National Exams December 2017

04-Bio-A8, Biophysical Measurements

3 hours duration

The following exam includes 7 questions of which you must answer 5. Use diagrams if necessary to aid in your explanations. Each question is worth 20 marks, with marks allocated for each subsection indicated.

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. This is an OPEN BOOK EXAM.
   Any non-communicating calculator is permitted.

3. FIVE (5) questions constitute a complete exam paper.
   The first five questions as they appear in the answer book will be marked.

4. Each question is of equal value.

5. Most questions require diagrams and/or answers in essay format. Clarity and organization of the answer are important.

1. (i) A resting transmembrane potential of -85 to -90 mV is maintained across excitable membranes. Describe the parallel conductance model for the excitable membrane, including a description of its components and use it to explain how this resting potential is generated. **10 marks**
(ii) How is an action potential generated across this membrane? Start from the linear transmembrane circuit response to the nonlinear membrane behavior resulting in the action potential. **10 marks**

2. (i) Fully describe a modern pH electrode, including its principles of operation including the underlying scientific basis. **10 marks**
(ii) How can this transducer be modified to measure pCO_2? **5 marks**
(iii) Describe the necessary electronic circuitry to obtain a voltage signal including compensation for temperature. **5 marks**

3. Bioelectric impedance plethysmography can be used to measure time varying changes in the volumes of different tissues or organs located between the measuring electrodes such as the lung volume during respiration.
(i) Describe <u>one</u> application (e.g. impedance cardiography to measure cardiac output, or venous blood flow in the leg to detect thromboembolisms, etc.) including the physical principles and electrical properties of the tissues involved. **10 marks**
(ii) Describe the instrumentation (4 electrode setup) used to obtain the measurements. Give the system block diagram and a functional description of each block. **10 marks**

4. Ultrasound is used to image soft tissue and in modern systems can create real-time images of moving organs. Discuss the principles of real-time cardiac ultrasound imaging using a single fixed transducer position. Your discussion should include the underlying physical principles of transmitting sound waves through tissue, the transducer systems sending and receiving the sound waves, the electronic system required to control the transducer(s), the signal processing required and the image construction algorithm/approach. **20 marks**

5. The electroencephalogram (EEG) was first observed in the 1920's and gave us the first measure of brain function.
(i) What is the origin (what electrophysiological events), amplitude range and bandwidth of the surface recorded EEG signals **5 marks**

(ii) In recent decades, surface recorded brain evoked potentials such as the brain stem auditory evoked potential (bandwidth 100 – 3000Hz, amplitude <1 μvolt) are being evoked by stimulating the brain repetitively with sensory input such as clicks into ear, changing visual patterns, etc. The auditory evoked potential above is recorded by one electrode placed at the centre of the scalp with an ear electrode as reference. Sketch an instrumentation system used to record this potential (block diagram) with function and specifications for each block **7 marks**
(iii) What sources of noise are present in the evoked surface signal or instrumentation system and how would your design remove each one. **8 marks**

6. Electrodes are used to convert or transduce the biopotentials in or on the body (a result of ion concentrations and flow) to an electronic current or voltage.
(i) Give the basic equivalent circuit of a metal electrode immersed in a solution containing ions and describe the physical/chemical basis of each circuit component. **8 marks**
(ii) In most applications, such as ECG, Ag- AgCl electrodes are used to record the biopotential on the skin surface. Give the equivalent circuit of such an electrode on the skin showing the equivalent electrical circuit component(s) added by considering skin properties and structure. What does each additional component represent? **8 marks**

(iii) In recording biopotentials it is important to have the lowest electrode/skin impedance possible to avoid motion artifact or other noise. Describe two methods of reducing this impedance. **4 marks**

7. One of the most important parameters measured in the operating, emergency, post anesthetic care and intensive care units is the oxygen saturation of arterial blood (the percent of hemoglobin carrying oxygen, So_2). In earlier decades this had to be done by drawing blood from an artery and performing a laboratory analysis. Since the 1980's an instrument has been developed based on light absorption called the pulse oximeter that is noninvasive and accomplishes this continuously in real time. This is done by shining light on the skin and measuring either reflected or transmitted light energy.

(i) Describe the physical principles underlying the transmitted light technique including the absorption characteristics of the tissues involved. **10 marks**

(ii) Describe the instrumentation required to accomplish this from sensor to display **5 marks**

(iii) How can we accommodate darker pigmentation or thicker tissue in transmission oximeters. **3 marks**

(iv) List two sources of noise in the measurement. **2 marks**