

Medical Biophysics 9530A / BME 9529A

HUMAN BIOMECHANICS WITH BIOMEDICAL APPLICATIONS

1. Course Information

Medical Biophysics 9530A and BME9529A - *Human Biomechanics with Biomedical Applications*: The mechanical properties of biological structures and fluids in relation to function: deformability, strength, and viscoelasticity of hard and soft tissues, modes of loading and failure. Special topics include mechanics of synovial joints, mechanics of hearing, and mechanics of orthopedic implants and joint replacement.

Lectures:

Tuesdays 11:30 am – 12:30 am / NCB-117

Thursdays 11:30 am – 1:30 pm / NCB-117

Tutorial / Laboratory:

Fridays 3:30 pm – 5:30 pm / NCB-293

Prerequisites:

Prerequisite(s): One of Calculus 1000A/B, Mathematics 1225A/B, Applied Mathematics 1413, or an equivalent 1000-level Calculus course; one of Physics 1028A/B, 1301A/B, 1401A/B or 1501A/B, and one of Physics 1029A/B, 1302A/B, 1402A/B, 1502A/B or an equivalent 1000-level Physics course. A 1000-level Biology course is advantageous.

3 lecture hours, 2 laboratory/tutorial hours, 0.5 course.

Senate regulation regarding the student's responsibility regarding requisites:

Unless you have either the requisites for this course or written special permission from your Dean to enroll in it, you may be removed from this course and it will be deleted from your record. This decision may not be appealed. You will receive no adjustment to your fees in the event that you are dropped from a course for failing to have the necessary prerequisites.

2. Instructor and TA Information

Instructors and TAs	Office	Office Hours
Instructor: Dr. Abbas Samani	MSB402	TBD
TAs: <ul style="list-style-type: none"> • Sergio Dempsey • TBD 	TEB 206	TBD

3. Course Syllabus

Expected Learning Outcomes: By the end of the course, students will be able to demonstrate broad understanding of the principles of tissue mechanics. They will

demonstrate how to apply these principles in developing specific diagnostic and therapeutic methods. The students will achieve these abilities through solving problem assignments, tutorials and computer labs.

Aims and Objectives - Biomechanics is a broad topic, drawing on the laws and principles of mechanics across the whole spectrum of biology – from subcellular biology to large organisms and structures. This course is restricted to human mechanical aspects of biology and biophysics. It is geared toward learning the true mechanical behaviour of tissues, organs and some human body systems, and to recognize these qualities when making assumptions, predicting behaviour and solving problems.

Special examples include the orientation-dependent elasticity of skin and its importance to the plastic surgeon, synovial fluid – the magical fluid that lubricates and protects the sliding surfaces of mammalian joints – and interaction between bone and prosthetic material and its impact on the prosthesis longevity. Finite Element Method (FEM) is a numerical technique to solve complex differential equations. To complement the basic mechanics laws and analytical solutions presented in the course, FEM is introduced and some of its applications in biomedicine is discussed.

Our objectives, through assignments, lectures and tutorials, are to demonstrate the basic laws of mechanics, the development of internal stresses in tissues under external load – in order that students will develop skills in integrating the concepts in mechanics for interpreting the behaviour of tissues and anatomical structures. Another objective is to provide exposure to more advanced tools such as FEM software (ABAQUS) to solve complex biomechanics problems.

Learning Outcomes

Knowledge Base	2/2	Life-long Learning	1/2
Interdisciplinarity	2/1	Creative Thinking	2/2
Communication Skills	2/2	Professionalism	2/2

Notation: x/y , where x is the cognitive level (1: Remember/Understand, 2: Apply/Analyze, 3: Evaluate/Create) at which the attribute is assessed and y is the academic level (1: Beginner, 2: Intermediate, 3: Advanced) at which the attribute is assessed.

Approach - Weekly notes should provide a framework for following the lecture presentations. From time to time supplementary text material will be suggested for amplification, and the course OWL will be used as a means of enhancing communication between the instructor and students in the course.

