BME 2504 Foundations of Biomechanics
Dr. Kristen Billiar
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kbilliar@wpi.edu – please post general questions on the Discussion Board

Lectures: MT_RF 11-11:50am SL 105
Solution sessions: W 11-11:50am SL105, and day before each exam 4pm –location TBA

Office Hours: 2-3pm daily in SL121-C (corner office). Other times please email for appt.

TA: Ben Cleveland – times and location TBA – based on class response

Grading:
- Quizzes 40%
- Problem Sets 20%
- Project 20%
- Lab 15%
- Class Participation 5%

Required Text: Fundamentals of Biomechanics: Equilibrium, Motion, and Deformation (2nd Ed., 1999) by Nihat Ozkaya and Margareta Nordin

Course Schedule

Part I: Rigid body biomechanics

Lect 1-3 Ch. 1, 2 & 3 Introduction, vectors, forces, moments
Lect 4-9 Ch. 4 Equilibrium, FBDs, COG
Lect 10-13 Ch. 5 Models, approximations, and analysis of biological systems

Group presentation feedback sessions

Part II: Deformable body biomechanics

Lect 14-16 Ch. 6 & 7 Stress, strain and models of material behavior
Lect 17-21 Ch. 9 Properties of biological tissues, viscoelasticity
Lect 22-24 Ch. 8 Multiaxial loading, principal stresses and strains
Lect 25-27 Ch. 8 Failure, torsion, and bending

Supplemental Texts (on reserve in Gordon Library)
- YC Fung, Biomechanics: Mechanical Properties of Living Tissues 1993
- Whitting and Zernicke Biomechanics of Musculoskeletal Injury, 1998
- Knudson, Fundamentals of Biomechanics, 2003
- Luciano, Vander & Sherman, Human anatomy and Physiology, 1983
- Seireg, Biomechanical analysis of the musculoskeletal structure for medicine and sports., 1989
Course Description
This course focuses on the identifying and formulating problems in biomechanics so that they can be solved as relatively simple mechanics problems. Basic principles of Newtonian mechanics, stress, strain and deformation are presented and used to determine the forces in bones, muscles, and tendons and to characterize the material properties of tissues such as skin, tendon, ligament, bone and cartilage. Principles of biomechanics are also applied to the design of medical devices and bioengineered tissues. Topics include forces, moments of forces, free body diagrams, principal stresses, shear stresses and beam loading. Dynamic systems will not be covered.

Recommended courses: BME 2504 is taught at the sophomore level and draws heavily from Newtonian physics (mechanics) and utilizes college-level calculus. Thus, it is expected that all students have taken MA 2051 (Ordinary Differential Equations) or equivalent and either PH 1110 (General Physics – Mechanics) or PH 1111 (Principles of Physics – Mechanics). This course is meant to introduce how concepts of Newtonian physics can be applied to biological systems before or concurrent with the study of classical mechanics (e.g., ES 2501 (Introduction to Static Systems) and ES 2502 (Stress Analysis)). Students who have previously received credit for BME/ME 4504 Biomechanics may not receive credit for BME 2504.

Course Topics Include
<table>
<thead>
<tr>
<th>Vectors</th>
<th>Stress, Strain, and principal axes</th>
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<tbody>
<tr>
<td>Free body diagrams</td>
<td>Constitutive relations/equations of biological tissues</td>
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<tr>
<td>Forces, Equilibrium</td>
<td>Biomechanical testing techniques</td>
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Course Objectives and Outcomes
The objective of this course is to aid each student in making progress in the following areas:
1. learning to apply course material to improve thinking, problem solving, and decision making in analyzing the mechanics of the musculoskeletal system and characterizing the mechanical properties of biological materials using proper assumptions and simplifications
2. gaining factual knowledge about the mechanics of joint systems and biological tissue mechanical properties
3. learning fundamental principles and generalizations of engineering mechanics (e.g., Newton’s Laws, equilibrium, stress, and strain)

At the end of this course, each student should be able to:
1. apply knowledge of advanced mathematics, science, and engineering to solve the problems at the interface of engineering and biology (ABET criterion 3a)
2. identify, formulate, and solve engineering problems (ABET criterion 3e)
3. use the techniques, skills, and modern engineering tools necessary for engineering practice (ABET criterion 3k)

Course Website:
Copies of the course syllabus and schedule as well as homework assignments, solution sets and grades will be available online at my.wpi.edu. If you are registered for the course you will have a link to the website for BME2504 in myWPI. YOU ARE RESPONSIBLE FOR ANNOUNCEMENTS AND ASSIGNMENTS POSTED ON myWPI, CHECK IT OFTEN.

