Syllabus

BMED 4754/6754: "Computational Biomaterial and Tissue Mechanics"; 3 credits

Undergraduate and Graduate Course

Fall 2026: MW 12:30-1:45 1103 Whitaker

Instructor Information

Instructor	Email	Office Hours & Meeting Link
Scott Hollister 2102 UAW	scott.hollister@bme.gatech.edu It is preferred if you send messages to me via Canvas Inbox	Mon/Wed; 1:45-3pm also, by arrangement

Note on Office Hours: ***I welcome you and highly encourage you to use office hours!*** **Even if you would like to discuss topics in biomedical engineering outside the homework assignment, please stop by. If you cannot make the scheduled office hours, please reach out to me (for example in class or on Canvas) and I can arrange other times.**

General Information

Description - General

This class focuses on computational tissue and biomaterial mechanics modeling, which also includes computational modeling of medical device tissue interaction. Tissues and biomaterials exhibit complex nonlinear solid and fluid behavior, and computational methods are needed to model this behavior. At the same time, tissue-implant interaction is recognized to play a major role in medical device performance, and the FDA increasingly urges device manufacturers to use computational modeling as part of the device development and regulatory approval process. Image-based tissue modeling includes creating surface STL models from medical image data as well as creating volumetric models for simulation, including solid and fluid modeling. Simulation includes developing constitutive models, also known as material properties. Biological tissues require advanced constitutive models that account for large deformation and nonlinearity. This requires that we study continuum mechanics to develop such constitutive models. For computational modeling, we will utilize software widely used in tissue modeling research, predominantly Simpleware, Mimics and FEBio. Requirements for the course will include homework covering software as well as continuum mechanics, a mid-term covering the continuum mechanics portion of the course, and a final computational project to be performed using combinations of the class software.

Pre- &/or Co-Requisites

Pre-Requisite is BME 3410 Intro to Biomechanics and one of either CS 1371 Computing for Engineers *or* CS 1301 Intro to Computing. Students will perform symbolic math calculations for continuum mechanics and use optimization algorithms to fit constitutive models to experimental data. Students may either use MATLAB or Python to complete the symbolic math and optimization calculations for Homeworks 4, 5 and 6 . All other homework will be completed using FEBio and/or Simpleware ScanIP.

Texts (all available as PDFs):

All notes will be posted on Canvas. Reference texts that you may use as supplements, but are not required:

Nonlinear Solid Mechanics, Gerhard Holzapfel, (2000)
Cardiovascular Solid Mechanics: Cells, Tissues and Organs, Jay Humphrey, (2002)

Also FEBio manuals are available for free at febio.org

Software to Download:
FEBio Software Suite (FEBio Studio): (febio.org)
Synopsis ScanIP (available on BME cloud server via mycloud.gatech.edu)
Mimics Materilaise Student Version (available on BME cloud server via mycloud.gatech.edu)

Course Goals and Learning Outcomes

The goal of this course is for students to learn how to create, analyze, perform and interpret computational models of tissue biosolid and biofluid mechanics, as well as biomaterials and medical devices. In addition, due to the complex mechanical behavior of biological tissues and biomaterials, students will learn continuum mechanics which is the basis for performing nonlinear simulations of tissue, biomaterial and medical device behavior. Upon completion of this course, students will be able to:

- Construct surface STL models and volumetric Finite Element simulation models using patient image data
- Apply a nonlinear finite element code (FEBio) to perform simulations of tissue and biomaterial mechanics
- Describe continuum mechanics principles as a basis for analyzing nonlinear and large deformation behavior of tissues and biomaterials
- Apply advanced constitutive models including nonlinear elasticity, nonlinear viscoelasticity, biphasic, damage and plasticity in finite element simulations to predict tissue and biomaterial mechanical behavior
- Apply inverse modeling procedures to fit tissue and biomaterial experimental results to constitutive models (material properties)
- Evaluate literature studies of tissue and biomaterial mechanics

- Interpret and use FDA guidelines for use of computational modeling to help assess medical device safety and efficacy

Course Requirements & Grading

Course requirements are split into three major categories: 1) Homework (**45% of grade**), 2) Mid-Term (**25% of grade**), and 3) Final Computational Project and Report (**30% of grade**). The difference between the undergraduate and graduate portion of the course will be that undergraduate students will be given specific datasets to fit to constitutive models for Homeworks HW6, HW7 and HW8 (highlighted below). Graduate students will be expected to extract experimental datasets for tissues or biomaterials from the literature to fit to experimental data for Homeworks HW6, HW7, and HW8. Graduate students will be expected to read the paper, describe the test methods, and explain the strengths and weaknesses of the approach.

