<u>Introduction to Biomedical Engineering: 2018 Spring Midterm</u>

April 26, 2018

Close book, 120 minutes (PM 1:10~PM 3:10)

<u>Do **not** leave your answer along without any brief explanation.</u>

Equations for reference:

a. Nernst equation (of a permeable ion C)

$$E_C = v_i - v_o = \frac{kT}{qZ}\ln\frac{[C]_o}{[C]_i}$$

k (Boltzmann's constant): 1.38×10^{-23} Joule/K

T: Kelvin scale of absolute temperature (K)

Z: ionic valence

q(the magnitude of electron charge): 1.6×10^{-19} Coulomb

b. Goldman equation

$$E = \frac{kT}{q}\ln\left(\frac{P_K[K^+]_o + P_{Cl}[Cl^-]_i + P_{Na}[Na^+]_o}{P_K[K^+]_i + P_{Cl}[Cl^-]_o + P_{Na}[Na^+]_i}\right)$$

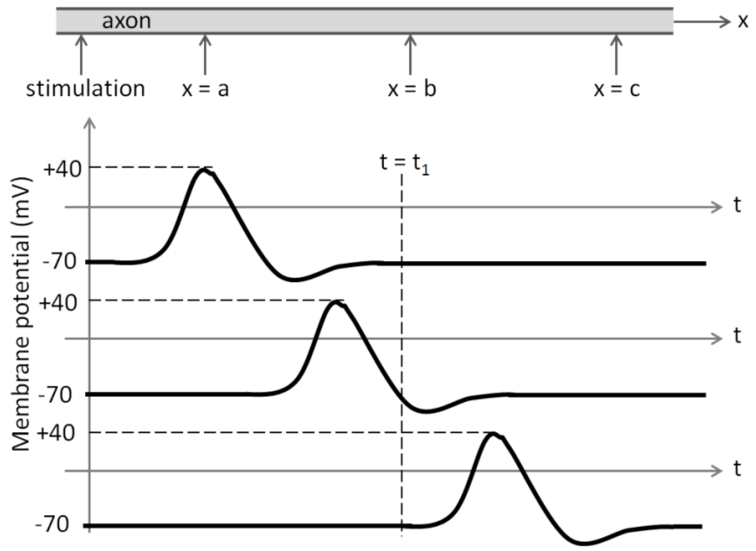
1. 解釋名詞 (20%)
   (1) the all-or-none law of action potential
   (2) myelin sheath of axon
   (3) motor unit
   (4) superconducting quantum interference device (SQUID) sensor for MEG
   (5) automated external defibrillator (AED)

2. (Biopotentials, 14%) The steady-state intracellular and extracellular concentrations of important ions and the ratio of permeabilities was measured on the frog <u>skeletal muscle</u> (骨骼肌). As known the experiment was done at room temperature (27℃). Note A^+ that is not permeable.

Ion	Cytoplasm (mM)	Extracellular (mM)	Ratio of permeability
K^+	140	2.5	1.0
Na^+	13	110	0.019
Cl^-	3	90	0.381
A^+	64	12	---

   (1) What is the resting membrane potential predicted by the Goldman equation? (8%)
   (2) What would be the direction of diffusion and drift for Na^+ ions? Brief explanation is necessary. (6%)

3. (Action potential, 12%) The membrane potential of an axon after electrical stimulation was recorded as below. From up to bottom, three time curves of action potential which were measured at x = a, b, and c were shown respectively.
   (1) Try to illustrate the distribution of electrical charge inside and outside the axon from x = a to x = c at $t = t_1$. Quantitative values are not required. You just need to use "+" or "—" sign to show relative polarity. (6%)
   (2) What kind of ion channel is the most activated at x = b when $t = t_1$? What is the direction of the corresponding ion flow? (6%)

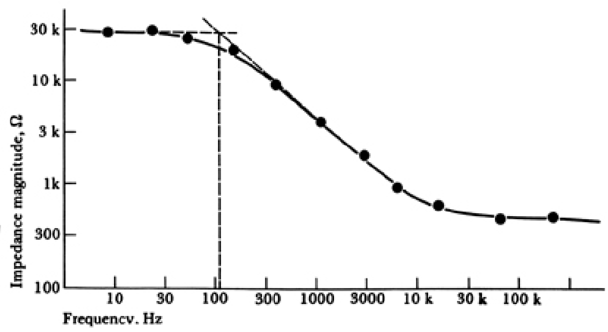


4. (Biopotential, 12%) Here are seven components on the pathway of bioelectric activation of human heart (in the order of the first alphabet): atrial muscle, AV node, bundle branches, common bundle, Purkinje fibers, SA node, and ventricular muscle.
   (1) List these components in the order of the occurrence of action potential during a normal cardiac contraction. (6%)
   (2) The normal ECG rhythm is characterized by the PQRST waveform. Please explain the <u>physiological meaning</u> (生理意義) of P wave, QRS complex, and T wave. (6%)

5. (Biopotential, 18%) Electroencephalography (EEG) is commonly recorded at a sampling rate more than 1 kHz, so it can provide very high temporal resolution on the detection of neural activation, on the order of milliseconds or even sub-milliseconds. However, the signal-to-noise ratio (SNR) is poor. As a result, sophisticated data analysis is usually needed to extract useful information.
   (1) The amplitude of EEG recoding is usually lower than that of ECG or EMG. Why? (6%)
   (2) Name any three kinds of electrical potentials which commonly interfere the measurement of EEG. (6%)
   (3) Magnetoencephalography (MEG), just like EEG, is used to record the regional cortical

activity at high sampling frequency. In contrast to EEG, only neural activation in the sulci (腦溝) can be measured by MEG. Why? (6%)

6. (Biosensor, 12%) The magnitude of impedance as a function of frequency, i.e. frequency response, of surface electrodes is shown below. Obviously, you can find the impedance of electrodes decreases as the frequency gets higher. Recall that an equivalent circuit was introduced to simulate the electrical properties of a biopotential electrode. What element in the equivalent circuit causes this phenomenon? What does this element stand for?



7. (Biosensors, 12%)
   (1) The structure of a strain-gage fluid pressure sensor is illustrated as below (left). Explain how pressure of fluid can be measured by this instrument. (6%)
   (2) The structure of a linear variable differential transformer is shown at right. Explain why an alternating current (AC) source is demanded for the primary coil A. (6%)