**EGRB 604: Biomechanics – Spring 2024**

**VCU Department of Biomedical Engineering**

**Instructor: Carrie L. Peterson, PhD**

\**Email*: [clpeterson@vcu.edu](mailto:clpeterson@vcu.edu) *Office Hours*: By Appointment

*Office* *Phone*: 804-827-5270

**Location/Time:**

*Lecture*: Tuesday & Thursday 3:30-4:45, Engineering West Hall 103

**Credits:** 3 hours (lecture)

**Prerequisites:** Statics and Mechanics of Materials

Linear Algebra

Differential Equations & Partial Differential Equations (preferred)

**Course Texts:** \**An Introduction to Biomechanics Solids and Fluids, Analysis and Design*

by Jay D. **Humphrey** and Sherry L. O’Rourke: Springer, 2nd edition 2015

*\*Fundamentals of Biomechanics: Equilibrium, Motion, & Deformation*

by **Ozkaya**, Leger, Goldsheyder, Nordian: Springer, 4th edition 2017

*\*Biomechanics: Mechanical Properties of Living Tissues*

By Y.C. **Fung**: Springer, 2nd edition 1993.

**\*AVAILABLE FREE ONLINE THROUGH THE VCU LIBRARY!**

**\*See Text under Files on Canvas**

**Online Requirements:** Canvas

**1. Overview**

Biomechanics is the study of how mechanics reciprocally affects the multiscale structure and function of living systems. For translational applications, the ability to understand, quantify, and model the healthy biomechanical behavior of a living system opens opportunities for diagnosing and assessing pathological states and guiding reparative or assistive interventions. The objectives of this course are to refresh students on the fundamentals of biomechanics (statics, kinematics, and stress-strain relationships) followed by the exploration of the theoretical frameworks and constitutive relations that can be used to mathematically model mechanical behavior in a variety of biological materials including bones, skin, and vascular tissues.

**2. Course Objectives**

* To apply the principles of static equilibrium to the mechanics of joints.
* To understand and mathematically describe the relationship of stress and strain in deformable biological tissues.
* To understand the composition of biological tissues and the influence the components and

microstructure has on biomechanical behavior.

* To understand the utility and limitations of constitutive models.
* To describe and apply classic biomechanical models of archetypal biological tissues, including for bone, various soft collagenous tissue, and vasculature.
* To appreciate the mechanical theory and complexities of biomechanical testing

**3. Evaluation and Grading Procedures**

*Homework:* Homework problems will be assigned weekly and will generally be due on the following Tuesday by the beginning of class. Be sure to show all your work legibly. Answer keys will be posted for your review following the due date. Homework problems are your opportunity to gain mastery of the material. I highly encourage you to work the problems by yourself first before meeting in small groups, if desired.

*Research Topic Written & Oral Presentations:* Working in teams of 2, each group will submit a 5-6 page single-space review of a contemporary biomechanics topic of choice. The paper should include a review of the clinical/scientific importance of the topic, current knowledge and open questions in the field, biomechanical principles and constitutive models being used, relevant description of experimental methods from key studies, pertinent results, and conclusions. Note this is a review paper, so you do not have to propose your own new detailed experiments, but you should conclude with suggestions for avenues of future work. Your team will then prepare a PowerPoint presentation to present on the last day of class.

*Unit Examinations:* Two unit exams will occur as scheduled in the syllabus.

*Make-up Work:* Missed homework assessments or tests may not be given except under prior arrangements with Dr. Peterson for approved extenuating circumstances (e.g., illness treated by a physician) with proper documentation. Make-up work could be different than the original assignment and may include an oral component.

*Regrading:* Any request to regrade a HW or exam question must be made in writing within 1 week of the grade being released. Regrading may result in a higher or lower grade.

*Calculation of Grades:* Final course grades will be determined as follows:

Homework (30%) Research Topic: Written (10%)

Unit Test 1 (25%) Research Topic: Presentation (10%)

Unit Test 2 (25%) **TOTAL (100%)**

90-100 A

80-89 B

70-79 C

60-69 D

< 60 F

**4. Respect for Diversity**

It is my intent that students from all diverse backgrounds and perspectives be well served by this course, that students' learning needs be addressed both in and out of class, and that the diversity that students bring to this class be viewed as a resource, strength and benefit. It is my intent to present materials and activities that are respectful of diversity: gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture. Your suggestions are encouraged and appreciated. Please let me know ways to improve the effectiveness of the course for you personally or for other students or student groups. In addition, if any of our class meetings conflict with your religious events, please let me know so that we can make arrangements for you.

**5. University Policy on Student Conduct in the Classroom**

All students are expected to conduct themselves in an appropriate manner in the classroom. Each student is expected to abide by VCU policies on Student Conduct in the Classroom.

**6. Other General Syllabus Information from the University**

**Campus emergency information**  
Sign up to receive at [**alert.vcu.edu/signup/**](https://alert.vcu.edu/signup/). It is essential to keep your information up-to-date within VCU Alert and to keep your permanent address and emergency contact information current in eServices. VCU uses a variety of communication methods to alert the campus community about emergency situations and safety threats. Learn more about types of alerts at [**alert.vcu.edu/know/typesofalerts.php**](https://alert.vcu.edu/know/typesofalerts.php)

Know the emergency phone number for the VCU Police (828-1234), and report any suspicious activities and objects.