Assignment	Due Date	Weight (Percentage, points, etc)
Homework 1	September 9	5%
Homework 2	September 16	5%
Homework 3	September 28	5%
Homework 4	October 12	5%
Homework 5	October 19	5%
Homework 6	October 26	5%
Mid-Term Exam	November 2	25%
Homework 7	November 16	5%
Homework 8	November 23	5%
Homework 9	December 2	5%
Final Project	December 14	30%
Grade deadline	December 21	

Description of Graded Components

Grading will be split into three major components: 1) Homework worth 45% of the final grade, 2) Mid-Term exam worth 25% of the final grade and 3) the final computational project and written report worth 30% of the final grade. Homework will focus on computational homework problems, done with software including FEBio, Simpleware and either MATLAB or Python, as well as some written homework on continuum mechanics. The Mid-term will be a written exam in class covering continuum mechanics and nonlinear elasticity. Finally, the computational project will use FEBio and if desired some image processing software like ScanIP to perform a computational modeling project on a topic of the students' interest in tissue mechanics, biomaterials, and/or medical devices. In addition to the computational simulation, a written project will be required introducing the problem, methods used, results and a discussion of the results. The written project will follow the format and recommendations of the FDA guidance document on computational modeling.

Grading Scale

Your final grade will be assigned as a letter grade according to the following scale:

A 90-100%
B 80-89%
C 70-79%
D 60-69%
F 0-59%
According to policy, grades at Georgia Tech are interpreted as follows:

A Excellent (4 quality points per credit hour)
B Good (3 quality points per credit hour)
C Satisfactory (2 quality points per credit hour)
D Passing (1 quality point per credit hour)
F Failure (0 quality points per credit hour)
See http://registrar.gatech.edu/info/grading-system for more information about the grading system at Georgia Tech.]

Course Materials

Course Website and Other Classroom Management Tools

All course material will be available on Canvas. You may find the auxiliary texts available at the Georgia Tech library. All communication if possible should be done through Canvas. Required written assignments will be submitted on Canvas.

Course Text

There is no course text. Material will consist of instructors' notes posted on canvas. Manuals for all software may be downloaded with the software. Auxiliary texts cited above are available at from the GT library website.

Course Expectations & Guidelines

Attendance and Participation

It is expected that students attend lectures, as there is your chance to glean additional information on course content through questions. The instructor encourages students to actively participate in class and ask question concerning the material. **Use of Mobile Devices**

Please silence all mobile devices during class to avoid disrupting the classroom environment.

Health-Related Considerations

It is expected that the instructor and students are responsible regarding health issues. If you test positive for contagious conditions for example including the flu, COVID-19 or RSV, please DO NOT attend class to risk spread. If you need to miss class due to health related issues, please inform the instructor and remote access to lectures will be provided through Teams. More information about health issues and related Georgia Tech policy may be found at: https://health.gatech.edu/.

Academic Integrity

Georgia Tech aims to cultivate a community based on trust, academic integrity, and honor. Students are expected to act according to the highest ethical standards. For information on Georgia Tech's Academic Honor Code, please visit http://www.catalog.gatech.edu/policies/honor-code/ or http://www.catalog.gatech.edu/rules/18/.

Any student suspected of cheating or plagiarizing on a quiz, exam, or assignment will be reported to the Office of Student Integrity, who will investigate the incident and identify the appropriate penalty for violations.

