Workshop Tutorials for Physics

ER10: **Circuits II**

A. Qualitative Questions:

1. Rebecca is helping Brent study for a test on circuit theory. Brent is having trouble remembering Kirchhoff's rules. Kirchhoff's rule for junctions states that the total currents going into a junction must be equal to the total currents coming out of a junction. Kirchhoff's rule for loops says that the sum of all the potential changes around a loop must be zero.

Rebecca tells him that these things are pretty obvious, and are really just statements of conservation of charge and conservation of energy. How can Rebecca justify this claim? (Hint: the potential difference (or voltage) between two points is the difference in potential energy per unit charge at those points.)

2. Two of the most common circuit components are resistors and capacitors.

a. Why is it that resistors connected in series give a large total resistance, but resistors connected in parallel give a low total resistance?

b. Why do capacitors in series and parallel add to give a total capacitance the opposite way to resistors?

B. Activity Questions:

1. Measuring Current and Voltage

Examine the circuit.
Why is the ammeter connected in series in the circuit?
Why is the voltmeter connected in parallel?
Should the internal resistance of voltmeters be large or small? Why?
What about the internal resistance of ammeters?

2. Wheatstone Bridge

Explain how this circuit works.
Find an expression for R_x, the unknown resistor, when the bridge is "balanced".
Balance the bridge to find the value of the unknown resistor.

3. Charging capacitors

Connect up different resistors and observe the effect on the capacitor voltage, V_c, during charging. What do you notice about the rate of charging with different resistors in the circuit?
Suppose instead that we kept the resistor value fixed and changed the value of the capacitor in the circuit – would this produce a similar result?

C. Quantitative Questions:

1. Rebecca has gotten home from university after dark and accidentally left her headlights on, so that the next morning her car battery is flat. Brent kindly offers to recharge her battery using his car's battery. He first gets out a multimeter to check that the problem is with the battery. He measures the potential across Rebecca's battery terminals to be 10 V, and that across his own battery to be 12.5 V. The jumper leads have a resistance of 0.1 Ω, and each battery has an internal resistance of 0.02 Ω.

a. To which terminal of Rebecca's car battery should Brent connect the positive terminal of his car's battery? Why?

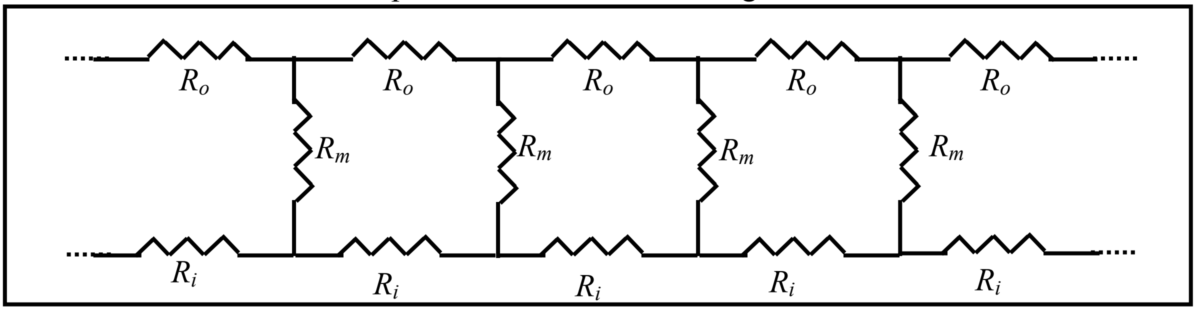
b. Draw a circuit diagram showing how the batteries should be connected. Include all resistances.

c. What will be the charging current if Brent has connected the batteries together correctly?

d. What will be the current if he has gotten them the wrong way around?

e. How much charge does Brent's battery add to Rebecca's battery?

2. The diagram below shows a simple circuit equivalent for a cell membrane, for example the membrane of a nerve cell. The resistances R_m represent the resistance across the membrane, R_i represents the internal resistance of the cell and R_o represents the resistance along the outside of the membrane.



If $R_o = R_i = R$, show that the total resistance of the membrane is $R_T = R + [R^2 + 2RR_m]^{1/2}$.
(Hint: start by separating the circuit into one unit plus the rest of the chain. As the chain is infinite subtracting one unit does not change the total resistance.)