Whether in person or online, your instructor and fellow students wish to foster a safe learning environment. No matter how different or controversial they may be perceived, all opinions and experiences must be respected in the tolerant spirit of academic discourse. You are encouraged to comment, question, or critique an idea, but you cannot attack an individual. Our differences, some of which are outlined in the University's inclusion statement below, will add richness to this learning experience. Please consider that sarcasm and humor can be misconstrued in online interactions and generate unintended disruptions. Working as a community of learners, we can build a polite and respectful course ambiance.

## TENTATIVE COURSE SCHEDULE

Week # - class date	Topic(s) for in-class	Assignment (due the next Fri or Mon on Canvas)
Week 1 – September 6	<b>NO CLASS</b>	
Week 2 – September 13	<b>Course Introduction:</b> <i>Topics, class layout, expectations</i>	Pre-course survey due
Week 3 – September 20	<b>Cellular Biomechanics I:</b> <i>Atomic force microscopy (AFM)</i>	Project groups assigned
Week 4 – September 27	<b>Cellular Biomechanics II:</b> <i>Viscoelastic models</i> ~See Mimics lecture on own	Mimics Survey due
Week 5 – October 4	<b>Cellular Biomechanics III:</b> <i>Mechanotransduction and bioreactors</i>	HW Assignment #1 due
Week 6 – October 11	<b>Muscles and Movement I:</b> <i>Muscle physiology and mechanics, Muscle-bone interactions</i>	
Week 7 – October 18	<b>IN-CLASS EXAM #1</b>	
Week 8 – October 25	<b>Muscles and Movement II:</b> <i>Muscle physiology and mechanics, Muscle-bone interactions,</i> ~Discuss final project	Mimics Assignment #1 due
Week 9 – November 1	<b>Skeletal Biomechanics I:</b> <i>Trabecular and cortical bone, Fast fracture mechanics,</i> Exam#1 review	Final Project Part #1 due
Week 11 – November 8	<b>Skeletal Biomechanics II:</b> <i>Fatigue fracture mechanics, Soft connective tissues</i>	HW Assignment #2 due
Week 12 – November 15	<b>Clinical Statistics:</b> <i>Good experimental design, Interpreting p-values, Statistical power, Parametric vs non-parametric tests, Special cases</i>	Mimics Assignment #2 due
Week 13 – November 22	<b>NO CLASS (Thanksgiving Week)</b>	
Week 14 – November 29	<b>Locomotion I and II:</b> <i>Standing jump, Running jump, Inverse dynamics, Optimization</i>	Final Project Part#2 due
Week 15 – December 6	<b>IN-CLASS EXAM #2</b>	
Week 16 – December 13	BUFFER, Exam#2 review? (optional attendance)	HW Assignment #3 due
Week 17 – December 20	<b>FINAL PROJECT PRESENTATIONS</b>	Final Project files (presentation, report) due

## **COURSE MATERIALS**

### **Textbook(s)**

Introductory Biomechanics – From Cells to Organisms  
C. Ross Ethier and Craig A. Simmons  
Cambridge University Press  
ISBN 978-0-521-84112-2

### **Other Readings**

Custom lecture materials (e.g., derivations) provided by the Professor.

## **COURSE REQUIREMENTS**

### **Attendance**

Students should attend every class as scheduled or provide notice to the Professor with an acceptable (as deemed by the Professor) reason for absence or lateness. If acceptable, the Professor will excuse absence or lateness and work with the student to make up for the missed material or class obligations.

### **Participation**

Students will be graded in part by participation in class workshop activities. A submission of the student's workup for these activities (as PDF) to Canvas will be due after each class. Thus, regular attendance and class engagement is expected.

### **Homework**

All homework assignments will be uploaded to Canvas as PDF files. There will be a total of three homework assignments associated with lecture material. Additionally, there will be two assignments to be submitted associated with learning the software package Mimics used for finite element analysis of biological structures.

