Last name:

First name:

MOCK Midterm test

Sensors in Medical Instrumentation

May 2023

Important

- This mock test is intended to let you to make a self-assessment of your knowledge and to give you an idea about how the final exam will look like.
- This test consists of 3 problems (P1-P3), worth 5, 7, and 6 points, respectively and 6 multiple-choice questions (multiple answers may be correct for each such question), each worth 1 point
- Print the exam sheets and use it to provide solution directly on the exam sheets. If you have no access to printer, provide solutions in separated sheet of paper
- Solutions must be comprehensible.
- Write your name on the title page

Duration: 2 hours

This is an open-book exam but only the official lecture materials posted on the moodle site (slides, notes, textbook, selected pages) and your own personal notes are allowed. No homework or former exam, nor their solutions, are allowed. Standard tables (trigonometric, integrals, derivatives, etc.) are allowed

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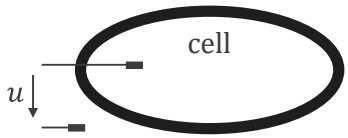
P1—Cell potentials (5 pts)

The table below shows the ion concentrations and channel conductances of a cell.



ion	ion concentration (mM)		channel conductance (μS)
	intracellular	extracellular	
K^+	400	20	340
Na^+	50	400	33
Cl^-	40	550	300

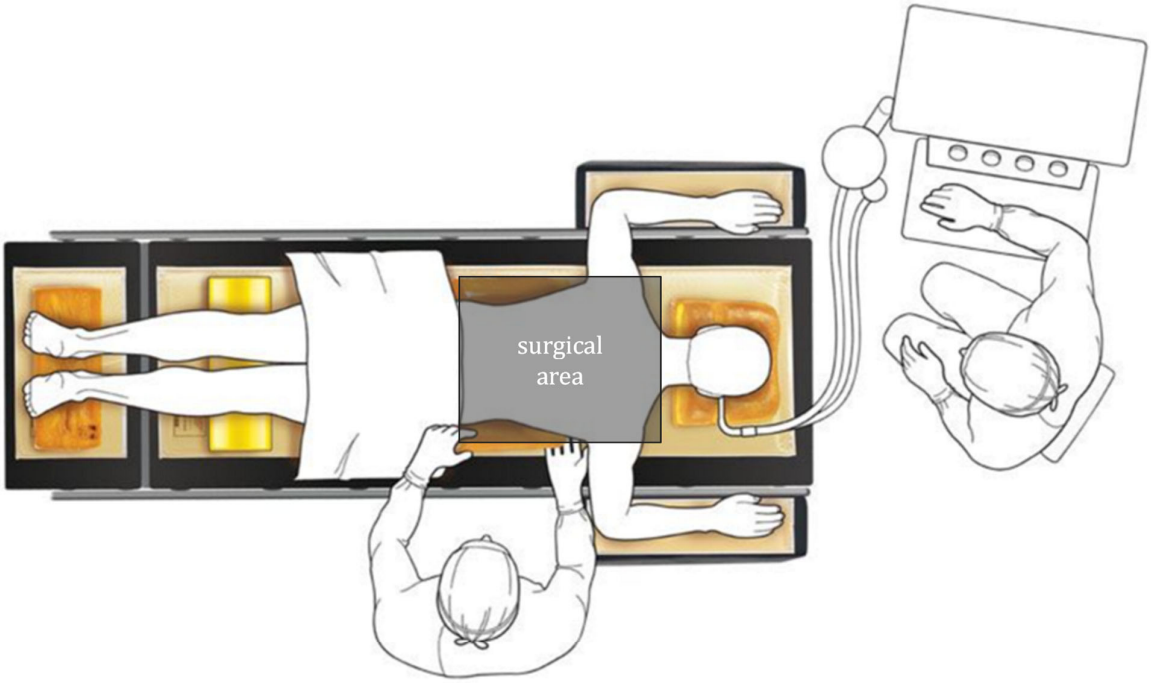
1. Calculate the voltage u for each ion channel at 37 °C (all other channels being closed).

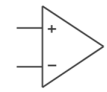
2. Calculate the voltage u for all ion channel simultaneously open.

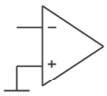
3. Calculate the channel currents i_{K^+}, i_{Na^+}, i_{Cl^-} entering the cell.

