# Questions

1. The ionic concentrations of a uniform isolated cell are given in the following table.

	Concentration (mmol/L)	
	Inside	Outside
Potassium	150	15
Sodium	15	150

An electrode is inserted into the cell and connected to a current source so that the current through the cell membrane is I_m. The steady-state voltage across the cell membrane V_m is determined as a function of the current as shown in the following figure.
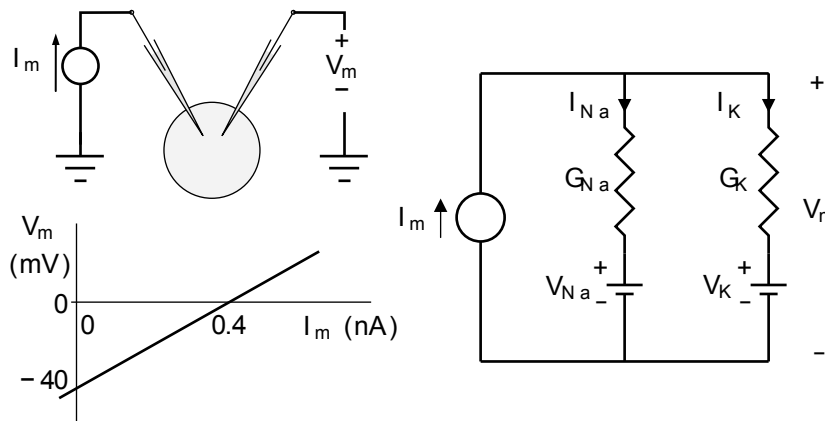

Assume that: (1) the cell membrane is permeable to only K^+ and Na^+ ions; (2) the Nernst equilibrium potentials are $V_n = (60/z_n) \, log_{10} \left(c_n^o / c_n^i \right)$ (mV); (3) ion concentrations are constant; (4) active transport processes make no contribution to these measurements.

   a) Determine the equilibrium potentials for sodium and potassium ions, V_{Na} and V_K.

   b) What is the resting potential of the cell with these ionic concentrations?

   c) With the current I_m adjusted so that $V_m = V_K$, what is the ratio of the sodium current to the total membrane current, I_{Na}/I_m?

   d) What is the total conductance of the cell membrane $\mathcal{G}_m = \mathcal{G}_{Na} + \mathcal{G}_K$?

   e) Determine $\mathcal{G}_{Na}$ and $\mathcal{G}_K$.

2. The membrane of a cell is known to contain sodium/potassium pumps and supports passive electrodiffusion of sodium, potassium, and chloride ions. The potassium conductivity is 8 times the sodium conductivity. The sodium/potassium pump drives 3 molecules of sodium outward for every 2 molecules of potassium that is driven inward. The cell is allowed to come to quasi-equilibrium in a very large bath that contains 460 mmol/L Na^+, 40 mmol/L K^+, and 500 mmol/L Cl^-. At quasi-equilibrium, the cell contains 400 mmol/L K^+ and unknown concentrations of Na^+ and Cl^-. The cells volume is constant, so there is no water transport across the cell membrane. The resting potential is -50 mV.

a) Determine the concentration of chloride ion inside the cell or explain why it cannot be determined from the available information.

b) Determine the Nernst equilibrium potential for sodium or explain why it cannot be determined from the available information.

c) The pump is blocked by adding a trace concentration of ouabain to the bath. The cell quickly reaches a new resting potential. Is the new resting potential greater than, less than, or the same as the old resting potential? Explain.

3. In circuit analysis, mesh equations are used to solve any given system regardless of complexity; these equations stem from Kirchhoff's laws. Specifically, Kirchhoff's voltage laws are used to write loop equations to solve for the unknown loop currents. For the following questions, refer to the figure below:
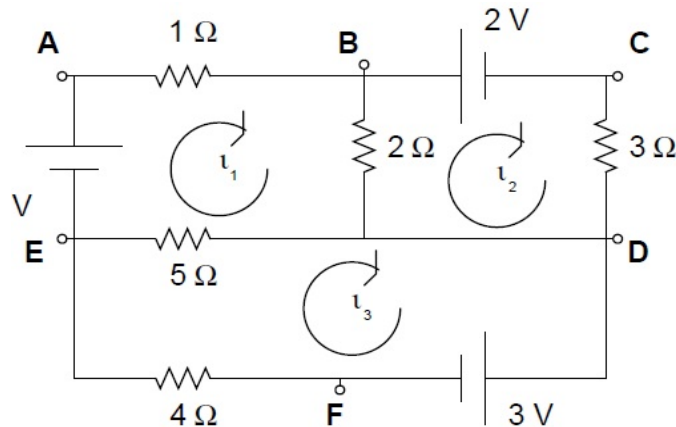
a) Determine the mesh equations using Kirchhoff's Voltage Law by using the following defined points to form the loops (ie. the ABDE loop, the BCDB loop & EDFE loop)

b) Solve the created mesh equations for the currents i_1, i_2, and i_3; ensure that the solution is in accordance with the direction notation seen in the above figure (ie. the currents flow clockwise)

4. An RLC circuit consists of a resistor, an inductor, and a capacitor, connected in series or in parallel. The circuit forms a harmonic oscillator for current and will resonate; however, the presence of the resistor forces any oscillation induced in the circuit to die away over time if it is not kept going by a source.
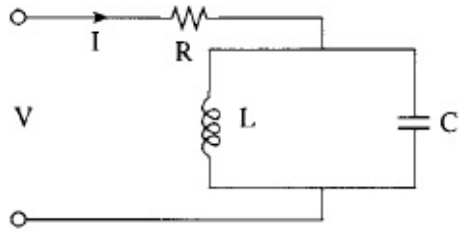
a) What is impedance, and what are the components that compose the real and imaginary parts of impedance? List the impedances of the components involved in the circuit shown above.

b) An AC source is now connected at the input terminals wihtin the circuit shown above; this source drives a sinusoidal voltage $v_s = V_s \cdot sin(\omega t)$, where v_s denotes the source voltage, V_s the amplitude, and ω the angular frequency of the sinusoid. What is the total impedance of the circuit shown above to the AC source?

5. A number of cellular processes depend on the intracellular concentrations of ions, such as the catalytic action of certain cytoplasmic enzymes, as well as many secretory processes where the cell secretes chemical compounds into the extracellular environs.

a) Define the *Nernst equilibrium potential*, and explain its physical basis. Can an electric potential across the membrane exist without a measurable difference in the global concentration of positive and negative ions across the membrane? Explain.

b) Active ion transport within an organism in a process that is capable of having a direct and an indirect effect on the resting potential of the organism. Define both effects, and explain the distinction between them.