### **Quizzes and Exams**

There will be a quiz to start each class on the material for that week students should have reviewed by viewing the associated pre-recorded lectures. Two in-class sessions during the semester will be used to conduct examinations. Each exam will cover class material from the preceding weeks.

### **Project(s)**

Each student will present and submit a report for a final project at semester's end. Details of the project will be provided by the Professor over the course of the semester.

## **TECHNOLOGY REQUIREMENTS**

### **Baseline technical skills necessary for online courses**

- Basic computer and web-browsing skills
- Navigating Canvas

### **Technology skills necessary for this specific course**

- Live web conferencing using Zoom (occasional remote class session)

- Compiling and sharing documents in Word, Powerpoint (or equivalent platforms)
- Run basic statistical analyses in software package (e.g., Excel, Matlab (as guided in this class))

#### **Required Equipment**

- Computer: current Mac (OS X) or PC (Windows 7+) with high-speed internet connection
- Webcam: built-in or external webcam, fully installed
- Microphone: built-in laptop or tablet mic or external microphone

#### **Required Software**

- Current or first previous major release of Chrome, Firefox, Edge, or Safari browser
- Microsoft Office (Word, Excel, PowerPoint)
- Statistical Software Package (e.g., Microsoft Excel, MATLAB Statistical Toolbox, R,.....)
- Matlab
- Mimics for FEA (to be downloaded/installed through Stevens teamdynamix, see Canvas instructions)

## **GRADING PROCEDURES**

#### **Assignments: 20% total grade – ~4% per assignment**

Expectations for assignments (5 total – 3 for lecture material, 2 for Mimics) are for you to clearly and neatly present your work. Typed work is generally preferred, and is good practice for professional submissions, but 'neatly' handwritten assignments when appropriate are acceptable. Assignments are due online by 11:59pm on designated days. **They should be in pdf format.** Late assignments will result in up to 10% reductions per day late at discretion of Professor. Please make sure you include the honor code statement and sign the end of each assignment. Problems being solved should state assumptions and show all major steps in calculations.

#### **Exams: 30% of total grade – 15% each for two in-class exams**

These exams are to be done individually without external assistance, unless otherwise directed, and may be either online or in-person (depends on real-world circumstances and discretion of Professor).

#### **Participation (includes Attendance): 20% of total grade**

Class attendance will be monitored. If you run into any issues and must miss class, please contact me as early as possible so I may excuse the absence (no attendance penalty) that I can help you navigate that week's course agenda. **Expectations are that all students will conduct themselves professionally in class. That includes no internet surfing, social media, e-mailing, texting, or creating disruptions during class.** Class participation will also be a part of this grade as it contributes to your overall learning. For evaluating participation, you may be asked to do sample problems, participate in group activities, answer prompted (e.g., poll) questions, fill-out surveys, present or discuss assigned content, or take short in-class quizzes. You will receive 'credit' for this work based on online submission of your work the same day. Full credit will be given for each class based on 'satisfactory' completion according to discretion of Professor and/or grader.

**Final Project: 30% of total grade – Report and Presentation**

You will have a to work on a final project that will be due at the end of the semester. The project will include a report and presentation of a 'theoretical' proposal to evaluate a solution for a musculoskeletal problem. The proposal will be for an experimental paradigm or specific device that improves biomechanical function. The presentation will be given in-class during the final week of classes. The report will be due on CANVAS during the Final Exam period.

***\*All 'final' grading will be done at the Professor's discretion***

**Late Policy**

Each class deliverable due in class or to be submitted to Canvas is subject to a 10% per day penalty at the Professor's discretion, pending student consultation with the Professor explaining the need for an extension on any deliverable to be graded.

**Academic Integrity**

- Graduate students in 500-level courses are bound by the Graduate Student Code of Academic Integrity, while undergraduate students in those courses have special provisions that have been agreed upon by the Senior Vice Provost for Graduate Education and the Honor Board.

