Course Title: BIOEN 301 – Bioengineering Systems Analysis

Instructor: Lecture: Lewis, TN and Lab: Neils, CM   Credits: 4

UW General Catalog Course Description: Investigates static and dynamic problems that are found in medicine and biology. The students are exposed to real biomedical applications of first- and second-order differential equations. Students analyze current bioengineering and biomedical problems and make measurements of systems that present those problems.

Instructor's Detailed Course Description: Bioengineering 301 looks at the application of engineering principles to living systems. The course has three components. The first component is the lectures which develop methods of engineering analysis from basic principles of physics and applies advanced mathematical methods in calculus and differential equations. The second component is the laboratories where students get hands-on experience with empirical methods in model systems. The third component is the textbook which covers a broad spectrum of living systems and their interaction with the physical world (i.e. "seeing the physics in the biology"). The specific topic for this course is biomechanics and a number of areas within the continuum are covered. The course begins with engineering statics and mechanics, and examining how external applied forces are transmitted to external supports and how they are distributed within rigid bodies. The skeletal system is a useful model where joints act as supports and muscles provide forces. The same analytical methods of free body diagrams and force balances are then applied to fluid systems to derive basic principles and to model the cardiovascular system. The transport concepts developed in fluid systems are then applied to thermal systems. Laboratory assignments illustrate these principles.

Prerequisites by Topic: Biology, Calculus, Computer Programming, Physics

Textbook: *Comparative Biomechanics* by Steven Vogel

Course Objectives: Introduces sophomore bioengineering students to the application of engineering principles to problems in biological systems by using mechanics as an example. The course integrates analytical and experimental techniques to understanding and problem solving in these systems.

Topics Covered:

1. Statics
2. Mechanics of Materials
3. Inflatable Structures
4. Fluid Mechanics
5. Heat Transfer

Class Schedule: Lectures (3 hrs/week) Labs (one 3 hr session per week)

Computer Use: Requires use of computer-based laboratory data acquisition systems. Requires MATLAB programming for complex numerical solutions of analytical systems and data analysis. Requires use of internet to access class notes and supplemental teaching materials.

Laboratory Projects: Laboratory exercises afford the application of engineering analysis to hands-on experimental systems and data collection. Exercises could include structure examination in gross anatomy, and introductory data collection, analysis, and reporting. Theoretical and analytical models are compared to results from model experimental systems (*e.g.*, force determination in structures, steady and oscillatory fluid flow, and diffusive heat transfer).

Course Outcomes and Assessments: BIOEN 301 presents, in interactive lectures, weekly laboratory exercises, and assignments, engineering principles and their application in biological systems. This course addresses certain ABET outcome criteria at a variety of levels.

Specific outcomes in BIOEN 301 and their assessment mechanisms to be used by the department for ABET program assessment are:

(a) *Application of knowledge in mathematics, science and engineering* Lectures teach analytical techniques grounded in science which uses mathematical techniques to arrive at solutions. These analytical techniques are used to make predictions on biomechanical systems modeled in the lab. Students then run experiments and compare analysis to data in their lab reports. For example, heat diffusion theory is taught in lecture. Students complete homework assignments on heat diffusion problems. One lab is geared to analysis of a heat exchanger systems, measurements, and comparison between the two. Students submit a lab report comparing their analysis and experimental results.

(d) *Working in teams*. Laboratory exercises require that students work in groups. Groups set up, execute, and collect data from experiments. Lab reports will be group reports.

(e) *Identification, formulation, and solution of engineering problems.* Class lectures cover the development and application of engineering analysis to the solution of problems in biomechanics. For example, lectures cover truss analysis, and examples of engineering and biological trusses are given in homework and quizzes for the students to solve. Truss analysis is then applied to structures in living systems such as the shoulder.

