BE172 Spring 2018

Instructors:  Dr. Jeff Omens
             Room 2004 BSB (School of Medicine), jomens@ucsd.edu
             Office Hours: Monday 3:00-4:00
Dr. Pedro Cabrales
             Room 182 PFBH, pcabrales@ucsd.edu
             Office Hours: TBN

Engineer:  Doug Gurevitch, Room 112 PFBH, dgurevitch@ucsd.edu
TAs:  Gabby Colvert
      Lauren Severance

Class Web Page:  http://cmrg.ucsd.edu/Courses/be172.  Weekly handouts are posted on the Web.


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
## BE172 Course Outline

### Schedule/Reading

<table>
<thead>
<tr>
<th>Wk</th>
<th>Date</th>
<th>Topic</th>
<th>Instructor</th>
<th>Reading</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4/2</td>
<td>Hydraulically Coupled Blood Pressure Recording System. Dynamics of 2nd order systems, frequency response of catheters. Introduction to lab measurement techniques</td>
<td>Omens</td>
<td>Sections 1.1-1.11*, 7.1-7.8*</td>
</tr>
<tr>
<td>3</td>
<td>4/16</td>
<td>Force-Velocity in Skeletal Muscle. Isolated frog muscle mechanics: Isotonic contractions</td>
<td>Omens</td>
<td>Sections 9.7-9.8§</td>
</tr>
<tr>
<td>4</td>
<td>4/23</td>
<td>Nervous System Impulse Conduction using a Bioamplifier. Compound action potentials from the frog sciatic nerve and properties of a bioamplifier</td>
<td>Omens</td>
<td>Sections 3.1-3.6*, 4.1-4.3*, 5.1-5.3*, 5.10-5.11*</td>
</tr>
<tr>
<td>5</td>
<td>4/30</td>
<td>Cardiac Mechanics: Pressure-volume relationships in the heart. Strain softening and residual stress. Finite element modeling</td>
<td>Omens</td>
<td>Chap. 10§</td>
</tr>
<tr>
<td>6</td>
<td>5/7</td>
<td>Viscoelastic Properties of Tissues. Creep, stress relaxation tests; simple mathematical models</td>
<td>Omens</td>
<td>Sections 2.11-2.14§, 2.1-2.3*</td>
</tr>
<tr>
<td>7</td>
<td>5/14</td>
<td>Hemorheology. Fluid mechanics of blood</td>
<td>Cabrales</td>
<td>Chaps. 3§; 2,4,5£</td>
</tr>
<tr>
<td>8</td>
<td>5/21</td>
<td>Human Electrocardiogram. ECG recording with a instrumentation amplifier on fellow students</td>
<td>Cabrales</td>
<td>Sections 4.6*, 6.1-6.8*</td>
</tr>
<tr>
<td>10</td>
<td>6/4</td>
<td>Mechanical Properties of Arteries. Experimental design using the techniques learned throughout the quarter. Determine mechanical properties of arteries.</td>
<td>Omens</td>
<td>Chap. 8§</td>
</tr>
<tr>
<td></td>
<td>6/11/18</td>
<td>FINAL EXAM: 2 hours only, 9:00 -11:00 a.m.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Grading Policies**
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.

- Group study and discussion of assignments is allowed and encouraged
- Each person in the group is responsible for their own pre-lab, data analysis and lab report for each week
- Raw data is the same for each group member and can be copied.
- 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**
- Arrive on your assigned day to the lab for the entire quarter, no changing sections.
- Typical stations have 3 students at one of 8 lab stations. Work with same people the entire quarter.
Lab Equipment, Supplies, Computers
• All supplies and equipment are provided, just bring a notebook, prelab, pencil, calculator
• Windows PC are for use in the lab during experiments, and for data analysis when the lab is open
• PCs have some specialized software for this course, and most software is also in the student computer room in PFBH
• Printing for this course in our room: laser and inkjet, for this course only!