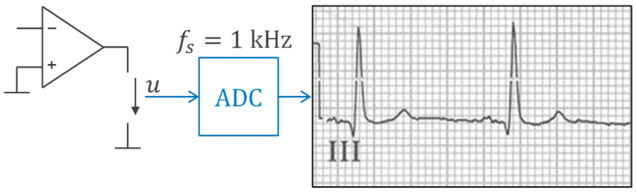
P2—Electrocardiograph (7 pts)

ECG lead III of a patient in prone position for back surgery (see figure below) needs to be monitored.









2. Circle which of the electrodes among the list below are required for the measurement of this lead III.

   R L F N C1 C2 C3 C4 C5 C6

   Indicate in the drawing above a suitable position for the selected electrodes.
3. Assuming that the gain of the ADC and display is 1 mm/1 mV (1 mm is the distance between two lines of the grid), determine the gain g of the amplifier (from the electrodes to u).

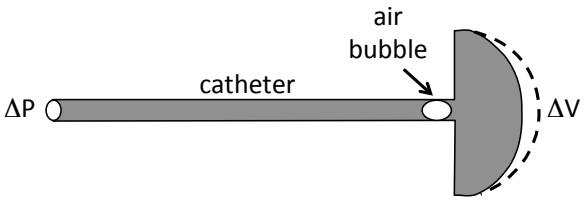
   Assuming a first order low-pass filter with a cut-off frequency of 150 Hz for the anti-aliasing filter, determine the time constant τ.

   Write the transfer function of the amplifier (from the electrodes to u).

4. Draw (in the above figure) a suitable electronic circuit with the three drawn operational amplifiers, adding capacitors and resistors as appropriate (safety and protection resistors not needed).

   Connect the electrodes to the electronic circuit with cables (shielded as appropriate).
5. Determine suitable values of resistors and capacitors to implement the gain and first order low-pass filter time constant calculated above.

P3-Blood pressure (6pts)



Consider the extravascular catheter filled with liquid on the right where an air bubble has appeared in the catheter tube, thereby changing the compliance of the whole catheter-liquid-membrane system. The cross-sectional area of the catheter is $A = 5mm^2$ and its length is $l = 0.5m$. The fluid in the catheter has a density of $\rho = 1mg/mm^3$.

a) Depict the simplified analogous electrical circuit modelling the catheter in the presence of the air bubble and justify why the air bubble change only the compliance of the system.

b) Calculate the inertance L_c of the circuit in Kg/m^4.

c) To estimate the compliance of the membrane C_m and the compliance of the bubble C_b, an additional quantity of 0.1 μl of fluid is injected into the catheter, which caused a pressure change of 200 Pa when the air bubble was present and a change of 5 kPa when it was absent. Calculate C_m and C_b in m^3/Pa.

d) Calculate the natural frequency of the system with and without the air bubble. Explain the effect of the air bubble on the accuracy of blood pressure measurement.

Quiz (6pts) [Note that each question may have more than one option correct]

1. In "constant temperature" thermal flowmeter
   - ☐ The time constant of the system is multiplied by the gain of current amplifier
   - ☐ The temperature of the fluid is kept constant
   - ☐ The control current to heat the resistance is kept constant
   - ☐ The time constant of the system is shorter that the time constant of "constant current" thermal flowmeter

2. A temperature sensor has a sensitivity of 1mV/^{o}C and an offset of 5mV in the range of [0^{o}C-50^{o}C]. Assuming that the error in sensitivity is ±1%, the maximum error is:
   - ☐ ±0.01mV
   - ☐ ±5.01mV
   - ☐ ±0.5^{o}C
   - ☐ ±0.25^{o}C

3. An APPLIED PART must include:
   - ☐ 1 MOPP
   - ☐ 2 MOPP
   - ☐ 1 MOOP
   - ☐ 2 MOOP

4. Compared to metallic strain gage piezoresistive strain gage has:
   - ☐ Higher gage factor
   - ☐ Lower sensitivity to temperature
   - ☐ Better linearity
   - ☐ Same performance

5. An intravascular pressure sensor with a sensitivity of 10μV/V/mmHg use a Wheatstone bridge excited with a voltage of $5V_{DC}$. For systolic pressure of 120mmHg, the amplitude at the output of sensor is :
   - ☐ 1.2 mV
   - ☐ 6 mV
   - ☐ 0.240 mV
   - ☐ 1.6 mV

6. The tetrapolar method is used to measure:
   - ☐ skin impedance (EDA)
   - ☐ ECG with 4 electrodes
   - ☐ oHRM
   - ☐ (core) body impedance