BE 172: Bioengineering Laboratory
Spring 2020

General Information & Schedule

Lecture: Monday 10:00-10:50 Warren Lecture Hall Room 2111

Laboratory: Wednesday 9:30-1:00, 2:00-5:30; Thursday 1:30-5:00: Room PFBH 108

Instructors: Dr. Jeff Omens
Room 2004 BSB (School of Medicine), jomens@ucsd.edu
Office Hours: Monday 2:00-3:00 pm

Dr. Pedro Cabrales
Room 182 PFBH, pcabrales@ucsd.edu
Office Hours: TBN

Engineer: Doug Gurevitch, Room 112 PFBH, dgurevitch@ucsd.edu

TAs: TBN
Note: Wednesday 6:00 pm discussion section is optional

Class Web Page: Canvas Learning Management System (Formerly on TritonEd). Weekly handouts are posted on the course WebSite.

Text: Webster JG. *Medical Instrumentation: Application and Design,* 4th ed. 2010 John Wiley & Sons: New York.

References:

- Baura G, *Medical Device Technologies: A System Based Overview Using Engineering Standard.* 2011, Oxford: Elsevier (Academic Press).
- Chien S, et al. [editor], *Clinical Hemorheology: Applications in Cardiovascular and Hematological Disease, Diabetes, Surgery, and Gynecology.* 1987, Boston: M. Nijhoff.
- Cobbold RSC, *Transducers for Biomedical Measurements: Principles and Applications*. 1974, New York: John Wiley & Sons.
- Doebelin EO, *Measurement Systems: Application & Design.* 4th ed. 1990, New York: McGraw Hill.
- Fung YC, *Biomechanics: Mechanical Properties of Living Tissues.* 1981, NY: Springer-Verlag.
- Geddes LA, Baker LE, *Principles of Applied Biomedical Instrumentation*. 3rd ed. 1989, New York: John Wiley & Sons.
- Lieber RL, *Skeletal muscle structure and function: implications for rehabilitation and sports medicine.* 1992, Baltimore: Williams & Wilkins.

Course Objectives (the 4 D's):

(1) Demonstrate the basic concepts of bioengineering design through experimental procedures involving humans, animals and tissues

(2) Design physiological experiments; analyze and interpret data using statistical and error analysis

(3) Develop laboratory skills including maintenance of laboratory records that are accurate and precise

(4) Develop scientific writing skills by preparing formal "brief communications" that describe experimental findings

Schedule/Reading

Wk	Date	Topic	Instructor	Reading
1	3/30	*Hydraulically Coupled Blood Pressure Recording System.* Dynamics of 2nd order systems, frequency response of catheters. Introduction to lab measurement techniques	Omens	Sections 1.1-1.11*, 7.1-7.8*
2	4/6	*Length-Tension in Skeletal Muscle.* Isolated frog muscle mechanics: Isometric contractions	Omens	49-69†, Sections 9.1-9.6§
3	4/13	*Force-Velocity in Skeletal Muscle.* Isolated frog muscle mechanics: Isotonic contractions	Omens	Sections 9.7-9.8§
4	4/20	*Cardiac Mechanics:* Pressure-volume relationships in the heart. Strain softening and residual stress. Finite element modeling	Omens	Chap. 10§
5	4/27	*Nervous System Impulse Conduction using a Bioamplifier.* Compound action potentials from the frog sciatic nerve and properties of a bioamplifier	Omens	Sections 3.1-3.6*, 4.1-4.3*, 5.1-5.3*, 5.10-5.11*
6	5/4	*Viscoelastic Properties of Tissues.* Creep, stress relaxation tests; simple mathematical models	Omens	Sections 2.11-2.14§, 2.1-2.3*
7	5/11	*Hemorheology.* Fluid mechanics of blood	Cabrales	Chaps. 3§; 2,4,5£
8	5/18	*Human Electrocardiogram.* ECG recording with a instrumentation amplifier on fellow students	Cabrales	Sections 4.6*, 6.1-6.8*
9	5/25	**No Monday Lecture**. *Mechanical Testing of Biocompatible Materials.* Compressive, tensile and shear tests of implantable materials.	Cabrales	Chap. 12§
10	6/1	*Mechanical Properties of Arteries*. Experimental design using the techniques learned throughout the quarter. Determine mechanical properties of arteries.	Omens	Chap. 8§
	6/8/20	**FINAL EXAM:** 2 hours only, 9:00 -11:00 a.m.		

