National Exams May 2015

04-Bio-B6, Bioinstrumentation

3 hours duration

The following exam includes 6 questions of which you must answer 4. Use block diagrams where appropriate, with specifications and/or function for each block, to aid in your explanations. Detailed electronic circuits are not necessary but could be helpful in your solution. It is expected that most systems will require a mixed analog/digital solution. When using a microcontroller or computer in your solution it is necessary to describe the data acquisition/processing/display functions in a simple flow chart. Each question is worth 25 marks, with marks for each subsection as shown.

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. FOUR (4) questions constitute a complete exam paper.
   The first four 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. It is well known that the EEG pattern (0.5 to 32 Hz, 30 μvolt), as well as the core body temperature (35 to 40^0 C) as measured in the ear canal) changes during the sleep cycle. Design a system to measure the degree of correlation (linear dependence) between percent of power in the theta (4 – 7 Hz) and delta (1 – 3.5 Hz) EEG bands compared to the total signal power, and the core temperature. Pick a reasonable window length to average the data and obtain these averages for a maximum of 8 hours. How are you going to store and display the results? The principal noise sources will be EMG of the scalp muscles and movement artifact. Your instrumentation should be safe and comfortable and able to recognize and/or remove this noise.

25 marks

2. There are three broad categories of noise sources in biological, especially electrophysiological measurements. These categories are: environmental, biological and instrumentation. Describe five of these noise sources and how modern instrumentation system methods and technologies can accommodate or remove the associated noise. The descriptions of the methods or technologies should give detailed explanations or specifications respectively.

5 marks each

Total 25 marks

3. If a strong electrical stimulus (50 μs, 10 - 100 ma) is given to the fingertip of a relaxed subject, he/she automatically withdraws the finger. The subject is seated at a table with the hand resting on it and the elbow at 90^0. A researcher would like to measure the reaction time as a function of stimulus amplitude looking at both the electromyographic (EMG) signal (<± 2 mV, 10-300 Hz) of an elbow flexor (e.g. biceps brachii), and movement of the hand. That is, what is the delay between the stimulus at the fingertip and the start of the EMG and what is the delay before movement of the hand? Are the delays reduced as the stimulus amplitude increases and are they reduced when the subject is warned by turning a red light on 0. 5 sec before the stimulus is given? Design the experiment and all instrumentation. Have a computer automatically log the responses for at least 5 stimuli at each amplitude or condition with the amplitudes and warning randomized. Calculate the means and standard deviations for each condition.

25 marks

4. The strain gauge is a transducer used in instrumentation to measure pressures or mechanical forces.

(a) Describe in detail the underlying physical and electrical principles of a resistive strain gauge and the properties of a typical metal foil strain gauge used in industry.

10 marks

(b) Use metal foil strain gauge(s) to design a system to measure up to 30 kg forces applied to a fixed bar by a subject undergoing strength testing. Your design should include all the mechanical and electronic components necessary to present the force signal to a computer acquisition device. Your design should consider and compensate for environmental or other sources of noise.

15 marks

5. Bioinstrumentation is used extensively in the hospital or other high risk environments where the principle consideration is patient/subject/animal safety rather than instrumentation protection, as it is in industry. Consequently biomedical engineers must be very aware of electro-medical standards and safety guidelines.

(i) Describe the difference between macroshock hazard and microshock hazard. 5 marks

(ii) Why could a patient or subject be at greater risk from electrical shock in a hospital or laboratory environment? Think of patient attached or introduced sensors or instrumentation and impedances to current flow.

5 marks

(iii) What standards should a professional biomedical engineer be aware of and follow in the design or use of medical or laboratory equipment?

5 marks

(iv) Electrical isolation and isolated circuits are extensively used in bioinstrumentation. Describe the devices and circuits used to accomplish this and the advantages or disadvantages of different approaches

10 marks

6. 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 biophysical 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. Use a block diagram with each block representing the hardware or data processing element. 8 marks

(iii) How can we accommodate darker pigmentation or thicker tissue in transmission oximeters. 5 marks

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