**Generative AI Technologies**

Use of AI programs (e.g., ChatGPT) must be declared by the student for any submitted works that include such content. Procedures for creating the content and what material is used and how should be clearly articulated pending discussion with the Professor over the course of the semester. Students can always use AI programs to help generate ideas and brainstorm. However, you should note that the material generated by these programs may be inaccurate, incomplete, or otherwise problematic. Beware that use may also stifle your own independent thinking and creativity. You may not submit any work generated by an AI program as your own. If you include material generated by an AI program, it should be cited like any other reference material.

\*Any plagiarism or other form of cheating will be dealt with under relevant Stevens policies.

**Undergraduate Honor System**

Enrollment into the undergraduate class of Stevens Institute of Technology signifies a student's commitment to the Honor System. Accordingly, the provisions of the Stevens Honor System apply to all undergraduate students in coursework and Honor Board proceedings. It is the responsibility of each student to become acquainted with and to uphold the ideals set forth in the Honor System Constitution. More information about the Honor System including the constitution, bylaws, investigative procedures, and the penalty matrix can be found online at <http://web.stevens.edu/honor/>.

The following pledge shall be written in full and signed by every student on all submitted work (including, but not limited to, homework, projects, lab reports, code, quizzes and exams) that is assigned by the course instructor. No work shall be graded unless the pledge is written in full and signed.

***"I pledge my honor that I have abided by the Stevens Honor System."***

Students who believe a violation of the Honor System has been committed should report it within ten business days of the suspected violation. Students have the option to remain anonymous and can report violations online at [www.stevens.edu/honor](http://www.stevens.edu/honor).

### **Graduate Student Code of Academic Integrity**

All Stevens graduate students promise to be fully truthful and avoid dishonesty, fraud, misrepresentation, and deceit of any type in relation to their academic work. A student's submission of work for academic credit indicates that the work is the student's own. All outside assistance must be acknowledged. Any student who violates this code or who knowingly assists another student in violating this code shall be subject to discipline.

All graduate students are bound to the Graduate Student Code of Academic Integrity by enrollment in graduate coursework at Stevens. It is the responsibility of each graduate student to understand and adhere to the Graduate Student Code of Academic Integrity. More information including types of violations, the process for handling perceived violations, and types of sanctions can be found on the [Office of Graduate Academics web page](#).

### **Special Provisions for Undergraduate Students in 500-level Courses**

The general provisions of the Stevens Honor System do not apply fully to graduate courses, 500 level or otherwise. Any student who wishes to report an undergraduate for a violation in a 500-level course shall submit the report to the Honor Board following the protocol for undergraduate courses, and an investigation will be conducted following the same process for an appeal on false accusation described in Section 8.04 of the Bylaws of the Honor System. Any student who wishes to report a graduate student may submit the report to the Senior Vice Provost for Graduate Education or to the Honor Board, who will refer the report to the senior vice provost. The Honor Board Chairman will give the Senior Vice Provost for Graduate Education weekly updates on the progress of any casework relating to 500-level courses. For more information about the scope, penalties, and procedures pertaining to undergraduate students in 500-level courses, see Section 9 of the Bylaws of the Honor System document, located on the Honor Board website.

## **EXAM CONDITIONS**

Exams are taken within in-class sessions. They will either be in-person with written work-ups on the provided paper exams or over Zoom with PDF upload of each exam question solution. The format will be determined anew each semester at the discretion of the Professor based on number of students in the class and procedural continuities from previous semesters. Students are provided with the full class time (2.5 hours) to complete the exam with the expectation it should be completed within 2 hours. Thus, those needing time and a half accommodation are expected to complete within 3 hours and thus receive an additional hour (3.5 hours total).

## **ACCOMMODATIONS**

Stevens Institute of Technology is dedicated to providing appropriate accommodations to students with documented disabilities. The Office of Disability Services (ODS) works with undergraduate and graduate students with learning disabilities, attention deficit-hyperactivity disorders, physical disabilities, sensory impairments, psychiatric disorders, and other disabilities to help students achieve their academic and personal potential. They facilitate equitable access to the educational programs and opportunities offered at Stevens and coordinate reasonable accommodations for eligible students. These services are designed to encourage independence and self-advocacy with support from the ODS staff. The ODS staff will facilitate the provision of accommodations on a case-by-case basis.

