

BME 588-ST1 / SYDE 780 – University of Waterloo

Introductory Mechanics of Biomedical and Biological Materials

Draft Syllabus as of July 12th, 2022 (Subject to change at Instructor's discretion at any time)

Classes, Tutorials, Labs and Office Hours:

Session	Day and Time	Location
588/780 Class	Mondays 5:00pm – 7:50pm	E5-6111
780 Grad Meeting	Fridays, 9:00am – 9:50am	E5-6008
Tutorials/Lab	Wednesdays, 1:30pm - 2:20pm	EIT-1015

** Please refer to the term schedule for finer detail and exceptions to the information in the table above. **

Overall Grade Breakdown:

BME 588		SYDE 780	
Mid-term Basic MoDS Test	20%	Mid-term Basic MoDS Test	10%
Bi-weekly Assignments (6)	15%	Bi-weekly Assignments (6)	10%
Case Studies (2)	20%	Case Studies (2)	20%
Laboratory	15%	Laboratory	10%
Take-Home Final Exam	30%	Mini-Review Paper	15%
Total	100%	Technical Mini-Project	15%
		Take-Home Final Exam	20%
		Total	100%

Instructor:

Thomas Willett, PhD, PEng
 Associate Professor, Systems Design Engineering
 Director, Composite Biomaterial Systems Laboratory
 Office: E7-6438

E-mail: thomas.willett@uwaterloo.ca

Video conferencing: MS teams (twillett)

* If you require guidance outside of classes and tutorials in the schedule above, please email Prof. Willett. Meetings on MS Teams can be arranged.

Course Overview from your Instructor:

This course will cover select topics foundational and fundamental to the study of the mechanical behaviour of natural and synthetic biomaterials with a strong emphasis on materials found in medicine. Example biomaterials include polymers, ceramics, metals, composites, human and animal tissues (soft (cartilage, skin, tendon, ligament, etc.) and hard tissues (bone, nacre, antler)). Topics will include (as time and logistics allow) basics of continuum mechanics, structure-function-property (mechanistic) relationships, elasticity,

viscoelasticity, anisotropy, failure criteria, fracture, fatigue, and fundamentals of mechanical testing in the biomaterials and tissues context.

Course Learning Goals and Objectives:

By successfully completing this course, you will be able to competently apply the fundamentals of mechanics of deformable solids, materials science, and biology, towards a) investigating, describing and modeling the mechanical behavior of biomaterials and tissues, b) basic design of load-bearing medical implants for restoring structure-function in biological/physiological systems, and c) investigating and modeling mechanisms of injury and disease in bones and soft tissues.

Intended Learning Outcomes, Activities and Assessments for BME588:

Intended Learning Outcomes Upon completion of this course, you should be able to <i>competently</i> :	Learning Activities	Assessments
A. Explain and exemplify key concepts and principles of Mechanics of Biomaterials and Tissues.	In class learning activities, demonstrations, videos, tutorial explain and exemplify activities, case studies and lab(s)	Case studies, Lab, Test, Take-Home Exam
B. Apply fundamentals of Mechanics of Biomaterials and Tissues towards a) investigating, describing and modeling the mechanical behavior of biomaterials and tissues, b) basic design of load bearing medical implants for restoring structure-function in biological/physiological systems, and c) investigating and modeling mechanisms of injury and disease, especially in bones.	In class learning activities, collaborative tutorials, case studies and lab(s)	Assignments, Case studies, Lab, Test, Take-Home Exam
C. Evaluate your answers, assumptions and simplifications.	Participatory learning activities in class, collaborative tutorial problems, case studies and lab(s)	Case studies, Lab, Test, Exam
D. Document your work appropriately.		Assignments, Case studies, Lab, Test, Exam

CEAB Graduate Attributes for BME 588:

Completing this course will contribute to your development in the following areas:

CEAB Graduate Attribute	Intended Learning Outcome	Assessments
1. Knowledge Base (Applied Level)	A, B	Assignments, Case studies, Lab, Test, Exam
2. Problem Analysis (Applied Level)	A, B,C,D	Assignments, Case studies, Lab, Test, Exam
3. Investigation (Applied Level)	A, B,C,D	Assignments, Case studies, Lab, Test, Exam
4. Design		
5. Engineering Tools		
6. Individual & Teamwork		
7. Communication		
8. Professionalism		
9. Engineering Society and Environment		
10. Ethics & Equity		
11. Economics & Project Management		
12. Life-Long Learning		

Texts and Sources:**Required:**

“Mechanics of Biomaterials: Fundamental Principles for Implant Design” by Pruitt and Chakravartula, Cambridge texts in Biomedical Engineering, ISBN: 978-0-521-76221-2 *** This textbook is available online through the library. Using Knovel, you can download the entire textbook for free!! Also, ~\$120 on Amazon.ca ***

“Biomechanics: Concepts and Computation” by Oomens, Brekelmans and Baaijens, Cambridge texts in Biomedical Engineering, ISBN: 978-0-521-87558-5 *** Available in the Davis Centre library; ~\$60-80 on Amazon.ca ***

Highly Recommended:

“Orthopaedic Biomechanics: Mechanics and Design in Musculoskeletal Systems” by Bartell, Davy and Keaveny *** Also in the library; ~\$200 on Amazon.ca ***

Supplemental:

1. “Mechanics of Materials” by R.C. Hibbler, 10th Edition, Pearson, ISBN: 978-0-13-431965-0
* This text is ubiquitous, available in the DC library. Review Chapters 1 – 10 from MoDS*
2. “Mechanics of Materials” by Meyers and Chawla, Cambridge, *Available in Davis Centre Library*

Detailed Course Schedule (Subject to change at Instructor's discretion at any time):

Week	Date	Deliverables/Assessments/Notes	Class Content (<i>Readings</i>)
0	September 5th	No class, tutorial or grad meeting this week	
1	September 12th	* Survey and MODs assessment quiz (informative only) * No tutorial or grad meeting ☹️	Introduction to the course and subject matter. Maths and Mat. Sci. review. (<i>Pruitt Chapters 1 – 5; Oomens Chapters 1 and 7</i>)
2	September 19th	* Assignment 1 posted	Strain (<i>Pruitt Chapter 6</i>)
3	September 26th	* 780 Mini-Review Paper assigned	Stress (<i>Pruitt Chapter 6</i>)
4	October 3rd	* Assignment 2 posted * Assignment 1 due	Stress continued Basic Elasticity (3D Hooke's Law)
5	October 10th	READING WEEK (No Classes)	
6	October 17th	* Case Study 1 posted	Anisotropy and Cortical Bone (<i>Pruitt Chapter 6; Bartel Chapter 3</i>) Bone Mechanics Workshop (tentative)
7	October 24th	* Mid-term Test in tutorial * Assignment 3 posted * Assignment 2 due	Anisotropy and Trabecular Bone Mechanical Testing Basics (<i>Pruitt Chapter 6</i>)
8	October 31st	* Assignment 4 posted	Non-linearity Elasticity Guest Lecture: Prof. T. Sigaeva (tentative)
9	November 7th	* Case Study 2 posted * Assignment 3 and Case Study 1 report due	Viscoelasticity Soft tissues and Polymers (<i>Pruitt Chapter 7</i>)
10	November 14th	* Assignment 5 posted * Assignment 4 due * 780 Mini-Project assigned	Viscoelasticity, Cartilage and OA, Dynamic Mechanical Analysis (<i>Pruitt Chapter 7</i>)
11	November 21st	* Assignment 6 posted * Case Study 2 report due	Failure Theories 1 Metals, Ceramics and Polymers, (<i>Pruitt Chapter 8.1 – 8.8</i>)
12	November 28th	* Assignment 5 due * Mechanical Testing Lab in tutorial (tentative)	Failure Theories 2 Composites and Cortical Bone (<i>Bartel Chapter 3</i>)
13	December 5th	* Assignment 6 due * Laboratory report due	Stress Concentrations, Notches, Fracture and Fatigue (<i>Pruitt Chapter 8.9 – 8.12, 9 and 10</i>)
Dec 9th to 23rd	SYDE 780: Mini-Review Paper and Technical Mini-Project Due (Date to be determined) All Students: Take-Home Exam Date and Time to be determined		

* The class content and readings given in the table above are a guide. I will be supplementing my lectures and slides with addition content from other sources, which will be noted in the slides.