* Webster
† Lieber
§ Fung
£ Chien

Grading

75% Lab reports (10% of each report is for the pre-laboratory section)
25% Final Exam
Do not expect a passing grade in the course if you do not turn in 2 or more lab reports.

Grading Policies

Group study and discussion of assignments is allowed and encouraged. Each person in the group is responsible for turning in their own pre-lab, data analysis and lab report for each week; raw data needs to be copied for each person's report since only one set will exist. If duplicate documents (except raw data) are turned in by members of the group, the grade will be divided by the number of students with the same report. In cases of suspected academic dishonesty, the student will be given a copy of the academic conduct code, and the case referred to the appropriate Dean. Generally, the penalty for academic dishonesty is a failing grade.

Roll will be taken each lab session; you cannot turn in a lab report if you did not participate in the lab experiments.

Lab Day Assignments

Each student is enrolled in a lab section on Wednesday or Thursday. You will need to show up to the lab at that time for the entire quarter, and cannot switch sections. Please arrive prepared and on time!

You should divide into working groups of 3 people since there are 8 lab stations. You will work at the same lab station, with the same group, each lab session, for the entire quarter.

Pre-laboratory Preparation

The purpose of the required pre-laboratory preparation is to allow you to become familiar with the experimental techniques to be used and with the concepts underlying the laboratory investigation, and to enable you to conduct the experiment and learn as efficiently as possible during the valuable laboratory time period. At the beginning of the laboratory period, a TA will check your prelab, and then it will be turned in at the end of the lab session for grading. ***Anyone who has not demonstrated adequate preparation for the laboratory will not be allowed to participate.*** It is important to be familiar with the lab exercises before the actual lab, so pre-labs are taken seriously. They will also count for part of the lab write-up score (10% unless otherwise noted). The pre-lab assignment consists of 2 parts: the protocol summary and questions, as described below.

Pre-laboratory Protocol Preparation

Bioengineering experiments usually involve studies on living cells, tissues, or animals. By its very nature, such experimentation is a perturbation of the living preparation from its normal environment. This is quite different from a typical "engineering" or "computational" experiment where the test sample may be, for example, an "inert" metal bar or computer program. In addition, many bioengineering experiments require carefully timed procedures. Thus, it is critically important that the conduct of an experiment is efficient and precise.

Good laboratory technique therefore starts with the preparation of a clear **laboratory protocol**. Accurate record keeping of daily activities, including the date and time of procedures, is essential in an academic or industrial environment, where, for example, you may later desire to lay claim to an important discovery. The protocol should consist of a title, brief introduction (2-3 sentences), followed by a step-by-step protocol. This protocol can be outline or bullet form, and should list all of the steps that will be followed in the lab session. Formulating a step-by-step protocol allows you to plan things more efficiently. For example, if dissection of a tissue takes 30 minutes, that step should be done early to minimize its potential to be a “rate-limiting” step. The protocol may be typed or hand-written.

Pre-laboratory Exercises/Questions

These questions review some of the basic concepts and techniques that will be needed for the lab. Each lab has some form of pre-lab questions. Most are clearly labeled in the weekly handout, otherwise specific instructions will be given. The questions must be completed by *each* person individually in the group and turned in as part of the pre-lab report. TAs will check the pre-labs at the beginning of the lab session. The entire pre-lab assignment, which includes the pre-lab questions and protocol summary, should be 1-2 pages (1-2 sides of a piece of paper) long. Remember to turn in your pre-lab before you leave that day.

Lab Equipment and Supplies

All of the necessary equipment, materials, and supplies will be provided, either in the station cabinet or on the counter. You are responsible for this material and it should be returned at the end of the lab in good condition to the location you found it. If there is anything necessary that is not supplied by the TA at the start of the lab, ask the TA to get it for you. Do not go scrounging around in any of the equipment cabinets. If any equipment or part appears to be malfunctioning, notify a TA.

Laboratory Reports

All reports must be **typewritten (12 pt font minimum size)** and submitted in the appropriate format in order to be graded. Each person in the group should write their own report. None of the text in the report should be the same as anyone else's. Reports are based on data acquired by the group, but plots/figures etc. should be created separately. The complete report should include the 2-page lab report, followed by the raw data (or a copy of it) taken the day of the lab, co-signed and dated by a TA on the day of the lab. Other pages may be requested for particular labs, and should be attached as appropriate.

