

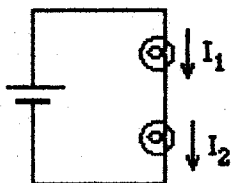
Name A. Ampere + G. Ohm Section _____ Date 2/5/07

Homework 23 #2: Qualitative Aspects of Kirchhoff's Laws

It is very useful to be able to calculate the electrical potential and the current through any element in a complex electrical circuit. It is possible to use the law of conservation of energy and electrical charge to define mathematical rules, known as Kirchhoff's laws, for calculating both currents and potential differences in complex circuits. These laws are discussed in every modern introductory physics text. They can be deduced logically using conservation principles or they may be discovered experimentally. In these exercises you will be asked to apply what you have already learned about circuits with batteries and bulbs to develop Kirchhoff's laws. *Before starting quantitative work with Kirchhoff's laws you should read about them in your text.*

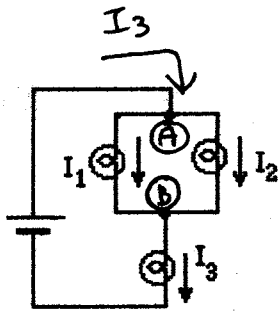
1. Deducing Kirchhoff's First Law

- (a) You have observed that two identical bulbs wired in series with a battery have equal brightnesses. In light of the assumption that the brightness of a bulb is an indicator of the amount of current passing through it, what can you say about whether or not current is used up in a circuit? What is the relationship between I_1 and I_2 ?



$I_1 = I_2 \leftarrow$ current is not used up in a circuit.

- (b) Use your answer to the question above and your observations of what happens to the brightness of two bulbs which are in parallel to develop a mathematical equation that expresses the relationship between the currents I_1 , I_2 , and I_3 in the circuit below.



Because you cannot gain or lose current in a circuit:

$$I_1 + I_2 = I_3$$

(c) Compare the equation you have written with Kirchhoff's first law (known as the junction or node rule) which states that at any junction, the sum of the currents entering must equal the sum of currents leaving.

At the two junctions the current entering should equal the current leaving: ① $I_3 = I_1 + I_2$ and

② $I_1 + I_2 = I_3$

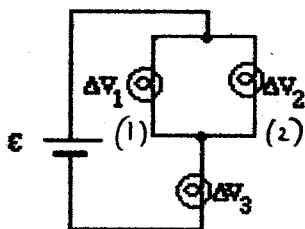
2. Deducing Kirchhoff's Second Law

The same as the equation in b).

(a) How is the work done by a coulomb of charge passing through a bulb related to the potential difference across the element?

~~The~~ The potential difference across a circuit element is equal to the work per coulomb of charge it takes to move a ~~coulomb~~ charge thru the ~~circuit element~~ circuit element.

(b) In view of what you have learned in the last unit about potential differences, consider the circuit below. Compare the work done by a coulomb of charge in passing from the positive terminal to the negative terminal of the battery along the following two paths: (1) through bulb 1 and then bulb 3, and (2) through bulb 2 and then bulb 3.



The work per coulomb of charge would be the same for both paths (1) and (2).

(c) Develop mathematical equations that express the relationships between the emf of the battery (assuming it has no internal resistance) and the potential differences ΔV_1 , ΔV_2 , and ΔV_3 for the circuit shown.

(1) $\mathcal{E} = \Delta V_1 + \Delta V_3$

(2) $\mathcal{E} = \Delta V_2 + \Delta V_3$

(d) compare the equation you have written with Kirchhoff's second law (known as the loop rule) which states that around any closed circuit loop, the sum of all the emfs and potential differences across resistors and other elements must be zero.

Because the potential drops across the resistors,
we can write:

$$\text{path (1)} \quad \mathcal{E} - \Delta V_1 - \Delta V_3 = 0$$

$$\text{path (2)} \quad \mathcal{E} - \Delta V_2 - \Delta V_3 = 0$$

These two equations are the same as
the two equations in (c).