Problem assignments are an integral part of the course; they will be marked soon after submission and discussed in the tutorials. There will be about 7 assignments throughout the course. I invite you to work in groups for the assignments (submitting one assignment per group). Up to two students may submit one assignment, provided that each student has contributed significantly to the assignment. ***Student contribution may be assessed by randomly inviting a few students who submitted group assignments to describe their solutions. Failing to demonstrate basic understanding of assignment solutions may lead to academic penalties.*** Group assignments promote sharing of ideas and improve learning for students of varied talent and academic background.

The problem lab offers an opportunity to work on the assignments with a teaching assistant or the instructor who is available to answer questions. Our role as tutors is to facilitate learning without short-cutting the thinking process.

Course Topics

A. Samani

2 Lecture hr

1. Introduction to Biomechanics

- (a) Objectives, learning outcomes and course structure
- (b) History and applications

A. Samani

1 Lecture hr

2. Biological Tissue Structure

A. Samani

2 Lecture hrs

3. Introduction to Statics

- (a) Free body diagram
- (b) Static equilibrium equations

A. Samani

5 Lecture hrs

4. Elasticity and the Biology of Tissue

- (a) Building blocks of animal tissues
- (b) Elasticity and pure elastic structures
 - Hooke's law (1D and 2D)
- (c) Non-linear elastic materials
- (d) Elasticity of biological tissues
 - Bone, tendon, ligament, skin and blood vessels
 - Composite materials

A. Samani

5 Lecture hrs

5. Soft Tissue Elasticity Measurement

- (a) Measurement of *ex vivo* soft tissue specimens by direct and indirect methods
- (b) Measurement of soft tissues *in vivo* using elastography (strain imaging and elastic modulus imaging)

A. Samani

4 Lecture hrs

6. Tissue Nonlinearity, Viscosity and Viscoelasticity

- (a) Tissue nonlinear behavior: source and modeling
- (b) Combination of elasticity and viscosity in biological materials
- (c) Creep and stress relaxation, spring and dashpot idealizations

A. Samani

1 review lecture hr

7. Midterm Review

Midterm TEST (100 min.) tentatively scheduled on Friday, October 18th in (TBD)

A. Samani

5 Lecture hrs

8. Mechanics of Joints

- (a) Joints with limited movement
- (b) Synovial joints - lubrication of synovial joints and the combination of articular cartilage and synovial fluid
- (c) Temporomandibular Joint mechanics

A. Samani
4 lecture hrs

9. Bone Mechanics and Bone Fractures

- (a) Introduction: Bone mechanical properties and density
- (b) Hard tissue mechanics: Ultimate strength in compression, tension and shear
- (c) Bending and torsion
- (d) Strength of irregular structures (bone)
 - stress concentration in brittle versus ductile materials
 - consequence of geometry for strength in bending

A. Samani
3 lecture hrs / Lab

10. Finite Element Method (FEM)

- (a) Introduction: Theory and practical issues
 - (b) Hard tissue and bone mechanics using FEM
- **Lecture will be held in the VERC Lab (M150)**
 - **Tutorial will be held in the VERC Lab (M150)**

A. Samani
3 lecture hrs

11. Special Topics

- (a) Mechanical Challenges in Replacement Joints
 - Hip replacement
- (b) Middle ear Biomechanics

A. Samani
1 lecture hr

12. Review

FINAL EXAM

Exam Period: December 8-19, 2019

4. Course Materials

Course Notes: Helper notes will be provided for each lecture. Previously used texts are either out of print or not sufficiently comprehensive for this course.

Supplemental Information:

1. Y. C. Fung, Biomechanics, Mechanical Properties of Living Tissues, Second Edition, Springer, 1993
2. V. C. Mow and R Huiskes, Basic Orthopaedic Biomechanics and Mechanobiology, Third Edition, Lippincott Williams & Wilkins, 2005
3. C. R. Ethier and C. A. Simmons, Introductory Biomechanics *From Cells to Organisms*, Cambridge University Press, 2007
4. R.M. Alexander, Animal Mechanics, Second Editon, Blackwell Scientific Publications, 1983
5. Y. C. Fung, N. Perrone and M. Anliker (editors), Biomechanics, Its Foundations and Objectives, Prentice Hall Inc., 1972

Please contact the course instructor if you require material in an alternate format or if any other arrangements can make this course more accessible to you. You may also wish to contact Services for Students with Disabilities (SSD) at 661-2111 x 82147 for any specific question regarding an accommodation.

