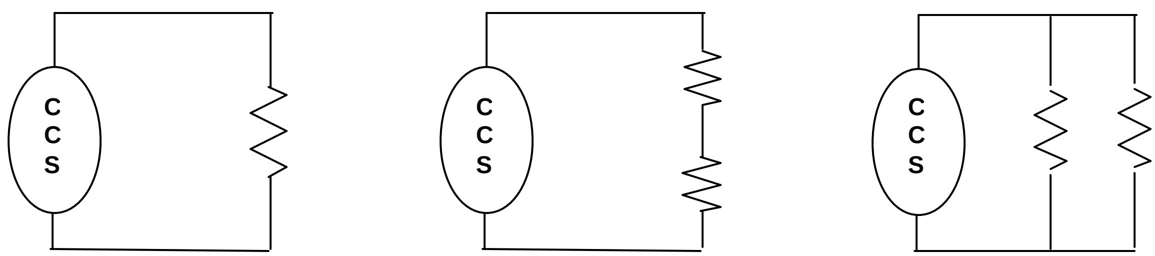
Physics 122, sections 502-4 and 8101 **Assignment 5**
Laura Lising **Due March 13, start of class**

Reference: Cutnell & Johnson, 19.4-19.7 (electric potential, capacitance)

1) We have studied batteries. which provide a fixed voltage across their terminals. In that case, we had to examine our circuit and use our physical principles in order to calculate the current through the battery. In neuroscience, it is sometimes useful to use a constant current source (CCS), which instead provides a fixed amount of current through itself . In this case, we have to use our physical principles in order to calculate the voltage drop across the source.

(a) Suppose we have a fixed current source that always provides a current of $I_0 = 10^{-6}$ amps. For the three circuits shown below, find the voltage drop across the current source. Each resistor has a resistance $R = 2000\ \Omega$. (If you prefer, you may leave your answer in terms of the symbols I_0 and R.)



(b) Constant voltage sources (batteries) get into trouble if their terminals are connected through a very low resistance (short circuit). Constant current sources get into trouble if their terminals are connected by a very high resistance (open circuit). Explain why and explain what "get into trouble" means.

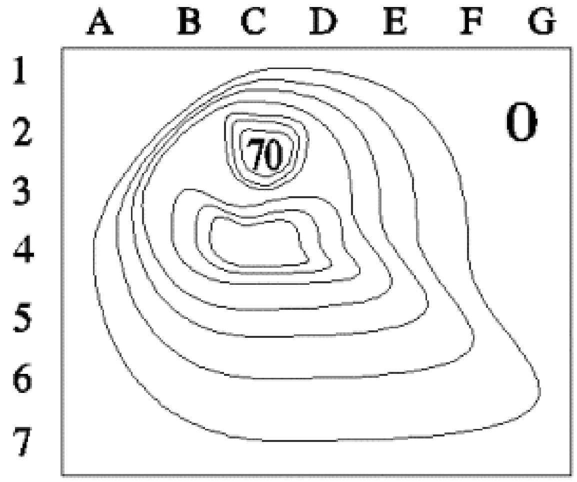
2) In this class we have introduced the concept of *electrostatic potential.* Define what this means, explain its relationship to potential energy, and give an example.

3) A positive charge is placed at rest at the center of a region of space in which there is a uniform electric field. (A uniform field is one whose strength and direction are the same at all points within the region.)

a)When the positive charge is released from rest in the uniform field, what will its subsequent motion be?

b) What happens to the electric potential energy of the positive charge, after the charge is released from rest in the uniform electric field?

4) (a) The figure on the right shows a contour plot of a piece of a range of hills in Virginia. The outer part of the figure is at sea level (marked 0). Each contour line from the region marked zero shows a level 10 m higher than the previous. The maximum height is 70 m and is shown by the number 70.



Answer the following questions by giving the pair of grid markers (a letter and a number) closest to the point being requested.

