Engineering Faculty Document No. 19-22

November 2, 2021

TO: The Faculty of the College of Engineering

FROM: The Faculty of the Weldon School of Biomedical Engineering

RE: New Undergraduate Course, BME 21400, Introduction to Biomechanical Analysis

The Faculty of the School of Biomedical Engineering has approved the following new course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

FROM:

BME 29500 Introduction to Biomechanical Analysis
Sem. 1, Lecture 3, Cr. 3
Prerequisite: ME 27000

This BME 29500 course is currently being taught in Fall 2021 (155).

TO:

BME 21400: Introduction to Biomechanical Analysis
Term Offered: Fall, Lecture 3, Cr. 3
Prerequisites: PHYS 17200 or [ENGR 16100 & 16200];
and [MA 16200 or MA 16600]
Major Restriction: Biomedical Engineering only

Description: The goal of this course is to provide a foundation in biomechanics (analysis of forces, moments, and stresses) that will allow students to quantify the loads in the skeleton as well as design surgical tools and total joint replacements. In addition to the topics on vectors, particle equilibrium, and rigid body mechanics one would expect in a classical mechanics course, biomedical engineers must also have a working knowledge of skeletal anatomy. Consequently, anatomical descriptions and anthropometric data will be incorporated throughout the course. As part of the implant design, students will also be introduced to more advanced topics in mechanics such as Hertz contact theory, shear-lag theory, and composite beam theory.

Reason: This course replaces BME 20400 and its prerequisite, ME 27000, as a core course for BME sophomores as part of our curricular redesign, combining the statics and mechanics concepts with applications directly relevant to the human body. BME students will learn elementary biomechanics that will prepare them to consider the effects of physical forces on biological systems at multiple length scales. These concepts are relevant not only in

biomechanics but also in considering the interaction between tissues and biomaterials or instrumentation, imaging of deformable biological systems, and evaluating the response to external forces within other biomedical engineering applications. This class is currently being taught successfully as a temporary course with an enrollment of 155 and is now being submitted for a permanent course number.

David M. Umulis
Dane A. Miller Head and Professor
Weldon School of Biomedical Engineering

Course Information

- **Course:** BME 21400 – Introduction to Biomechanical Analysis
- **CRN:** 24252
- **Meeting Times:** Monday, Wednesday, Friday 12:30pm – 1:20pm, WALC 3087
- **Instructional Modality:** Face-to-Face
- **Course credit hours:** 3
- **Prerequisites:** [PHYS 172 or (ENGR 16100 & 16200)] and [MA 16200 or MA 16600]
- **Lecture Book**: *Forces, Moments, and Stresses in Biomechanics* (Prepared by the Teaching Team)

Instructor(s) Contact Information

- **Instructor:** Professor Eric A. Nauman
- **Office:** ME 3061A
- **Office Phone Number:** (765) 494-8602
- **Email:** enauman@purdue.edu

- **Office hours, times, and location** – In an effort to ensure that students have the best opportunity to meet with the teaching team and get questions answered, we will determine office hours during the first week of class. Always feel free to email if you have questions outside of class or office hours and, if we cannot explain it by email, we will set up a face-to-face meeting or discuss your questions using a web-based platform. **N.B. Always put BME295 in the subject line of your email – that will make responding much easier for us.**

Course Description

The goal of this course is to provide a foundation in biomechanics (analysis of forces, moments, and stresses) that will allow students to quantify the loads in the skeleton as well as design surgical tools and total joint replacements. In addition to the topics on vectors, particle equilibrium, and rigid body mechanics one would expect in a classical mechanics course, biomedical engineers must also have a working knowledge of skeletal anatomy. Consequently, anatomical descriptions and anthropometric data will be incorporated throughout the course. As part of the implant design, students will also be introduced to more advanced topics in mechanics such as Hertz contact theory, shear-lag theory, and composite beam theory.