5. Evaluation:

Midterm I	15%
Final Examination	30%
Assignments (~7)	25%
Project / term paper *	30%

* The project involves in-depth literature review and presentation of a relevant Biomechanics related topic. See additional handouts related to the project component

IMPORTANT NOTES:

- To obtain a passing grade in the course a mark of 50% or more must be achieved in the final examination. A final examination mark <50% will result in a final course grade of 48% or less.
- Assignments may be done in groups of 2 students. In this case, each pair of students has to submit only one assignment and each student will receive identical mark.
- Assignment grades will be posted regularly on the class OWL site. Any errors, or appeals to your scores, must be reported to your instructor within two weeks of their initial posting.

6. Laboratories/Tutorials:

This course involves a problem solving / tutorial lab session every week unless otherwise announced. In this lab, the instructor or TA will present a tutorial or an overview to the weekly assignment to assist students to solve problems given in the assignment. One assignment will involve using a software package and will be held in the VERC computer lab. More details will be given prior to this assignment due date.

7. Examinations: Midterms and Final

- Both the midterm test and final examination will be closed book (closed notes). While the final examination will cover the entire course material, more emphasis will be given to parts that were not included in the midterm test.
- Use of calculators [HP 48G+ or equivalent/less complex] with no relevant data and program in memory will be allowed.
- Exam times will be posted on the course OWL when available. Students needing to make travel arrangements are advised to book a travel date after the end of the examination period. No makeup exams will be given to accommodate travel!

Accommodations for Religious Holidays

When scheduling unavoidably conflicts with religious holidays which a) require an absence from the University or b) prohibit or require certain activities (i.e., activities that would make it impossible for the student to satisfy the academic requirements scheduled on the day(s) involved), no student will be penalized for absence because of religious reasons, and alternative means will be sought for satisfying the academic requirements involved. If a

suitable arrangement cannot be worked out between the student and instructor involved, they should consult the appropriate department chair and, if necessary, the student's Dean.

It is the responsibility of such students to inform themselves concerning the work done in classes from which they are absent and to take appropriate action.

A student who, for either of the situations outlined in paragraph one above (a or b), is unable to write examinations and term tests on a Sabbath or Holy Day in a particular term shall give notice of this fact in writing to his or her Dean as early as possible, but not later than November 15 for mid-year examinations and March 1 for final examinations, i.e., approximately two weeks after the posting of the mid-year and final examination schedule respectively. In the case of mid-term tests, such notification is to be given in writing to the instructor within 48 hours of the announcement of the date of the mid-term test. If a Special Examination is offered as an alternative means to satisfy the academic requirements, the instructor(s) in the case of mid-term tests and the dean in the case of mid-year and Spring final examinations will arrange for special examination(s) to be written at another time. In the case of mid-year and Spring final examinations, the accommodation must occur no later than one month after the end of the examination period involved. It is mandatory that students seeking accommodations under this policy give notification before the deadlines and that the Faculty accommodate these requests.

For purposes of this policy, the University has approved a list of dates which are recognized religious holidays which require members of those religions to be absent from the University; this list is updated annually and is available at Departmental, Deans' and Faculty advising offices.

8. Make-up Policy

Midterm test, final examination and project:

If you are unable to meet a course requirement due to illness or other serious circumstances, you must provide valid medical or other supporting documentation to the Dean's office as soon as possible and contact your instructor immediately. It is the student's responsibility to make alternative arrangements with their instructor once the accommodation has been approved and the instructor has been informed. In the event of a missed final exam, a "Recommendation of Special Examination" form must be obtained from the Academic Counselling office of their home faculty.

For UWO Policy on Accommodation for Medical Illness, see:

http://counselling.ssc.uwo.ca/procedures/medical_accommodation.html.