(f) *Understanding of professional and ethical responsibility* This is covered in two contexts. First, there is discussion on professional and ethical responsibility in the generation and reporting of laboratory data in lab reports. This is assessed in the appropriate use and attribution of data in lab reports. Second, there is discussion on the responsibility when using human subjects. For example, one lab involves students making EMG measurements on the shoulders of fellow students, and in another, students make morphometric measurements on cadavers. As a method of assessment, student will prepare an application for Use of Human Subjects for performing EMG measurements, and the application will be graded in accordance with the standards of the Human Subjects Use Committee of the University of Washington. Students are taught proper etiquette in working in lab with human subjects and report on their experiences. Students are also posed questions on the ethics and cultural sensitivities of the use of human subjects as part of the lab report. This section of the report is graded and discussed in class.

(n) *Measurement and interpretation of data from living and non-living materials and systems* In the labs, students make measurements on materials and systems and/or interpret data. Students turn in a lab report or worksheet for each. For example, in an EMG lab, students collect data on muscle activity for an extended arm supporting different loads.

Additional specific outcomes and their assessment mechanisms (in parentheses) considered of high relevance by the department for BIOEN 301 are: none.

Additional specific outcomes and their assessment mechanisms (in parentheses) considered of medium relevance by the department for BIOEN 301 are:

(b) *Conducting experiments and analyzing and interpreting data.* In labs, students conduct experiments and interpret data. Examples of experiments that may be covered in the class are: digital signal acquisition, electromyography, truss loading, inflatable structures, anatomical measurements, fluid flow, oscillating fluid systems, heat diffusion and heat exchangers. Students submit lab reports detailing their experiments and explaining their results. Students are assessed in their reports on their ability to apply engineering analysis to the physical model system and on their understanding of the limitations of analytical and experimental methods. For example, in a heat transfer lab, students are given heat exchangers of unknown construction and are required to deduce the design based on the experiments they design and conduct. This requires the students to understand and apply the theories of heat exchanger design. Students are assessed on their approach and the results.

(g) *Effective communication.* In homework and exams, students are expected not only to solve analytical problems, but to make their solution methodology transparent. Lab reports are submitted from lab projects and are expected to be clear and concise.

(k) *Using computer and analytical equipment.* A number of homework problems are given which require the use of computer-aided numerical solutions (typically MATLAB). In the lab, computer based data acquisition equipment is used as well as computer programs.

(m) *Application of mathematics, science and engineering to solve problems at the interface of engineering and biology* This entire course is the application of mathematics, science and engineering to problems in biomechanics. All homework and quiz problems are on the topic as well as the labs and lab reports.

Relationship of Course to Departmental Objectives: The course serves to introduce sophomore level BioE students to the application of science and mathematics (engineering analysis) to the solution of problems in biological systems. For example, students learn truss analysis calculate forces in engineering trusses and go into the lab to make measurement on model trusses. Then students take this experience into the anatomy lab while examining the human shoulder to model and estimate loading on muscles and joints. The course also pairs analysis with laboratory experiments to compare and couple theoretical and experimental methods. An engineering approach is emphasized as the procedure for analysis: careful study of the problem, drawing and labeling diagrams, listing relevant principles in mathematical form, thinking about how the physical situation relates to the mathematical expressions, solving equations analytically then numerically, checking dimension and units, and finally examining solutions for reasonability using technical judgment. A major emphasis of the course is how forces interact between and within components of biological systems. This is important because of the interdependence of biochemistry and mechanical loading. The laboratory work is geared for small teams to practice experimental investigation and informal communication as they examine tools and techniques with relevance to a variety of analytical methods. Reporting integrates technical and ethical aspects of theoretical and experimental analysis as well as formal communication skills.

BIOEN 301 complies with departmental objectives by:

- Developing the process of engineering analysis for examining biological systems.
- Coupling analysis with hands-on experimental work.
- Developing the interpersonal skills to communicate problems and solutions effectively with other engineers through group discussion while working in teams.
- Taking ethical issues into consideration in teamwork and solving and reporting bioengineering problems.