National Exams December 2019

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 μV), as well as core body temperature (35 to 40^{0}C) change during the sleep cycle. Design a 32 channel sleep lab EEG system to measure degree of correlation (assuming linear dependence) between percent of power in the theta (4 to 7Hz) and delta (1 to 3.5Hz) EEG bands compared to the total signal power, and body core temperature. Pick a reasonable window length to average the data and obtain these averages for a maximum of 8 hours. Your instrumentation should be safe and comfortable to allow the patient to comfortably sleep.
5 marks	(i) Detail how data will be stored, analyzed and displayed.
5 marks	(ii) Describe differences one would have between a wired and wireless system in terms of design and safety.
7 marks	(iii) The dominant noise sources are electromyographical (EMG) and from patient movement artifact. How would the instrumentation be able to recognize and/or remove this noise?
8 marks	(iv) If one were classifying the EEG in the frequency domain describe the signal processing that would be necessary.

5 marks each = **25 marks**	2. There are three broad categories of noise sources in biological, especially electrophysiological measurements: environmental, biological and instrumentation. Describe five 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.

	3. Medical imaging is an important diagnostic procedure in every hospital. Two systems that provide tomographic imaging are computed tomography (CT) and magnetic resonance imaging (MRI)
10 marks	(i) How does MRI encode spatial information? Describe in terms of the three subsystems, the main field (B_0), orthogonal gradient fields (*dx/dt, dy/dt, dz/dt*) and the RF field (B_1^+/B_1^-).
5 marks	(ii) How would one characterize and monitor the spatial resolution of both MRI and CT scanning?
4 marks	(iii) Detail the shielding used for MRI and CT systems. Outline how and why each is different.
6 marks	(iv) Safety is always critically important. A patient arrives with a titanium artificial hip joint. Detail all MRI-related safety concerns surrounding the implant and describe resulting biological and image-associated effects one would be concerned about.

	4. In patients, heart sounds are produced when heart valves close abruptly or blood flow is turbulent. Physicians detect these sounds with a stethoscope during normal breathing.
12 marks	(i) Design a system that accurately measures and displays cardiac sounds (using measurement of both amplitude and duration) and correlates them with cardiac ECG *and* arterial blood pressure measured

	using Photoplethysmography (PPG).
8 marks	(ii) Describe your design including specifications and function for each component in a block diagram, with each block representing a hardware or data processing element, from measurement transducers to final signal display.
3 marks	(iii) Identify any possible sources of noise in your signals, and approaches to removing them.
2 marks	(iv) What safety issues need to be considered in your system?

	5. Bioinstrumentation is used extensively in the hospital or other high risk environments where the principle consideration is patient/subject safety, rather than instrumentation protection as it is in industry. Consequently biomedical engineers must be very aware of electromedical standards and safety guidelines.
5 marks	(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?
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?
7 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.
3 marks	(v) Elaborate on the term "ground loop", why it is potentially dangerous and how it can be avoided?

	6. Bedside monitors in the intensive care unit (ICU) have ECG, pulse oximeter, respiration and periodic blood pressure using a programmed sphygmomanometer (i.e. this measures blood pressure at a pre-programmed desired interval, e.g. 15min).
8 marks	(i) Describe the biophysical principles underlying pulse oximetry including tissue absorption characteristics.
8 marks	(ii) Describe the instrumentation required to for the ICU monitor, from sensors to display. Use a block diagram with each block representing the hardware or data processing element.
7 marks	(iii) One of the most difficult problems with the current ICU bedside monitor is the large number of wires/cables/leads/hoses etc. which get tangled. This problem can be exacerbated by having one or more intravenous (IV) lines also in the patient. How can a better system be designed? Outline the changes in the block diagram already done in part (ii) above.
2 marks	(iv) List two sources of noise in the measurement of arterial O_2 saturation for ICU patients.