Learning Resources, Technology & Texts

The primary resource for the course will be a lecture book, entitled *Forces, Moments, and Stresses in Biomechanics*. That is, perhaps, not the most original title. But the difficulty was that there was no text that covered the combination of mechanics and anatomy that we need to explore in this class. So the teaching team developed a custom lecture book based on those developed in Mechanical Engineering. It incorporates active learning and case studies in an effort to engage students in all the different ways that they learn material. This method has been shown to not only improve grades, but also ensure that students are able to solve problems relevant to their internships, co-ops, research experiences and future jobs.

Learning Outcomes

By the end of the course, you will be able to:

1. Understand solid mechanics and dynamics principles and concepts underlying experimental methods
2. Apply mathematical equations and underlying assumptions of biomechanics to experimental methods
3. Analyze selected biomechanical systems and measurements at a range of biologically relevant length scales
4. Evaluate quality and reliability of assumptions and methods used in selected biomechanics applications

Assignments

You will get feedback on your progress in a number of different ways. First, there will be in class active learning assignments so class participation is expected. Weekly homework problems will be collected and graded and returned with comments. Those problems will often include mechanics and anatomical concepts and are meant to be the foundation of how you learn the material. While the homework sets themselves are only worth 5% of the grade, they will be incorporated into the quizzes and exams. In particular, one or two of the homework problems will be used as the basis for weekly quizzes. There will also be three exams within the semester and a final exam. You can expect a homework problem to show up on each of the exams as well.

Homework (5%): Problem sets will assess understanding and application of biomechanical concepts and equations.

Quizzes (20%): Quizzes are meant to ensure that students learn the concepts from the homework sets and are able to apply that knowledge independently.

In-Semester Exams (10% each*): Exams will assess learning of biomechanics concepts, mathematical equations, simplifying assumptions, anatomy, and knowledge synthesis.

Final Exam (45%*): The final exam will be cumulative, but there is a caveat. See below.

** If your final exam score is better than the average of your In-Semester exams, the percentages will remain as listed. If your In-Semester exam average is higher than your final exam score, then the In Semester exams will count 45% and the Final exam will count 30%.*

Grading Scale

In this class, grades reflect the sum of your achievement throughout the semester. As noted, there is some flexibility in the percentage that the In-Semester and Final exams count towards your final grade. We anticipate that grades will be assigned according to the standard rubric below, but it is possible that there will be a curve. If there is a curve, the rubric below will be a guarantee. The grade breaks may be lowered, but they will not be raised so such a curve can only benefit you. Percentages will be rounded to the nearest 0.1% for this purpose.

A+	A	A-	B+	B	B-	C+	C	C-	D+	D	D-	F
97 - 100%	94 - 96.9%	90 - 93.9%	87 - 89.9%	84 - 86.9%	80 - 83.9%	77 - 79.9%	74 - 76.9%	70 - 73.9%	67 - 69.9%	64 - 66.9%	60 - 63.9%	0 - 59.9%

If suspected academic dishonesty occurs near the end of the course or cannot be resolved before final grade submissions, the instructor may assign a grade of Incomplete until investigations conclude.

Attendance Policy

Students are expected to attend all classes in-person unless they are ill or otherwise unable to attend class. If they feel ill or feel that they have been exposed to a virus, students should stay home and contact the Protect Purdue Health Center (496-INFO). Notes and/or videos will be posted from each lecture to help students who are not able to attend class. But it is also recommended that you contact other students to ensure that you are aware of any changes to assignments or due dates.

Classroom engagement is extremely important and associated with your overall success in the course. The importance and value of course engagement and ways in which you can engage with the course content even if you are in quarantine or isolation, will be discussed at the beginning of the semester.

Only the instructor can excuse a student from a course requirement or responsibility. When conflicts can be anticipated, such as for many University-sponsored activities and religious observations, the student should inform the instructor of the situation as far in advance as possible. For unanticipated or emergency conflicts, when advance notification to an instructor is not possible, the student should contact the instructor/instructional team as soon as possible by email, through Brightspace, or by phone. In cases of bereavement, quarantine, or isolation, the student or the student's representative should contact the Office of the Dean of Students via email or phone at 765-494-1747. Our course Brightspace includes a link to the Dean of Students under 'Campus Resources.