A student requiring academic accommodation due to illness should use the Student Medical Certificate when visiting an off-campus medical facility, or request a Records Release Form (available in the Academic Counselling office) for visits to Student Health Services. Students seeking academic accommodation on medical grounds for any missed tests, exams, participation components and/or assignments worth 10% or more of their final grade must apply to the Academic Counselling office of their home Faculty and provide documentation. Academic accommodation cannot be granted by the instructor or department.

Assignments:

If you are unable to submit an assignment due illness or other serious circumstances, you must provide valid medical or other supporting documentation to the Dean's office as soon as possible and contact your instructor immediately. If accommodation is approved, while

the student is encouraged to solve the assignment, his/her submitted assignments will be reweighted in order to compensate for the missed assignment's mark. If accommodation is not approved, assignments submitted for evaluation after the due date will be subjected to a late penalty of 10%/day but will not be accepted after marked material has been returned to the class.

Final Examination:

In accordance with Senate Policy, a Special Examination will be held within thirty days of the regular final examination for students who are unable to write the regular examination for medical or other documented reasons. Requests for such a Special Examination must be made to the Associate Dean, Faculty of Science.

Note that if you fail to write a scheduled Special Examination, permission to write another Special Examination will be granted only with the permission of the Academic Counseling Office in exceptional circumstances and with appropriate supporting documents. In such a case, the date of this Special Examination normally will be the scheduled date for the final exam the next time the course is offered.

9. Cheating (Scholastic Offenses)

Cheating

Scholastic offenses are taken seriously and students are directed to read the appropriate policy, specifically, the definition of what constitutes a Scholastic Offense, at the following Web site:

http://www.uwo.ca/univsec/handbook/appeals/scholastic_discipline_undergrad.pdf

Plagiarism

Students must write their essays and assignments in their own words. Whenever students take an idea, or a passage from another author, they must acknowledge their debt both by using quotation marks where appropriate and by proper referencing such as footnotes or citations. Plagiarism is a major academic offence (see Scholastic Offence Policy in the Western Academic Calendar).

All required papers may be subject to submission for textual similarity review to the commercial plagiarism detection software under license to the University for the detection of plagiarism. All papers submitted for such checking will be included as source documents in the reference database for the purpose of detecting plagiarism of papers subsequently submitted to the system. Use of the service is subject to the licensing agreement, currently between The University of Western Ontario and Turnitin.com (<http://www.turnitin.com>).

10. Internet and Electronic Mail:

Students are responsible for regularly checking their Western e-mail and the course web site (<https://owl.uwo.ca>) and making themselves aware of any information that is posted about the course.

11. Accessibility:

Please contact the course instructor if you require material in an alternate format or if any other arrangements can make this course more accessible to you. You may also wish to contact Services for Students with Disabilities (SSD) at 519-661-2111 ext. 82147 for any specific question regarding an accommodation.

12. Support Services:

Office of the Registrar, <http://www.registrar.uwo.ca/>

Student Development Centre, <http://www.sdc.uwo.ca/>

Science and Basic Medical Sciences Counseling, <http://uwo.ca/sci/counselling/>

Engineering Undergraduate Services, <http://www.eng.uwo.ca/undergraduate/>

USC Student Support Services, <http://westernusc.ca/services/>

Students who are in emotional/mental distress should refer to Mental Health @ Western, http://www.health.uwo.ca/mental_health/, for a complete list of options about how to obtain help.

13. Classroom Conduct

Disruptive behaviour will not be tolerated in class. Please respect the rights of your classmates to benefit from the lecture by limiting your conversations to those essential to the class. Students who persist in loud or rude behaviour will be asked to leave and may have their clicker codes disabled for an extended period.

14. Complaints and Suggestions

If you have a concern about something, please let us know. We rely on your feedback. Please contact initially the person most directly concerned; this will usually be your instructor. If that is not satisfactory, or if there is something more general bothering you, talk it over with the Medical Biophysics Department Graduate Chair.

15. Contacting Us

The simplest way to contact the instructor or TAs outside of the lectures is via e-mail using your UWO e-mail account.