Reports are to be submitted both via Hardcopy on paper, and electronically via the course web site. All pages of the paper report must be stapled together. Reports held together with paper clips, scotch tape, spit, or similar devices are not acceptable and will not be graded. Reports are due one week after the actual lab as shown on the schedule. Turn in your lab report at the beginning your weekly lab session, 1 week after the actual lab session. Late reports will not be accepted. Electronic submissions should be the same file saved at PDF, including raw data.

The Brief Communication

One form of scientific report is a two-page ***brief communication***. This is the style of lab report we will be using in this course. This format is longer than many abstracts submitted for scientific meetings; a brief communication contains a bit more detail regarding the scientific methods as well as a larger body of data, and a more in-depth discussion of the results and their implications, and may include figures. A typical example of this form of report can be found in *Biophysical Journal* or the *Journal of Biomechanical Engineering*. A sample can be found on the course web page, with extra information on the formatting, figures, etc. Only the first page of this type of report should have the title, names and group header.

Format of Lab Reports

The Brief Communication format of a lab report must include:

Header on first page only:

Title - The title should describe the area of investigation without necessarily giving away the results. Make it interesting enough that someone would want to read the report, but not so detailed. Most scientific publications limit the length of the title.

Names - Include your name **FIRST**, followed by the other members of your group.

Group – Under the names include your Lab day (with AM/PM) and Station number, for example: “Wednesday AM, Station 8”

Introduction - This is where the objective of the study or the hypothesis under investigation should be stated along with a **short** review of relevant background information (i.e., what is already known about the field). For this report it should be about 1/4 of a page of text.

Material and methods - A brief summary of the experimental techniques should be included so that the reader has some idea of how the experiment was performed. In a full-length publication, enough detail should be included so that the reader could duplicate the experiment. However, in an abstract, there is not room for such a level of detail. Assume that the reader is a specialist in the field. The lab handout may be referenced, but not without further explanation (i.e., “We did what the lab manual said” is not an acceptable method). Since this describes work that is completed, it should be worded in the past tense. This should be 1/3 of a page at most.

Results - Include a summary of the data that you obtained. This should include descriptive prose (paragraphs, also in the past tense) that contain or describe the data in graphs or tables. The data that you present should be appropriately reduced from the raw data. For example, if multiple readings were taken, it may be appropriate to determine a mean and standard deviation, or fit a hypothetical relationship. Remember that every data reading has units associated with it; be sure to include units on all plots. Data may be presented in graphical or tabular form if necessary. However, don’t include figures just because they look nice! They should demonstrate some relationship or trend. The text in the results is minimal, it should be mostly figures, tables and numbers.

Discussion and conclusion - A discussion of the data and its relevance to the objective of the lab should be included. What do your findings show and how do they relate to the function of the body? If one set of measurements is bigger, stronger, or faster than another, why are they that way, and what are the implications? Do your findings support or refute other investigators work, and can they explain differences in other experiments? The discussion is worth a large portion of your grade, and is the hardest part to write. It should be 1/2-3/4 of a page long.

References - Include and cite in the appropriate place in the report any references used in writing the report or which relate to your research findings. You should also reference raw data of other groups if you do not get data for some section of the lab and used theirs instead, with prior approval of the instructor or TA.

Page Layout - Include the line borders around the text as shown it the sample. If all else fails, draw them in by hand! The margin widths should be uniform and between 0.5 and 1". Please make plots large enough so that they are legible. Color plots can be an excellent way of getting your point across (but not required).

Grading Criteria for Lab Reports

In the absence of specific guidelines for a particular write-up, the following criteria will be used for grading of the lab reports.

Style / Grammar (15%)

Poor writing reduces the effectiveness of your presentation, makes it difficult for the reader to understand what was done or what was found, and decreases the excitement of your findings. In addition, typographical errors and spelling mistakes (easily avoidable in this modern age by using the spelling and grammar checking features that are available in most word-processing programs), changes in tense, and improper punctuation all indicate oversights by the investigator.

Introduction / Content (15%)

The report should convey a general understanding of subject in the introduction and how measurements relate to the topic of that week's laboratory. The engineering and scientific background should be accurate. Overall content of the report is included here.

Data and Analysis (25%)

If a measurement is requested, the relevant data should be presented. An adequate description of the data and its accuracy and repeatability should be included along with any potential sources of error. Statistical analysis should be included where appropriate. If no data was obtained, either the expected results should be discussed with an explanation of the difficulties encountered, or data from another group should be used and properly referenced.