Academic Guidance in the Event a Student is Quarantined/Isolated

If you must quarantine or isolate at any point in time during the semester, please reach out to me via email so that we can communicate about how you can continue to learn remotely. Work with the Protect Purdue Health Center (PPHC) to get documentation and support, including access to an Academic Case Manager who can provide you with general guidelines/resources around communicating with your instructors, be available for academic support, and offer suggestions for how to be successful when learning remotely. Your Academic Case Manager can be reached at acmq@purdue.edu. Importantly, if you find yourself too sick to progress in the course, notify your academic case manager and notify me via email or Brightspace. We will make individualized arrangements based on your particular situation.

Course Schedule

Session	Topic
1	Introduction to the course , history of mechanics, and some basic physiology
2	Units, unit vectors, and force vectors
3	Vector operations, dot products and projections
4	Particle equilibrium in two dimensions
5	Particle equilibrium in two dimensions
6	Particle equilibrium in three dimensions

7	Rigid Bodies – Moments about a point
8	Rigid Bodies – Two dimensions (upper extremities)
9	Rigid Bodies – Two dimensions (lower extremities
10	Exam 1
11	Rigid Bodies – Two dimensions (mechanics of the spine and torso)
12	Rigid Bodies – Two dimensions (methods to reduce the order of the system)
13	Walking and running two dimensions
14	Rigid Bodies – Three dimensions (mechanics of the spine and torso)
15	Rigid Bodies – Three dimensions (lower extremities)
16	Rigid Bodies – Three dimensions (upper extremities)
17	Distributed Loads
18	Centroids and Centers of Mass
19	Simple friction models
20	Exam 2
21	Trusses – method of joints
22	Trusses – method of sections
23	Trusses – problem solving
24	Frames and machines – medical devices
25	Frames and machines – medical devices
26	Frames and machines – medical devices
27	Gait Analysis
28	Forward vs Inverse Dynamics Approaches
29	Internal force-couple analysis in the long bones
30	Internal force-couple analysis in the long bones
31	Internal force-couple analysis in the long bones
32	Exam 3
33	Shear force and bending moment diagrams
34	Shear force and bending moment diagrams
35	Tensile stresses in tendons and ligaments
36	Tensile and compressive stresses in the musculoskeletal system
37	Tension and compression in biomedical materials
38	Pressure vessels – eyes, blood vessels, and the bladder
39	Introduction to shear stress and strain
40	Shear stress in the skeleton
41	Bending Stresses
42	Implant Design – Part 1
43	Implant Design – Part 2
44	Implant Design – Part 3
45	Final Exam (The Ultimate Celebration of Knowledge!)

* Schedule and assignments subject to change. Any changes will be posted in the learning management system.

Classroom Guidance Regarding Protect Purdue

The Protect Purdue Plan, which includes the Protect Purdue Pledge, is campus policy and as such all members of the Purdue community must comply with the required health and safety guidelines. Required behaviors in this class include: staying home and contacting the Protect Purdue Health Center (496-INFO) if you feel ill or know you have been exposed to the virus, properly wearing a mask in classrooms and campus building, at all times (e.g., mask covers nose and mouth, no eating/drinking in the classroom), disinfecting desk/workspace before and after use, maintaining appropriate social distancing with peers and instructors (including when entering/exiting classrooms), refraining from moving furniture, avoiding shared use of personal items, maintaining robust hygiene (e.g., handwashing, disposal of tissues) prior to, during and after class, and following all safety directions from the instructor.

Students who are not engaging in these behaviors (e.g., wearing a mask) will be offered the opportunity to comply. If non-compliance continues, possible results include instructors asking the student to leave class and instructors dismissing the whole class. Students who do not comply with the required health behaviors are violating the University Code of Conduct and will be reported to the Dean of Students Office with sanctions ranging from educational requirements to dismissal from the university.

Any student who has substantial reason to believe that another person in a campus room (e.g., classroom) is threatening the safety of others by not complying (e.g., not properly wearing a mask) may leave the room without consequence. The student is encouraged to report the behavior to and discuss the next steps with their instructor. Students also have the option of reporting the behavior to the Office of the Student Rights and Responsibilities. See also Purdue University Bill of Student Rights.