Deliverables and Assessments:***All Students:*****Assignments**

Six bi-weekly assignments will be given during the term. Assignment will be posted on LEARN and mainly consist of a couple of textbook problems. Assignments are due at/before the start of class two weeks after they are assigned. Please refer to the course schedule and the assignment document once posted on LEARN.

Case Studies

Students will work collaboratively in pairs to conduct some research/investigation, literature review, experimentation, calculations and analysis in order to complete each case study report. Two cases studies are planned for the F2022 term.

Laboratory

If all goes well this term, we will run an in-person mechanical testing laboratory in which students will conduct tests, collect data, conduct calculations and analyses, and write a report.

Open Book Mid-Term Test and Take-Home Final Exam

Both the mid-term test and final exam will be open book. The mid-term test will be held as documented in the schedule and will cover basic mechanics of deformable solids content taught at the beginning of term. The final exam will be a take-home exam during the exam period and cover the content of the entire course. The exam will involve questions on mechanics (for which calculations are required) as well as conceptual and applied “design problem” questions.

780 Students:**Mini-Review Paper**

Graduate students enrolled in SYDE780 will write a mini-review article on the mechanical behaviour of a selected biomaterial or tissue. This will be discussed and assigned early in the term during our weekly 780 meetings.

Technical Mini-Project

Graduate students enrolled in SYDE780 will be assigned a technical mini-project involving the modeling of the mechanical behaviour of a biomaterial or tissue using MatLab. This will be discussed and assigned later in the term during our weekly 780 meetings.

Course Communications:

To facilitate communication, we will use these three electronic means of communication:

- Email
- LEARN
- MS Teams

When communicating with fellow students and Prof. Willett, you are expected to use professional practices, including respectful, clear messaging.

Email:

All course email should follow the following guidelines:

- All emails must be sent using your official UW email account.
- Address your email appropriately and be professional.
- Sign your email with your first and last name, and your student number. If you use a name different from your name as shown on QUEST, please include both.
- Assume 24-48 hours for a response to your email. I am usually faster than this.
- Email should be used for brief questions that can be answered quickly. Please make an appointment to speak with Prof. Willett on MS Teams for detailed discussions/explanations.

LEARN:

Course content will be delivered using LEARN - <http://learn.uwaterloo.ca>. Prof. Willett intends to maximize use of the functionality of the LEARN platform this year.

The course LEARN site will provide:

- Lecture slides and notes
- Informational materials (e.g., deliverable instructions, resource materials, course updates, course calendar, course contacts).
- Electronic drop boxes for course deliverable submissions (assignments, cases studies, laboratory report, mid-term, final exam).

MS Teams:

Online students will attend classes, tutorials, the laboratory and the mid-term test on MS Teams. All registered students will be invited to join this channel at the start of term. Classes, tutorials and the laboratory will be recorded on and posted to the channel.

Rules:**In-Person Classes in the days of COVID-19:**

- Students **MUST NOT** attend class if they are ill, have been in close contact with someone who is ill, or have travelled outside of Canada within the past 14 days.
- Wearing of face-covering/mask is a requirement in common use areas on campus and must be worn in the classroom/lab.
 - As such, no food is allowed to be consumed during the class, beverages are allowed. Best to drink using a straw.
 - When a student asks or answers a question it may be difficult for them to be heard if they are asking from the back of these large classrooms while wearing a mask. A student may briefly lower their mask to ask/answer the question and then the mask must be replaced.
- Students are expected to practice frequent hand hygiene (handwashing with soap and water or use of hand sanitizer) before coming to class.
- Students must maintain physical distancing while entering and exiting the classroom/lab. Classes have been scheduled with a one-hour break between them in the same room; students can enter and exit the room at their leisure.
- Sanitizing wipes are provided in all classrooms with scheduled classes. Students are encouraged to use a wipe to sanitize their chair and desk prior to class starting. Wipes must be disposed of in the waste receptacles upon leaving class.