Grading:
• **Quizzes:** 40 percent of the final grade will be based upon the cumulative score from the top 4 of 5 regularly scheduled *closed-book closed-notes* quizzes, i.e., we drop your lowest score so each of your best 4 quizzes is worth 10% of the grade. **IF YOU COME IN LATE, YOU WILL NOT BE ALLOWED ANY EXTRA TIME.** The quiz solutions are provided immediately after the quizzes are collected. Each quiz will cover the material taught the previous Thursday thru Tuesday. **Makeup quizzes:** Makeup quizzes will be administered only in extreme cases (e.g., medical emergency with physician signature or observing a religious holiday).

• **Homework:** 20 percent of the final grade will be based upon the cumulative score of 5 collected homework assignments i.e., each homework is worth 4% of the grade. In order to obtain maximum credit, homework problem solutions must be *neat, clearly presented, easy to follow* and have the *correct units and number of significant digits*. Grading will be weighted heavily towards the work shown, thus the answer should be given in variable form before plugging in the numbers. Each homework assignment will cover the material taught the previous Thursday thru Tuesday. Homework is due at the beginning of class (11am) each Thursday. **Homework solutions will be posted after class to allow students to study the solution before the following quiz thus LATE HOMEWORK WILL NOT BE ACCEPTED FOR GRADING.**

• **Project:** 20 percent of the final grade will be based upon a team project. So that you will not be overburdened, no homework or quiz will be assigned during the project time. The project will be done in teams of three and will be used to assess your understanding of how to formulate a relatively simple static equilibrium problem from a complex human joint. I reserve the right to give different grades for each member of a team. Essentially, you will be assigned a portion of the musculoskeletal system to analyze (e.g., hip joint) and will:

  1. Provide a short summary of the system being studied including anatomical and mechanical information from the literature.
  2. Simplify the system to a tractable problem using assumptions and calculate the forces acting in the system including an analysis of error.
  3. Justify the validity of the assumptions and compare your calculated values with values from the literature. Assess the reasonableness of the values.

A "white paper" summary and a group presentation must be completed so that formative assessment may be provided for your group in a timely manner.

• **Lab:** 15 percent of the final grade will be based upon the score from a laboratory. One lab involving mechanical characterization of a biological material will be performed in groups of three students. Due to limited amount of equipment, each group will perform the lab at a different time over an approximately 10 day period. Student understanding of the lab material will be assessed by a prelab and a short lab report. Each student will learn machine safety and operation using online tutorials and will be required to pass online and practical tests on these topics before being allowed to perform the testing using the sophisticated material tests systems in lab.

• **Class participation:** 5 percent of the final grade will be based upon class participation. Types of participation include answering questions (orally or written), participation in class discussions and demonstrations, and providing feedback.

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**Academic Integrity**

In your *Campus Planner and Resource Guide* (p. 91-92 or www.wpi.edu/Pubs/Policies/Judicial/sect5.html) there is a statement regarding Academic Honesty. You should read and understand this policy and the implications for any violation of that policy. You may work together in groups on homework problems, but *assignments must be completed and submitted individually*. Copying of a solution is *not* acceptable. For written and oral projects, copying text and figures from the Web or from the literature without proper citations will be treated as plagiarism. **As required by WPI, any occurrences of academic dishonesty will be reported to the Department Chair and Dean of Student Life.**

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**Schedule:**
8/24: Physics/mechanics review session - optional
8/27 – 9/6: Project groups meet with professor to discuss project proposal during office hours (required)
8/30: HW#1 due
8/31: Quiz #1
9/7: Project proposal due
9/10: HW#2 due
9/10-9/13: Chalk talks of project approaches
9/13: Project draft due for feedback
9/13: Mid-course evaluations
9/14: Quiz #2
9/20: Project due
9/20-10/1: Labs (each group will go at a separate time on one of those days)
9/24: Pre-lab analysis due
9/27: HW#3 due
9/28: Quiz #3
Oct 4: HW#4 due
Oct 5: Quiz #4
Oct 8: Lab due
Oct 10: HW #5 due (note: Wednesday)
Oct 11: Quiz#5 (last day of class!)

**Students with Disabilities:**

If you need course adaptations or accommodations because of a disability, or if you have medical information to share with me, please make an appointment with me as soon as possible. My office location and hours are listed above. If you have not already done so, students with disabilities, who believe that they may need accommodations in this class, are encouraged to contact the Disability Services Office (DSO), as soon as possible to ensure that such accommodations are implemented in a timely fashion. The DSO is located in Daniels Hall, (508) 831-5235.