Pre-laboratory Protocol Preparation
• Good laboratory technique starts with the preparation of a clear laboratory protocol
  • Title
  • Brief introduction (a couple sentences)
  • Step-by-step protocol, including sketches, steps in the lab, data to be acquired, etc.
  • Pre-lab “questions” to be answered.
  • Pre-lab report counts for part of your lab score, and will be tuned in before leaving your lab session.
  • Typically 1-2 pages (1-2 sides of a piece of paper) long.
Written Reports: the brief communication

- 2-page “abstract” summarizing your experiments, results and conclusions.
- Similar to scientific abstracts or engineering white-papers
- Includes some methods, but should be more focused on the results and in particular, interpretation of the results (the hard part!)
- Details in on-line syllabus, and example on the web site

---

**Characteristics of a Second-Order Pressure Measurement System**

Jeffrey M. Cohen, Richard Lisher and Peter Chen

Group: Friday AM, Station #3

**Introduction:** The introduction should start with a general statement about the importance of the study, for example “Accurate measurements of systemic pressure in patients is important because...”. This should be followed by the objective of the study or the hypothesis under investigation, in one sentence. There should also be a short review of relevant background information, i.e., what is already known about the field, general background on the topic, etc. Finally, a summary of how the results of the experiments help answer the hypothesis or complete the objective should be included, for example “In order to determine the inter-relationship between both metrics, tests were performed by varying...”. Make sure all text is no smaller than 12 pt, single spaced. For these reports, the introduction should be no longer than one paragraph at most 1/3 of a page.

**Materials & Methods:** A brief summary of the experimental techniques and protocols should be included so that the reader has some idea 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. Information that is important would be a number of repetitions, range of test cases, environmental variables, data manipulation information. The lab handbook may be referenced, but not without further explanation. For example, “As described in detail in the lab manual [1], data were collected in 10 uniform increments (0.1 mm) starting at a length of 10 mm.” is acceptable. Since this describes work that is completed, it should be avoided in the past tense. Details on the materials and methods can be found in the referenced lab manual, hence this section should not be very long, again one paragraph of 10-12 lines.

**Results:** Include a summary of the data that you obtained. This should include descriptive prose (paragraphs, also in the past tense) that contains or describes the data in graphs or tables. The data that you present should be appropriately reduced from the attached raw data. Remember that every data reading has units associated with it; be sure to include the correct units on all data and place. Descriptions presented table item, but figures are usually more informative. Color can be very useful on plots, however, don’t include figures just because they look nice. They should demonstrate some relationship or trend. Each figure should have a short description with it. For example “The pressure-volume relations shown in Figure 1 demonstrate...” is much more effective than “The pressure-volume relations are shown in Figure 1.” without the second sentence.

**Discussion and Conclusions:** The discussion section is probably the most important section of your report and also the hardest to write! Notice that the discussion is a worth a percentage of the score, so spend some time on it. It should be about 1/4 of a page in length. Include discussion of the data and its relevance to the objective of the lab. Typically the results section contains just that, the results (with some brief interpretation). The discussion is used to interpret the results and present the conclusions as related to the original hypothesis or objective. What do your findings show and how do they relate to the function of the body? Is one set of measurements bigger, stronger, or faster than another? Why are they, and what are the implications? Do your findings support or refute other investigators work, and can they explain differences in other experiments? What are limitations of the experiment and how could it be improved?

**References:** Include and cite the appropriate place in the report any references used in writing the report or which relate to your research findings. For example, “The Frank-Stauffager mechanism was important in the experiment [2].” You should also reference any data from other groups if you do not get data for some sections of the lab and used theirs instead with prior approval of the instructor or TA.

Note about borders: The line borders such as those shown here are easily applied in Microsoft Word with the Format, Borders and Shading tool, using page border. The border is a required part of the write up (get used to it, many scientific submissions require specific items such as this).

**Reference:**

[2] Lecture notes from Dr. Lisher, 4/02.