Attendance, Late or Missed Deliverables:

Attendance will be noted (and considered towards your final grade in the course, if necessary).

Late or missed deliverables, tests and exams will receive a **mark of zero (0%)** towards the final grade in this course.

Class Room Etiquette: Appropriate professional tone and presentation are expected on all student submissions, tests and examinations. This is done to maintain academic integrity, as well as to help you develop strong professional practice skills.

Academic Integrity: We are all expected to know and follow the University of Waterloo's policies relating to Academic Integrity and Inclusive Classroom Environments. Students are expected to be courteous and respectful of others, and mindful that a classroom is a shared working space with the primary goal of learning course material. Please minimize unnecessary distractions – but I do understand that we are all hooked to our smartphones, so just be courteous and respectful, i.e. turn your ringer and sounds volume down. If for some reason you arrive late, then enter quietly and move quietly to the nearest vacant seat when it is appropriate to do so.

Absence Due to Special Circumstances or Illness

Let me know in advance if you need to be away due to special circumstances. If the event conflicts with scheduled activities (lecture, laboratory, test, exam), then verification of the reason for absence is needed. In the event of illness that prevents attendance, participation or submission of deliverables, a Health Services Verification of Illness form must be completed by an authorized medical practitioner.

See: <https://uwaterloo.ca/health-services/student-medical-clinic/services/verification-illness>

Also refer back to the section “Deadlines and Late Penalties”.

Academic Integrity Policy:

It is expected that within this course, the highest standards of academic integrity will be maintained, in keeping with UW's Policy 71, “Student Academic Discipline Policy.” While all aspects of Policy 71 apply to all UW courses, it is each student's responsibility to avoid:

- **Plagiarism**, “which is the act of presenting the ideas, words or other intellectual property of another as one's own...properly acknowledged use of sources is an accepted and important part of scholarship” (UW Policy 71).
Plagiarism will not be tolerated. If you are caught plagiarizing, you will receive a failure in this course and will most likely be expelled from your program. Follow conventional rules regarding citations, referencing and generally giving credit where it is due. This includes references for figures taken from other sources. If you are not up-to-speed on academic integrity, now is the time to educate yourself.
- **Misrepresentation**, “lying, submitting or presenting false research [findings]...This includes, but is not limited to, actions such as: concocting research [test] or lab results; misrepresenting the date or time of submission” (UW Policy 71).

All referenced work in reports must be appropriately cited, including websites. If there are any questions whatsoever, feel free to contact the course instructor about any possible grey areas.

Students are strongly encouraged to review UW's Academic Integrity "For Students" webpage.
www.uwaterloo.ca/academicintegrity

*** NOTE REGARDING INTELLECTUAL PROPERTY:** Students must not distribute to the public domain any lecture notes, slides, tests, exams or any other material that I provide without prior written permission. This is a matter of academic integrity and avoidance of copyright infringement. Copyright might be held by Prof. Willett, the textbook publishers and/or other publishers.

Resources:

AccessAbility Services: AccessAbility Services (A.A.S.) is the University's centralized office for the provision of academic accommodations for students with a known or unknown disability, illness, or condition. Even if students are unsure of whether they qualify for A.A.S. support, an A.A.S. consultant can talk them through next steps, and refer them elsewhere if appropriate.
[Link [AccessAbility Services](#)].

SYDE-BME Required Syllabi Content regarding Course and Departmental Expectations

Guiding Principles for our SYDE-BME Community (faculty, staff, and students):

1) Be compassionate. 2) Be accountable. 3) Be patient. 4) Be safe and healthy.

Compassionate and respectful communication: Most online communication between the Department and students will be done through LEARN and/or email. Students are reminded that they should now use their email account name@uwaterloo.ca. Include an academic signature with your full name, program, student ID. We encourage you to include your preferred pronouns (he/him; she/her; they/them).