**Class registration required for attendance**  
Students may attend only those classes for which they have registered. Faculty may not add students to class rosters or Blackboard. If students are attending a class for which they have not registered, they must stop attending.

**Honor System: upholding academic integrity**  
The VCU Honor System policy describes the responsibilities of students, faculty and administration in upholding academic integrity. According to this policy, "Members of the academic community are required to conduct themselves in accordance with the highest standards of academic honesty, ethics and integrity at all times." Students are expected to read the policy in full and learn about requirements here: [**https://conduct.students.vcu.edu/vcu-honor-system/**](https://conduct.students.vcu.edu/vcu-honor-system/). Cheating on exams or plagiarism may lead to an automatic zero, failure of the course, and referral to the Honor Council for further investigation and disciplinary action.

**Important dates**  
Important dates for the semester are listed in the VCU Academic Calendar: [**https://academiccalendars.vcu.edu/**](https://academiccalendars.vcu.edu/)

**Attendance and consequences of poor attendance**  
The instructional programs at VCU are based upon a series of class meetings involving lectures, discussions, field experiences, special readings and reporting assignments. Therefore it is important for each student to be in attendance on a regular basis. A student who misses a class session is responsible for completing all material covered or assignments made during the absence. Students having attendance problems should contact their instructor to explain the reasons for nonattendance and to discuss the feasibility of continuing in the course. If the student has fallen so far behind that the successful completion of the course is impossible, the student should withdraw from the course before the end of the first 10 weeks of classes (or as prescribed by the University). If the student continues to miss class and does not officially withdraw from the course, the instructor may withdraw the student for nonattendance with a mark of W before the end of the first 10 weeks of classes or may assign an academic grade at the end. Withdrawals are not permitted after the end of the first 10 weeks of classes. For classes that do not conform to the semester calendar, the final withdrawal date occurs when half of the course has been completed.

**Career Services**  
Looking for ways to tie what you are learning in your class to your future career or professional goals? VCU Career Services provides career planning services for all current VCU students and alumni. Career Services can help students with finding a work-study job on/off campus, resume writing, internship development, interviewing, preparing for graduate school, networking, or job searching,. Students are invited to attend career events and workshops, and schedule individualized career advising appointments. Career Services is located on the ground floor of University Commons, in room 143. For more information and to make a career advising appointment, [**visit the VCU Career Services website**](http://www.careers.vcu.edu/).

**Managing stress**  
Students may experience situations or challenges that can interfere with learning and interpersonal functioning including stress, anxiety, depression, alcohol and/or other drug use, concern for a friend or family member, loss, sleep difficulties, feeling hopeless or relationship problems. There are numerous campus resources available to students including University Counseling Services (804-828-6200 MPC Campus, 804-828-3964 MCV Campus), University Student Health Services (MPC 804 828-8828, MCV Campus 804 828-9220) and the Wellness Resource Center (804-828-9355). 24 hour emergency mental health support is available by calling 828-1234 and asking to speak to the on-call therapist or utilizing the National Suicide Prevention Lifeline (1-800-784-2433).

**Mandatory responsibility of faculty members to report incidents of sexual misconduct**  
All employees, including faculty, department chairs and deans, are required to report any incidents of sexual assault, sexual exploitation and partner or relationship violence to the university's Title IX Coordinator.

Confidential offices which can provide support at VCU are: University Counseling Services (804) 828-6200;

For more information about Title IX, please visit please visit [**https://equity.vcu.edu/**](https://equity.vcu.edu/).

**Military short-term training or deployment**  
If military students receive orders for short-term training or for deployment/mobilization, they should inform and present their orders to Military Student Services and to their professor(s). For further information on policies and procedures contact Military Student Services at 828-5993 or access the corresponding policies.

**Student email standard**  
Email is considered an official method for communication at VCU. Students are expected to check their official VCU email on a frequent and consistent basis (the university recommends daily) in order to remain informed of university-related communications. Students are responsible for the consequences of not reading, in a timely fashion, university-related communications sent to their official VCU student email account. Mail sent to the VCU email address may include notification of university-related actions, including disciplinary action. Students must read this standard in its entirety at [**https://ts.vcu.edu/media/technology-services/content-assets/university-resources/ts-groups/information-security/StudentEmailStandard.pdf**](https://ts.vcu.edu/media/technology-services/content-assets/university-resources/ts-groups/information-security/StudentEmailStandard.pdf)

**Student financial responsibility**  
Students assume the responsibility of full payment of tuition and fees generated from their registration, all charges for housing and dining services and other applicable miscellaneous charges. Students are ultimately responsible for any unpaid balance on their account as a result of the University Financial Aid Office or their third party sponsor canceling or reducing their award(s).