---

**Written reports: the brief communication**

- 2-page “abstract” summarizing your experiments, results and conclusions.
- Similar to scientific abstracts or engineering white-papers
- Includes some methods, but should be more focused on the results and in particular, interpretation of the results (the hard part!)
- Details in on-line syllabus, and example on the web site

---

**Written reports: the brief communication**

- 2-page “abstract” summarizing your experiments, results and conclusions.
- Similar to scientific abstracts or engineering white-papers
- Includes some methods, but should be more focused on the results and in particular, interpretation of the results (the hard part!)
- Details in on-line syllabus, and example on the web site

---

**Written reports: the brief communication**

- 2-page “abstract” summarizing your experiments, results and conclusions.
- Similar to scientific abstracts or engineering white-papers
- Includes some methods, but should be more focused on the results and in particular, interpretation of the results (the hard part!)
- Details in on-line syllabus, and example on the web site
Other Information on Web site

Lab report grading criteria

- AVERAGE
- BELOW AVERAGE
- COMPLAIN UNTIL YOU GET A BETTER GRADE
- THE DEAN GETS INVOLVED
- FILE LAWSUIT
- IN COMPLETE DENIAL

Lab Safety Guidelines

Use and care of laboratory animals
Blood pressure measurement systems

Fluid-filled pressure system
- Temperature stable
- Inexpensive
- Disposable catheters

Micro-tipped manometer
- Best frequency response
- Small diameter
- Small diameter
- Very expensive

Sphygomanometer
- Simple, inexpensive
- Only gives max and min values

Non-invasive tonometer
- Low accuracy for waveform
- Movement susceptibility
Ideal characteristics of a pressure measuring system

Accurately reproduce the time-varying blood pressure

- Little distortion
- Easy to use and calibrate, patient comfort
- Record up to 6 harmonics above the base frequency (in this case heart rate)

Human system: base HR is around 1-2 Hz
System should have a “bandwidth” of at least 12 Hz, 20 would be better
Lab 1: Characterize a fluid-filled blood pressure system

**Goals:** Compare frequency response and resonance characteristics in 3 different catheters

Our system uses the following components:
System will be limited by the component with the worst frequency response: the catheter itself.

Electronics typically have good frequency response (KHertz-MHz), compared to mechanical components like a tube, < 1 KHz.

Characterize the system with a Bode plot: amplitude and phase.

- Highly Underdamped 2\textsuperscript{nd} order system
- Less Underdamped 2\textsuperscript{nd} order system
System characteristics

A “good” system will have $|V_{out}/V_{in}| = 1$, and a phase shift of 0°.

Systems will perform better at low frequencies.

Characterize system by its bandwidth: larger the bandwidth the better.

Also determine natural frequency of the system from this plot.
Experimental system

Acquire data to make Bode plots for 3 catheters, and also control (no catheter)

6-8 measured points for this type of experiment

Use known response of a second order system to help make plot

For this Lab: Can limit frequency range to -3dB point, and for phase shift of -180°
2\textsuperscript{nd} order electrical analog

RCL circuit response is similar to 2\textsuperscript{nd} order mechanical system

Physical components in our system have electrical analogs 
  e.g. R in circuit depends on catheter length, diameter, etc.

\[ i(t) = e^{-\alpha t}(B_1 \cos(\omega_d t) + B_2 \sin(\omega_d t)) \]

\(\alpha\) is a damping factor
\(\omega_d\) is the damped natural frequency (not \(f_n\!\!\))

Can measure damping and damped resonant frequency.....
Step response
(additional test....don’t forget it!)

Response to a step input in a second order underdamped system is an exponentially decaying sine wave. Measure damping and damped frequency.
Week 1 Class:

- Please arrive on time (room PFBH 108)
- Lab safety discussion: no open-toed shoes in lab!
- Bring completed pre-lab with you
- Start lab session with o-scope/signal generator review
- Take data for Bode plots, damping, electrical analog calcs, for 3 catheters (and without catheter). Have raw data signed by your TA. Copy and attach to your write up, turn in at following lab session.
- Week 1 typically goes the entire lab session (3.5+ hours)