

Name _____

Advisor _____

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BIOENGINEERING
Ph.D. QUALIFYING EXAM
Cell and Tissue Engineering

June 2006

Complete all questions.

Show all work.

Read the questions carefully, work neatly, and box your answer where appropriate.

Each problem is worth 25 points.

You have 4 hr to complete the exam.

Write your name on each page.

<u>Question</u>	<u>Grade</u>
<u>Bioinstrumentation</u>	<u>/25</u>
<u>Biomaterials</u>	<u>/25</u>
<u>Biomodeling</u>	<u>/25</u>
Concentration:	
<u>C&T Engineering</u>	<u>/25</u>
Total	/100

Bioinstrumentation

1. Design a system suitable for recording a biopotential signal with the following characteristics:

Bandwidth: 0.1 – 1000 Hz

Dynamic range: ± 100 mV

Assume that you have a 12-bit analog-to-digital converter with an input range of ± 10 V, and that you wish to digitally record the signal with the highest resolution possible.

- A. First, draw a *block diagram* that depicts each stage in your system, and gives the transfer function of each stage.

- B. What is the final calibration of your system, in Volts/Volt?

- C. What is the final resolution of your system, in Volts/bit?

Name _____

D. Draw the amplitude portion of the Bode plot describing your system (from the previous page). Plot the gain in decibels, and indicate the -3 dB pt(s).

E. Give a detailed circuit diagram for the system described on the previous page, showing all component values.

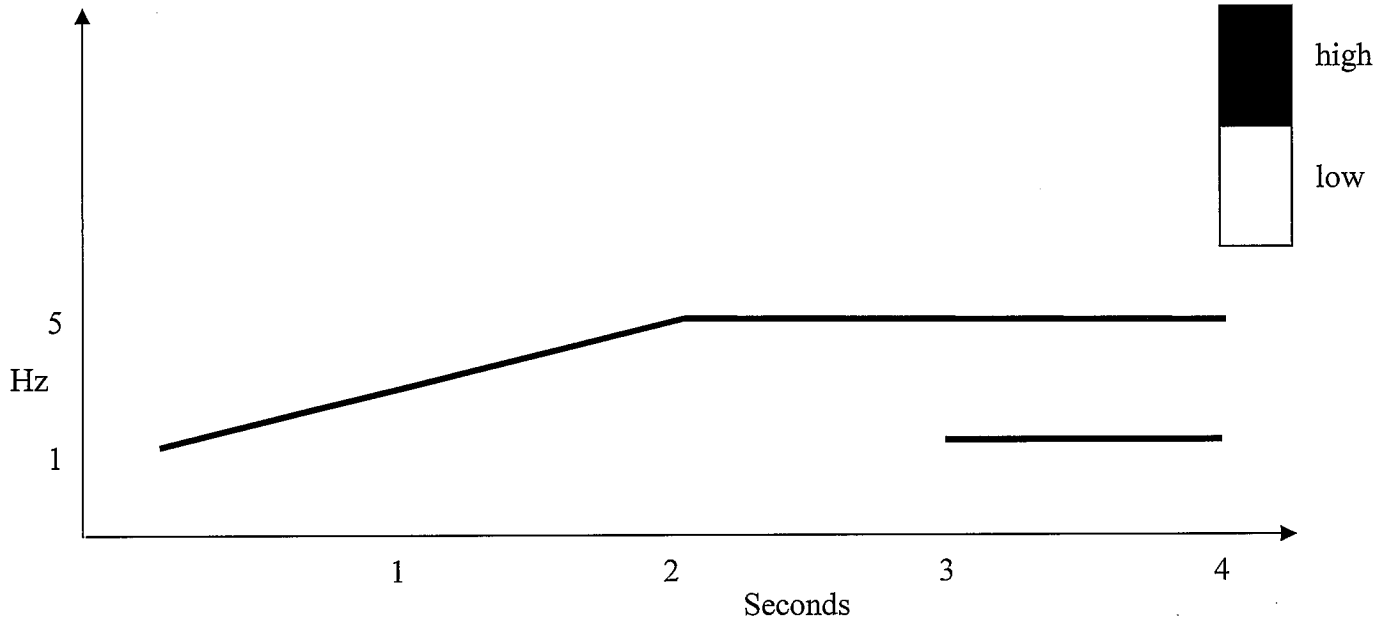
Name _____

- F. Assume that the biopotential signal above is a response to a sensory stimulus that has never been recorded before. You wish to characterize this novel signal so that you can report it in the journal *Nature*. How would you empirically determine the signal bandwidth? In particular, how would you distinguish the “unknown” signal from noise in the recording? (Be concise; think before you write.)

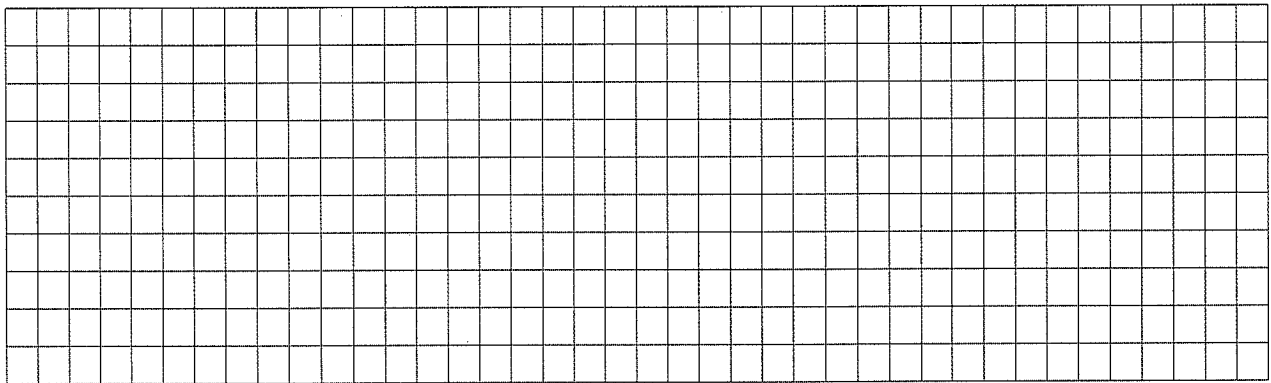
Name _____

2. A man is standing in a puddle, which grounds his feet. He reaches overhead to turn on a lamp, but the lamp is faulty and his hand touches a 120 V, 60 Hz AC voltage source. Draw a circuit diagram that describes the currents passing from the source to ground. Indicate the *physical origin* of all impedances in your circuit. State any assumptions, and be as quantitative as possible.

3. Consider the idealized spectrogram below



a. On the graph-pad below, draw a time-based voltage waveform from which this spectrogram could have been obtained. Label all axes.

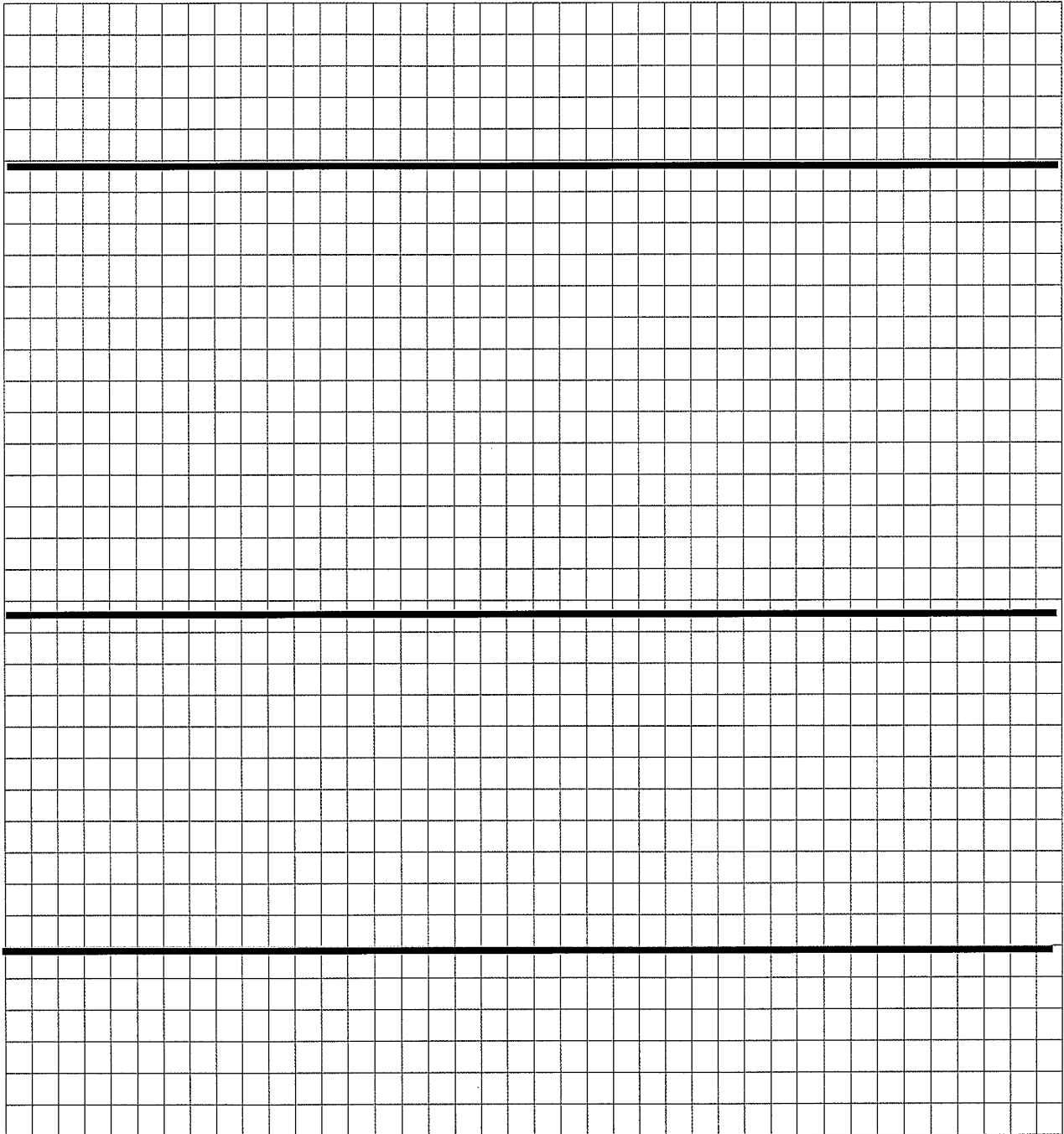


4. Using C, L and R components, create an electric circuit with second order response characteristics.
 - a. Draw and label a circuit diagram with components arranged to provide a second-order system with low-pass characteristics.
 - b. Derive an expression (in terms of R, C and L) for the transfer function of this circuit.
 - c. Choose/determine appropriate component values if the undamped natural frequency of this system is 485 rad/sec and the system is critically damped.
 - d. Determine the magnitude and phase of the transfer function for an 85 Hz sinusoidal signal input.
 - e. Consider the signal you drew in Problem 3 as the input to your circuit. Draw the likely output.

5. Cardiac Mechanics in a Normal Human Heart

- a. On the first line of the graph below sketch both a left and right typical ventricular pressure trace for two successive cardiac cycles.
- b. On the second line, draw the associated ECG trace
- c. On the third line, draw the likely heart sounds heard with a stethoscope

In all cases be sure to label and value both axes!



Name _____

- d. For TWO of the signals above (a and b, OR a and c, OR b and c):
 - i. Thoroughly discuss the transducer used in the measurement. Include the source of the signal, the method of transduction, how the transducer is placed etc.
 - ii. For those SAME TWO signals, state and justify the low and/or high-frequency cut-offs you would use for signal conditioning the output of the transducer.

Name _____

3. You plan to use an implant made out of material X. Your co-worker, Mr. Slow says that if you do this material X will cause neighboring cells to be lysed by the membrane attack complex.
 - i. What is the membrane attack complex?

- ii. Do you believe your co-worker? Explain why or why not.

Name _____

4. Dr. Glass needs to insert a rod in the body. He needs it to be soft while it is being inserted and needs it to be hard 1 hour after it is inserted. NITINOL is not an option for this. What type of material should he use, metal, polymer or ceramic? Explain the material property that will make this possible and how it will work in this case. (Hint: encrypted in this question is a helpful hint.)

Name _____

5. Design an **in vitro** experiment to determine if material Y is biocompatible. You must use a standard biocompatibility test. Explain your experimental design in **great** detail. Include sections on: A) how you will know from your results if material Y is biocompatible or not, B) the advantages of the method you chose and C) the disadvantages of your method.

Name _____

3. Derive a relation between b , \hat{b} , and the sample size n .

Cell & Tissue Engineering

(Remember, I will make no assumptions in the grading of your answers. For full credit you must include every aspect of the answer.)

1. Creatures from planet Mickey arrived in your lab and asked you to tissue engineer their Torbe. This is an internal organ, the function of which is to secrete Zabas into their "blood". One of the creatures is very smart and can answer all of your biology/physiology questions. Based on what you know about human biology/physiology and tissue engineering what questions will you ask the doctor? Explain how the answers will guide you to successfully tissue engineer a Torbe. Be thorough in your answer. This is not a short answer question. Think of **everything** a tissue engineer would have to do, from beginning to end.

Name _____

2. A tissue engineer cultured osteoblasts on a slide. They then removed the osteoblasts and cultured mesenchymal stem cells (MSCs) on the surface. They also cultured MSCs on slides that were never cultured with osteoblasts. They measured MSC proliferation rate and their differentiation into bone cells using a bone cell marker, a protein called osteopontin. The MSCs proliferated at a faster rate and differentiated quicker when seeded on slides precultured with osteoblasts. The same media was used for both MSC cultures. There were no differences in the MSCs at the beginning of the experiment.
- a. Hypothesize what may have caused these results. Be specific in your answer. You should have more than one hypothesis.
 - b. Design experiments to test your hypothesis. Explain your design in detail and how you will determine if you were right or not.

Name _____

Name _____

3. Explain what embryonic stem cells are and what adult stem cells are.

4. Discuss the advantages and disadvantages of using A) embryonic stem cells and B) adult stem cells in tissue engineering. (This is not a short answer question. It should be in depth and detailed.)