For more information about Disability Services and the process to receive accommodations, visit <https://www.stevens.edu/student-diversity-and-inclusion/disability-services>. If you have any questions please contact the Office of Disability Services at [disabilityservices@stevens.edu](mailto:disabilityservices@stevens.edu) or by phone: 201.216.3748.

### Disability Services Confidentiality Policy

Student Disability Files are kept separate from academic files and are stored in a secure location within the Office of Disability Services. The Family Educational Rights Privacy Act (FERPA, 20 U.S.C. 1232g; 34CFR, Part 99) regulates disclosure of disability documentation and records maintained by Stevens Disability Services. According to this act, prior written consent by the student is required before our Disability Services office may release disability documentation or records to anyone. An exception is made in unusual circumstances, such as the case of health and safety emergencies.

## INCLUSIVITY

Stevens Institute of Technology believes that diversity and inclusiveness are essential to excellence in academic discourse and innovation. In this class, the perspective of people of all races, ethnicities, gender expressions and gender identities, religions, sexual orientations, disabilities, socioeconomic backgrounds, and nationalities will be respected and viewed as a resource and benefit throughout the semester. Suggestions to further diversify class materials and assignments are encouraged. If any course meetings conflict with your religious events, please do not hesitate to reach out to your instructor to make alternative arrangements.

You are expected to treat your instructor and all other participants in the course with courtesy and respect. Disrespectful conduct and harassing statements will not be tolerated and may result in disciplinary actions.

### Name and Pronoun Usage

As this course includes group work and class discussion, it is vitally important for us to create an educational environment of inclusion and mutual respect. This includes the ability for all students to have their chosen gender pronoun(s) and chosen name affirmed. If the class roster does not align with your pronouns and/or name, please inform the instructor of the necessary changes.

### Religious Holidays

Stevens is a diverse community that is committed to providing equitable educational opportunities and supporting students of all ethnicities and belief systems. Religious observance is an essential reflection of that rich diversity. Students will not be subject to any grade penalties for missing a class, examination, or any other course requirement due to religious observance. In addition, students will not be asked to choose between religious observance and academic work. Therefore, students should inform the instructor at the beginning of the semester if a requirement for this course conflicts with religious observance so that accommodations can be made for students to observe religious practices and complete the requirements for the course.

## MENTAL HEALTH RESOURCES

Part of being successful in the classroom involves a focus on your whole self, including your mental health. While you are at Stevens, there are many resources to promote and support mental health. The Office of Counseling and Psychological Services (CAPS) offers free and confidential services to all enrolled students who are struggling to cope with personal issues (e.g., difficulty adjusting to college or trouble managing stress) or psychological difficulties

Commented [SK1]: @Philip Gehman please review this new stevens syllabus template and email me when you are done.

Commented [SK2]: @Liliana Delman please review this new stevens syllabus template and let me know when you're done. thanks!

Commented [LD3R2]: @Sara Klein reviewed - looks good to me



(e.g., anxiety and depression). Appointments can be made by phone (201-216-5177), online at <https://stevensportal.pointnclick.com/confirm.aspx>, or in person on the 2<sup>nd</sup> Floor of the Student Wellness Center.

## EMERGENCY INFORMATION

In the event of an urgent or emergent concern about your own safety or the safety of someone else in the Stevens community, please immediately call the Stevens Campus Police at 201-216-5105 or on their emergency line at 201-216-3911. These phone lines are staffed 24/7, year-round. For students who do not reside near the campus and require emergency support, please contact your local emergency response providers at 911 or via your local police precinct. Other 24/7 national resources for students dealing with mental health crises include the National Suicide Prevention Lifeline (1-800-273-8255) and the Crisis Text Line (text "Home" to 741-741). If you are concerned about the wellbeing of another Stevens student, and the matter is *not* urgent or time sensitive, please email the CARE Team at [care@stevens.edu](mailto:care@stevens.edu). A member of the CARE Team will respond to your concern as soon as possible.