Scheduling of Synchronous (live) online course events: Due to the recent lockdown, all University of Waterloo course components will be delivered online, until further notice. Hopefully, we will be able to resume our in-person activities later in January, 2021. To build and maintain supportive teaching environments, instructors may use the time slots (EDT) scheduled "in-class" hours to hold "live-stream" events such as lectures, tutorial help sessions, group activities, and open office hours. To accommodate different time zones, different working/studying conditions and limitations in internet access, all critical course components, including lectures and student support must be made available in asynchronous formats. Any timed component (for example: a test or quiz) must take time zone and internet availability into account.

SYDE-BME COMMENT ON ACCOMMODATION: We respect that our SYDE-BME students are independent adult decision-makers, with many opportunities to partake in activities that might be in time conflict with academic deadlines and deliverables. Along with the right to make adult decisions comes the responsibility and accountability for those decisions and any outcomes.

The University of Waterloo's policy on accommodation for missed deliverables pertains to verifiable health matters, and highly unfortunate events (for example: family tragedies). The Department of Systems Design Engineering follows University of Waterloo's general policy: students who self-elect to forgo a deliverable receive a "0" for that deliverable. It is preferred practice so that fairness is maintained for members of the same

class/course by avoiding preferential treatment, and so that instructors are not burdened with having to create extra quizzes, deliverables, etc. It also reflects professional practice, as failing to show up to work and missing deadlines can be very costly to the company and individual (for example: not submitting a contract proposal, or design review on time). **Please read the policy here:** [[Link Accommodation due to illness](#)]

SYDE-BME Academic Priorities over Co-op Interviews: With asynchronous schedules, students should be able to arrange co-op interviews that do not conflict with major deliverables (for example: timed course midterms, final exams). For deliverables with longer time windows (for example: 24-48 hours or more), students must manage their time for deliverables and co-op interviews accordingly. If a co-op interview conflicts with a short deliverable time window (for example: 1-3 hours), then students MUST follow the CECA procedure for rescheduling the interview: [[Link CECA rescheduling co-op interviews](#)]

Compassionate Accommodation: If you are facing challenges that are affecting more than one course contact the Associate Chair Undergraduate (email: sydeunde@uwaterloo.ca) or the Director of BME (email: sdbmedir@uwaterloo.ca). They will review your case and coordinate a reasonable and fair plan in consultation with appropriate others (for example: instructors, Department Undergraduate Studies Committee, Chair, AccessAbility Services, Engineering Counselling services, Registrar's Office).

Faculty of Engineering Required Content for Course Outlines

Faculty of Engineering website: [[Link Academic Support and Policies](#)].

Academic Integrity: In order to maintain a culture of academic integrity, members of the University of Waterloo community are expected to promote honesty, trust, fairness, respect, and responsibility. [Check Academic Integrity website for more information. Link [Office of Academic Integrity](#)].

Discipline: A student is expected to know what constitutes academic integrity (see link above) to avoid committing an academic offence, and to take responsibility for their actions. A student who is unsure whether an action constitutes an offence, or who needs help in learning how to avoid offences (for example: plagiarism, cheating) or about expectations for group work/collaboration should seek guidance from the course instructor, academic advisor, or the undergraduate Associate Dean. Relevant documents include:

- University of Waterloo Policy 71 [[Link Policy 71 Student Discipline](#)].
- Academic Penalty Guidelines [[Link Policy 71 Penalty Guidelines](#)].
- Assessment of Unauthorized Collaboration: [[Link Assessment of Unauthorized Collaboration](#)].

Grievance: A student who believes that a decision affecting some aspect of their university life has been unfair or unreasonable may have grounds for initiating a grievance. Read Policy 70, Student Petitions and Grievances, Section 4. When in doubt please be certain to contact the **Associate Chair Undergraduate or Academic Advisor** who will provide further assistance.

[[Link Policy 70 Petitions & Grievance](#).]

Appeals: A decision made, or penalty imposed under Policy 70 (Student Petitions and Grievances) (other than a petition) or Policy 71 (Student Discipline) may be appealed if there is a ground. A student who believes they have a ground for an appeal should refer to Policy 72 (Student Appeals)

[[Link Policy 72 Student Appeals](#)].