Academic Integrity

Academic integrity is one of the highest values that Purdue University holds. Individuals are encouraged to alert university officials to potential breaches of this value by either emailing integrity@purdue.edu or by calling 765-494-8778. While information may be submitted anonymously, the more information is submitted the greater the opportunity for the university to investigate the concern. More details are available on our course Brightspace table of contents, under University Policies.

Policy on Presentations, Materials, and Notes: The instructor's presentations and course materials are subject to the instructor's copyright. In addition, notes are "considered to be 'derivative works' of the instructor's presentations and materials, and they are thus subject to the instructor's copyright in such presentations and materials." As such, they cannot be sold or bartered without express written permission from the instructor.

Policy on Academic Dishonesty: Purdue prohibits "dishonesty in connection with any University activity. Cheating, plagiarism, or knowingly furnishing false information to the University are examples of dishonesty" (Section B.2.a of the *Student Regulations*). Furthermore, "the commitment of acts of cheating, lying, and deceit in any of their diverse forms (such as the use of ghostwritten papers, the use of substitutes for taking examinations, the use of illegal cribs, plagiarism, and copying during examinations) is dishonest and must not be tolerated. Moreover, knowingly to aid and abet, directly or indirectly, other parties in committing dishonest acts is in itself dishonest" (University Senate Document 72-18, December 15, 1972).

Suspected academic misconduct will be addressed by the instructor and referred to the Office of Student Rights and Responsibilities (OSRR) for review at the university level. Any violation of course policies as it relates to academic integrity will result minimally in a zero grade for that particular assignment, and at the instructor's discretion may result in a failing grade for the course. In addition, all incidents of academic misconduct will be forwarded to OSRR, where university penalties, including removal from the university, may be considered. Students can report issues of academic integrity that they observe, and may do so anonymously, through the OSRR by calling 765-494-8778 or emailing *integrity@purdue.edu*.

Nondiscrimination Statement

Purdue University is committed to maintaining a community which recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her potential. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. The University believes that diversity among its many members strengthens the institution, stimulates creativity, promotes the exchange of ideas, and enriches campus life.

Accessibility

The teaching team wants you to excel and recognizes that students excel in different ways. We strive to make learning experiences as accessible as possible. If there is an accommodation that will help you learn more effectively, please let us know about it as soon as possible. If it is within our power to provide the accommodation, we will do so. In some cases, Purdue University requires documentation of a particular need so that resources can be allocated. If you anticipate or experience physical or academic barriers based on disability, you are welcome to let me know so that we can discuss options. You are also encouraged to contact the Disability Resource Center at: drc@purdue.edu or by phone: 765-494-1247."

Mental Health/Wellness Statement

If you find yourself beginning to feel some ***stress, anxiety and/or feeling slightly overwhelmed***, try WellTrack. Sign in and find information and tools at your fingertips, available to you at any time.

If you need ***support and information about options and resources***, please contact or see the Office of the Dean of Students. Call 765-494-1747. Hours of operation are M-F, 8 am- 5 pm.

If you find yourself ***struggling to find a healthy balance between academics, social life, stress, etc.*** sign up for free one-on-one virtual or in-person sessions with a Purdue Wellness Coach at RecWell. Student coaches can help you navigate through barriers and challenges toward your goals throughout the semester. Sign up is completely free and can be done on BoilerConnect. If you have any questions, please contact Purdue Wellness at evans240@purdue.edu.

If you're ***struggling and need mental health services***: Purdue University is committed to advancing the mental health and well-being of its students. If you or someone you know is feeling overwhelmed, depressed, and/or in need of mental health support, services are available. For help, such individuals should contact Counseling and Psychological Services (CAPS) at 765-494-6995 during and after hours, on weekends and holidays, or by going to the CAPS office on the second floor of the Purdue University Student Health Center (PUSH) during business hours.

Emergency Preparation

In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control. Relevant changes to this course will be posted onto the course website or can be obtained by contacting the instructor via email or office phone. You are expected to read your @purdue.edu email on a frequent basis.