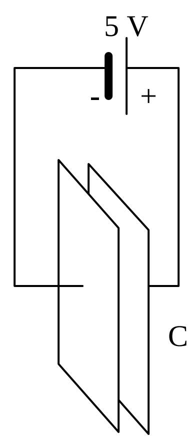
i. Where is there a steep cliff?
ii. Where is there a pass between two hills?
iii. Where is the easiest climb up the hill?

(b) Now suppose the figure represents instead a plot of the electric equipotentials for the surface of a glass plate. (Equipotentials are the places where the potential is equal.) The numbers now represent voltage. The maximum is 70 V and each contour line from the region marked zero shows a level 10 V higher than the previous.

i. Where would a test charge placed on the glass feel the strongest electric force? In what direction would it point?

Is there a place on the glass where a charge could be placed so it feels no electric force? Where?

5) Suppose you have a battery in a circuit with a battery and a "capacitor" that is made of two metal plates, parallel to each other and somewhat close, but unable to pass a charge between them. (Perhaps they are glued to opposite sides of a very good insulator.)



a) What is the voltage difference ΔV between the two plates of the capacitor?

b) Draw in the what the excess charges on the capacitor plates will look like.

c) If we say the two excess charges are Q and -Q, we can define a value called the capacitance C that is related to Q and ΔV. If I told you that C was either defined as $\Delta V Q$, $\Delta V/Q$, or $Q/\Delta V$, which would you say made more sense and why?

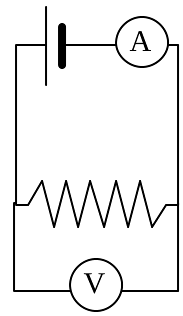
d) Alright, now I'm telling you that $C = Q/\Delta V$ and capacitance is measured in Farads = Coulombs/Volt. If this is a 100 microFarad capacitor, find Q.

e) Explain: Why is it called “capacitance”?

f) Does the capacitance get larger or smaller as we bring the plates closer? Why? What about making the plates bigger? What effect will that have on C?

g) That cell membrane in the last problem set, question 2, has a capacitance of 10^{-4} μF. And the potential difference from one side to the other is 70 μV. How many sodium ions would have to move across the membrane to change the potential difference from 70 μV in one direction to 30 μV in the other direction (i.e. from +70 μV to –30 μV)?

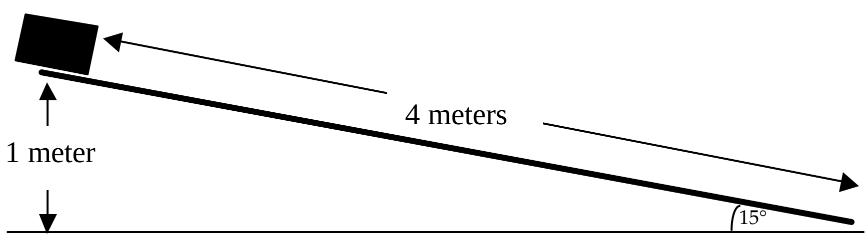
6) Your physics lab manual contains a lab similar to the following:



"1. Connect the circuit shown in the diagram
2. Measure the current through the resistor for at least five different voltages. Change the voltage by adjusting the dial on the power supply. Read the voltage from the voltmeter, and read the current from the ammeter.
3. Construct a graph of current as a function of voltage.
What is the relationship between I and V? Express this relationship in terms of an equation."

Discuss whether this procedure is appropriate for finding the relationship between I and V. (Would the relationship be convincing to you? Why or why not? Is there anything you'd change?)

7) (Not graded, just for review.) A box of mass M = 20 kg is at rest 1 meter off the ground and about to slide down a 4 meter ramp. Suppose has very low-friction wheels, so you can ignore friction.



a) Find the kinetic energy of the box at the bottom of the ramp.
b) What values in the problem could change without affecting the answer to a? Explain how you know and why that makes sense.