**Students with disabilities**  
Section 504 of the Rehabilitation Act of 1973 and the Americans with Disabilities Act of 1990, as amended, require that VCU provide "academic adjustments" or "reasonable accommodations" to any student who has a physical or mental impairment that substantially limits a major life activity. To receive accommodations, students must register with the Office of Student Accessibility and Educational Opportunity on the Monroe Park Campus (828-2253) or the Division for Academic Success on the MCV campus (828-9782). Please also visit the Student Accessibility and Educational Opportunity website via [**https://saeo.vcu.edu/**](https://saeo.vcu.edu/) and/or the Division for Academic Success website via [**https://das.vcu.edu/**](https://das.vcu.edu/) for additional information.

Once students have completed the registration process, they should schedule a meeting with their instructor (s) and provide their instructor (s) with an official accommodation letter. Students should follow this procedure for all courses in the academic semester.

**Withdrawal from classes**  
Before withdrawing from classes, students should consult their instructor as well as other appropriate university offices. Withdrawing from classes may negatively impact a student’s financial aid award and his or her semester charges. To discuss financial aid and the student bill, visit the Student Services Center at 1015 Floyd Avenue (Harris Hall) and/or contact your financial aid counselor regarding the impact on your financial aid.

**Faculty communication about students**  
VCU instructional faculty, administrators and staff maintain confidentiality of student records and disclose information in accordance with the Family Educational Rights and Privacy Act (FERPA). This means that VCU officials may disclose student record information without the consent of the student in certain situations. To support university operations, for example, VCU officials share information about students with other educational officials as necessary to perform their job duties. FERPA permits this disclosure to school officials who have a legitimate educational interest in the student information. In addition, VCU officials have obligations to report information shared by a student depending on the content of that information, for example, in compliance with VCU’s policy on the duty to report. Unless FERPA permits a certain disclosure, VCU generally requires consent from a student to disclose information from their education record to another individual. You may find additional information on the VCU FERPA website: [**http://rar.vcu.edu/records/family-educational-rights-and-privacy-act/**](http://rar.vcu.edu/records/family-educational-rights-and-privacy-act/).

**7. Schedule**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Week** | **Day** | **Date** | **Topics** | **Text** | **Due** |
| 1 | T | 16-Jan | Introduction, Vectors, Indiceal Notation | **H** 1.1-1.3, **O** 2 |  |
|  | Th | 18-Jan | Applied Statics to Joints I | **O** 5 |  |
| 2 | T | 23-Jan | Applied Statics to Joints II | **O** 5 |  |
|  | Th | 25-Jan | Joints III, Tensor Math | **O** 5 | HW1 |
| 3 | T | 30-Jan | Mech. Stress, Stress Transformation | **H** 2.1-2.4, **F** 2.2 |  |
|  | Th | 01-Feb | Principal Stress & Max/Min Shear Stress | **H** 2.3-2.4 | HW2 |
| 4 | T | 06-Feb | Kinematics | **H** 2.5 |  |
|  | Th | 08-Feb | Mechanical Strain | **H** 2.5 | HW3 |
| 5 | T | 13-Feb | Constitutive Law, Hooke’s Law | **H** 2.6-2.7 |  |
|  | Th | 15-Feb | Axial Extension & Torsion I | **H** 4.1-4.4 | HW4 |
| 6 | T | 20-Feb | No Class |  |  |
|  | Th | 22-Feb | Torsion II & Mohr’s Circle | **O** 14.5 | HW5,Topic Outline |
| 7 | T | 27-Feb | Catch Up & Review |  |  |
|  | Th | 29-Feb | **Test 1** |  |  |
| 8 | T | 05-Mar | Spring Break |  |  |
|  | Th | 07-Mar | Spring Break |  |  |
| 9 | T | 12-Mar | Basic Failure Theories | **O** 14.6-14.10 |  |
|  | Th | 14-Mar | Bone | **O** 15.7, **H** 2.7 |  |
| 10 | T | 19-Mar | Bending I | **H** 5.1-5.3 | HW6 |
|  | Th | 21-Mar | Bending II | **H** 5.1-5.3 |  |
| 11 | T | 26-Mar | Viscoelasticity I | **F** 2.11**, H** 11.4 | HW7 |
|  | Th | 28-Mar | Viscoelasticity II / QLV | **O** 15.1 |  |
| 12 | T | 02-Apr | ECM / Pseudoelasticity / Uniaxial Tests | **F**7.8-.11**, H**1.5,6.2 | HW8 |
|  | Th | 04-Apr | Strain Energy Functions | **H** 6.2, **F** 7.11-.14 |  |
| 13 | T | 09-Apr | Collagen Const. Law & Biaxial Tests | **H** 6.2, **F** 7.11-.14 | HW9 |
|  | Th | 11-Apr | Thin Walled Vessels | **H** 3.4-3.5 |  |
| 14 | T | 16-Apr | Thick Walled Vessels (Linear) | **H** 3.6 | HW 10, Paper Due |
|  | Th | 18-Apr | Nonlinear Vascular Mechanics | **H** 6.5-6.6 |  |
| 15 | T | 23-Apr | Catch Up & Review |  | HW 11 |
|  | Th | 25-Apr | Catch Up & Review |  |  |
| 16 | T | 30-Apr | **Test 2** |  |  |
| 17 | T | 07-May | **Presentation of Topics** |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |