National Exams May 2015

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. Use the parallel conductance electrical equivalent circuit of the excitable membrane 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. You are asked to measure the transmembrane action potential of a 50 μm unmyelinated nerve fiber. This requires you to stimulate the fiber past its threshold and record the resulting transmembrane potential. Use figures and block diagrams and give the specifications for each block. You will use a computer to acquire and measure the signal.
(i) Describe the stimulating instrumentation including transducers used and their placement. 7 marks
(ii) Describe the recording instrumentation including transducers, analog instrumentation and input to the computer. Consider any sources of noise. 13 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 one application (e.g. impedance cardiography to measure cardiac output, 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. The most recorded signal in medicine is probably the electrocardiogram (ECG or EKG). The principles of recording it have not changed significantly for many decades.
(i)Starting with the Einthoven triangle including its assumptions, describe the Lead I ECG signal relating each component to the cardiac event. 10 marks
(ii) Describe the instrumentation used to record this signal from sensors to final display. Use a block diagram, describing the function and specifications for each block. 10 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 150 – 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. Ultrasound has been used to both image soft tissue and measure blood flow.
(i)Describe how Doppler-shift ultrasound can be used to estimate blood flow in an artery lying near the skin surface (e.g. carotid artery). 5 marks
(ii) Describe the continuous Doppler-shift instrumentation used to obtain this estimate. 7 marks
(iii) What are the factors that determine depth and spread of the ultrasound wave? Give the relationships 6 marks
(iv) What ultrasound frequency would you choose for the above? 2 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