Figures (10%)

When figures are used to present data they should be clear and readable and in the appropriate style. This includes the proper use of curve fitting and error bars, along with a legible choice of tick marks and labels. Remember that if you fit a set of data to a curve, you have implied that a functional relationship exists and you should discuss this in the text. The figures should also be numbered and have short captions***. Make sure that all figure legends and symbols are clear and legible in the final document.***

Discussion (25%)

This is where the tie between the objective of the lab and the data obtained should be made. A thorough explanation of your findings and its implications in relation to normal or abnormal function of the material is important. Show how these results do or don’t fit with the existing literature. Do they support or refute current theories?

Pre-lab write up: turn in the day of the lab (10%)

Although raw data is not graded, it must be attached behind each 2-page lab report, both for the hard copy and electronic PDF submission.

Laboratory Procedures

Safety Guidelines

The guidelines listed here should not be considered comprehensive, but rather a list of common sense rules to follow for both your safety and good scientific practice.

- Have fun, but behave responsibly.
- No eating or drinking in the labs.
- No bare feet or open sandals.
- Know where the first aid kit, eyewash station, and fire extinguisher are located
- Keep your fingers out of your face and eyes while handling the equipment or chemicals and wash your hands at the end of the lab.
- Report any accident or injury to the TA or instructor.
- Keep your work area clean. Clean up any spills or leaks, try not to spill water on electrical equipment!
- Dispose of tissue sample in the appropriate waste containers, not the sink or trash can.
- Dispose of glass, syringes, needles and razor blades in a *"sharps"* container.

- Remove broken glass with a dustpan and brush right away.
- **THINK! It's not just your grade**.

In Case of an Emergency, call:

(Use an on-campus phone for 911, cell phones will go to the SDPD and they are not familiar with the campus)

Fire, Police, Medical:	911
Poison Center	3-6000
Environmental Health & Safety	4-3660
First Aid (Student Health):	4-3300

Use and Care of Laboratory Animals

Bioengineering research frequently uses humans and animals to study physiological function. Therefore the bioengineer must face the issue of the use of animals in research. While many benefits have been derived from this type of research, not all animal experiments have necessarily yielded useful results, and cases of abuse do unfortunately exist. The use of animals in science is a controversial subject that people must decide for themselves. Listen to both sides, rather than just making a blanket assumption about the issue from one source. Alternative techniques such as mathematical, computational, or tissue culture models should always be considered whenever experiments involving animals are contemplated. Bioengineers, by way of their multidisciplinary training, are in the unique position to be able to take advantage of all of these tools in their research.

In order to safeguard the health and well being of animals used at research facilities, national guidelines have been drawn up. In addition to local and state regulations, there are several federal laws aimed at protecting animals in the United States. The Endangered Species Act of 1973 desires "to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved, to provide a program for the conservation of such endangered species and threatened species, and to take such steps as may be appropriate to achieve the purposes of the treaties and conservation of wild flora and fauna worldwide." Regulatory authority is vested in the Fish and Wildlife Service.

While this act is aimed primarily at wild animals, animals used for research, exhibition, or as pets are covered under the Animal Welfare Act (AWA) which was enacted in 1966. It gave responsibility for regulating dogs, cats, hamsters, guinea pigs, rabbits, and nonhuman primates held by research facilities to the United States Department of Agriculture (USDA). The act was amended in 1970 to include other warm-blooded animals and again in 1976 to cover control of live animal transportation. The most recent revision in 1985, "Improved Standards for Laboratory Animals Act", requires regular exercise for dogs and an appropriate environment to insure the psychological well being of both dogs and nonhuman primates. This act also mandates that each institution have an animal care committee that approves research protocols, monitors projects and enforces administration of drugs. All research facilities must have an attending veterinarian who is involved in care of the animals and must be a member of the animal care committee. Proper pre-surgical and post-surgical care must also be provided, and multiple procedures must be restricted. The USDA was further instructed to develop regulations guaranteeing humane care and treatment of animals including minimal standards of handling, housing, feeding, veterinary care, and transportation.

The Regulatory Enforcement and Animal Care (REAC) unit of the Animal and Plant Health Inspection Service (APHIS) is responsible for enforcement of these standards. The REAC maintains five field offices throughout the United States and conducts regular unannounced inspections. The APHIS may issue a warning notice, offer a stipulation agreement, or prosecute the institution of any violations that are found.

For more information on the Care and Use of Laboratory Animals, see the link on the course web page.