Statement on the Use of AI for the Course

Use of AI will continue to expand. It is especially useful in researching the literature regarding tissue and biomaterial mechanics. Students are encouraged to utilize AI in the capacity to review literature for projects. These programs may include ChatGPT, Microsoft Co-Pilot, etc. If you use AI to help perform literature reviews for you project, please cite it as a reference source, for example as: Example citation (APA style):

- **In-text citation:** (Microsoft, 2023)
- **Full reference list entry:** Microsoft. (2023). Copilot [Large Language Model]. https://copilot.microsoft.com/

Please be award that material generated by AI programs may be inaccurate or incomplete, and always consider using additional sources.

Collaboration & Group Work

The Mid-term exam and the final computational project are expected to be done on your own. You may interact with other students and discuss homework projects, but the final homework that you turn in must be your own.

Accommodations for Students with Disabilities

If you are a student with learning needs that require special accommodation, contact the Office of Disability Services at (404)894-2563 or http://disabilityservices.gatech.edu/, as soon as possible, to make an appointment to discuss your special needs and to obtain an accommodations letter. Please also e-mail me as soon as possible in order to set up a time to discuss your learning needs.

Extensions, Late Assignments, & Re-Scheduled/Missed Exams

If you develop illness or other circumstances that prevent you from participating in quizzes, homework assignments, or design presentations, please let me know as soon as possible. Quizzes and homework assignments will be rescheduled.

Student-Faculty Expectations Agreement

At Georgia Tech we believe that it is important to strive for an atmosphere of mutual respect, acknowledgement, and responsibility between faculty members and the student body. See this Georgia Tech handbook page https://catalog.gatech.edu/rules/21/

for an articulation of some basic expectations that you can have of me and that I have of you. In the end, simple respect for knowledge, hard work, and cordial interactions will help build the environment we seek. Therefore, I encourage you to remain committed to the ideals of Georgia Tech while in this class.

Additional Course Policies

If the institute decides to go to shift to online classes/digital learning days due to, for example, inclement weather, lecture will continue online using Canvas and Teams as planned during the semester. If digital learning days fall on the date of the Mid-term examination, this will be rescheduled.

Campus Resources for Students

Please see the following website for access to resources that cover these aspects of student life: https://counseling.gatech.edu/content/campus-resources-0. This site includes mental health resources, career development resources, Office of Disability Services, Student diversity resources, Victim advocacy resources, Campus Recreation and the Georgia Tech Police Department. If you experience any issues that may affect your performance in the course, please feel free to speak to me concerning these issues. Also, please feel free to approach and contact me concerning any issues related to the course or related to computational biomechanics research in general, as well as general career questions in biomedical engineering. I welcome student interaction and questions during the semester.

Calendar – Schedule of Topics (Note: Day HW Assigned Given in calendar; Due dates are given below and in section on Course requirements and Grading)

Date	Day	In Class Discussion Topic
August 24	Monday	Class Overview; Syllabus **Lecture 1**: Computational Modeling, Device Development & FDA Regulation; FEBio website overview

		Next Lecture Preview Assignment: 1. View "Welcome to the Knowledgebase" https://febio.org/knowledgebase/ 2. Review webinar "Introduction to FEBio Studio" https://febio.org/knowledgebase/webinars/introduction-to-febio-studio/
August 26	Wednesday	**Lecture 2**: FEBio Studio Overview, Febio text file overview, Simple Mesh Creation/Analysis;
August 31	Monday	**Lecture 3**: Finite Element Overview and Basic Theory **Next Lecture Preview Assignment on Contact Modeling FEBio:** 1. View "Contact Modeling in FEBio webinar" https://febio.org/knowledgebase/webinars/webinar-contact modeling-in-febio-studio/ **HW 1 Assigned**: Simple Elastic Model Creation and Analysis in FEBio
Sept 2	Wednesday	**Lecture 4**: Contact Modeling in FEBio
Sept 7	Monday	**No class – Labor Day**
Sept 9	Wednesday	**Lecture 5**: Image Segmentation and STL Model Creation in Simpleware **HW 1 Due** ; **HW 2 Assigned**: Contact Modeling in FEBio
Sept 14	Monday	**Lecture 5**: Image Segmentation and STL Model Creation in Simpleware, Mimics, Snap ITK and 3D Slicer; **Lecture 6**: Creating FE Models Directly in Simpleware;
Sept 16	Wednesday	**Lecture 7**: Creating STL Based Models in FEBio Studio; **HW 2 Due; HW 3 Assigned**: Segmentation and STL model creation in FEBio

