MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Electrical Engineering and Computer Science,
Department of Mechanical Engineering,
Division of Bioengineering and Environmental Health,
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Quantitative Physiology: Cells and Tissues
2.791J/2.794J/6.021J/6.521J/BE.370J/BE.470J/HST.541J

Homework Assignment #4 Issued: October 8, 2004
Due: Thursday October 14, 2004

Reading

Lecture 15 — Volume 1: 7.5
Lecture 16 — Volume 1: 7.5

Announcements

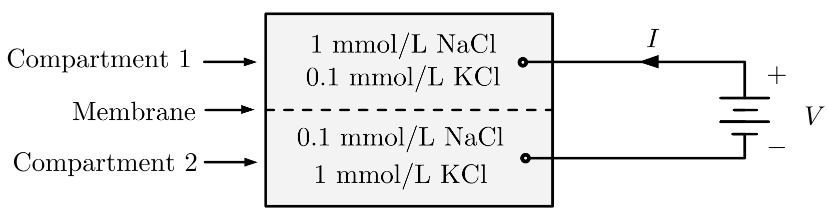
This homework assignment is smaller than average to give you time to work on your lab reports.

First drafts of your lab reports are due **Friday, October 15, 2004** at **10:00 AM.** Bring **3 copies.** One will be reviewed by the technical staff. One will be reviewed by the writing staff. One will be reviewed by a peer student group. You and your partner will be assigned to review the report of another student group. All reviews are due **Tuesday October 19, 2004** when they will be discussed at the Writing Clinic, to be held at 7:30 PM.

Exercise 1. Define electroneutrality and briefly explain its physical basis.

Exercise 2. Define the Nernst equilibrium potential and briefly explain its physical basis.

Problem 1. Two compartments of a fluid-filled chamber are separated by a membrane as shown in the following figure.



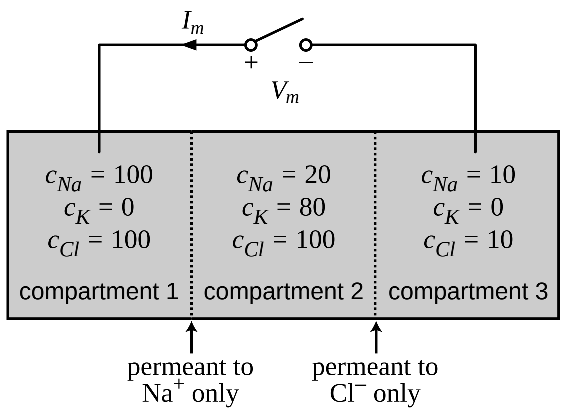
The area of the membrane is 100 cm^2 and the volume of each compartment is 1000 cm^3. The solution in compartment #1 contains 1 mmol/L NaCl and 0.1 mmol/L KCL. The solution in compartment #2 contains 0.1 mmol/L NaCl and 1 mmol/L KCL. The temperatures of the solutions are $24°$C. The membrane is known to be permeable to a single ion, but it is not known if that ion is sodium, potassium, or chloride. Electrodes connect the solutions in the compartments to a battery. The current I was measured with the battery voltage $V = 0$ and was found to be $I = -1$ mA.

a) Identify the permeant ion species. Explain your reasoning.

b) Draw an equivalent circuit for the entire system, including the battery. Indicate values for those components whose values can be determined.

c) Determine the current I that would result if the battery voltage were set to 1 volt. Explain your reasoning.

Problem 2. Three compartments are separated from each other by semi-permeable membranes, as illustrated in the following figure.



Each compartment contains well-stirred solutions of sodium, potassium, and chloride ions, with concentrations indicated in the figure (in mmol/L). The membrane between compartment 1 and 2 is permeant to sodium ions only, and its specific electrical conductivity G_{Na} is 5 mS/cm^2. The membrane between compartment 2 and 3 is permeant to chloride ions only, and its specific electrical conductivity G_{Cl} is 2 mS/cm^2. Both membranes have areas $A = 10$ cm^2. The temperature T is such that $RT/(F \log e) = 60$ mV.

a) Sketch an electrical circuit that represents the steady-state relation between current and voltage for the three compartments. Label the nodes that correspond to compartments 1, 2, and 3. Include the switch in your sketch. Label I_m, V_m, and the conductances.

b) Let V_1 and V_2 represent the steady-state potentials in compartments 1 and 2 with reference to compartment 3 when the switch is open. Calculate numerical values for V_1 and V_2.

c) Compute the steady-state value of the current I_m when the switch is closed.