Software Use for Modeling and Segmentation

Sept 21	Monday	**Lecture 8**: Continuum Mechanics: Index Notation;
Sept 23	Wednesday	**Lecture 9**: Continuum Mechanics: Finite Deformation;
Sept 28	Monday	**Lecture 10**: Alternative Stress Tensors **HW 3 Due**; **HW 4** Assigned Index Notation; Symbolic matrix calculations in MATLAB or Python

Continuum Mechanics & Constitutive Models

Sept 30	Wednesday	**Lecture 11**: Linear and Nonlinear Elasticity **HW 5 Assigned**: Finite Deformation/Alternate stresses; Symbolic math calculations in MATLAB or Python
Oct 5	Monday	**No Class, Fall Break**
Oct. 7	Wednesday	**Lecture 11**: Linear and Nonlinear Elasticity

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Oct. 12	Monday	**Lecture 12**: Nonlinear Elasticity Fitting in MATLAB and Python **HW 4 Due**
Oct. 14	Wednesday	**Lecture 12**: Nonlinear Elasticity Fitting in MATLAB and Python
Oct. 19	Monday	**Lecture 13**: Isotropic Nonlinear Elastic Finite Element Modeling in FEBio – **HW 5 Due; HW 6** Nonlinear Elasticity Fitting in MATLAB or Python → Undergrad students assigned dataset; Graduate students choose experimental dataset from literature
Oct. 21	Wednesday	**Lecture 13**: Anisotropic Nonlinear Elastic Finite Element Modeling in FEBio
Oct 26	Monday	**Lecture 14**: Nonlinear Elastic Parameter Optimization in FEBio **HW 6 Due**: Nonlinear Elasticity Fitting in MATLAB
Oct. 28	Wednesday	**Lecture 15**: Nonlinear Viscoelastic Theory Exam Review
Nov. 2	Monday	**Exam in class on Continuum Mechanics**
Nov. 4 Modeling from	Wednesday	**Lecture 16**: Quasilinear and Reactive Viscoelasticity in FEBio **HW 7 Nonlinear Elasticity Parameter Optimization Assigned** → Undergrad students assigned dataset; Graduate students choose experimental dataset literature **Next Lecture Assignment: "Webinar on Biphasic Materials"** https://febio.org/knowledgebase/webinars/webinar-on biphasic-materials-part-1/

Combined Software Modeling and Constitutive Models

Nov.	9	Monday	**Lecture 17**: Biphasic Theory, Modeling and Parameter Optimization in FEBio
Nov.	11	Wednesday	**Lecture 18**: Continuum Damage Mechanics and **Lecture 19**: Plasticity Modeling in Febio
Nov.	16	Monday	**Lecture 20**: Computational Fluid Dynamics Modeling in FEBio **HW 7 Due**; **HW 8 Assigned**: Nonlinear Viscoelasticity Modeling in FEBio → Undergrad students assigned dataset; Graduate students choose experimental dataset from literature
Nov.	18	Wednesday	**Lecture 21**: Fluid-Structure Interaction Modeling in FEBio; Final Project Discussion
Nov.	23	Monday	**Lecture 22**: Cardiovascular Modeling Applications using FEBio **Homework 8: Nonlinear Viscoelasticity Due; HW 9 Simple CFD Model Assigned;**
Nov.	25	Wednesday	**No Class, Thanksgiving Recess**
Nov.	30	Monday	**Lecture 23**: Orthopaedic Modeling Applications using FEBio
Dec.	2	Wednesday	**Lecture 24**: Tissue Adaptation/Growth Modeling in FEBio; **HW 9 Simple CFD Model Due**
Dec.	7	Monday	Last Day of Class: **Extra time reserved for topic lecture or Project Discussion**

Final Project Due: **Monday, Dec. 14** at 11:59pm.