Name: Teddy Rountree-Shtulman
Help From: Mr.Fletcher, and Mr. White (via LearnAPPhysics)

DC Circuit Review

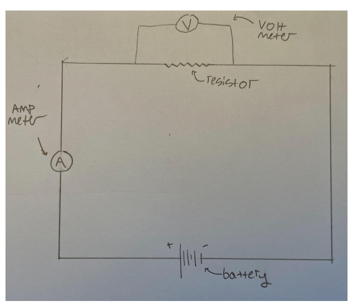
Summary of the topic: DC circuits are a large part of the AP test for E and M. In this review we will be learning the basics about how batteries (EMFs), resistors, and capacitors function in a circuit in order to carry a certain amount of current. We will also cover power and kirchhoff's laws, which are very useful in solving AP circuit problems.
IMPORTANT NOTE! When reading this review all things highlighted in blue are important pieces of vocabulary. And things highlighted in yellow are important relationships. Things that are just really important are highlighted in green.

Major Topics:

1. Basic circuits, Ohm's Law, and Power
2. Resistors in a circuit
3. Kirchoff's Laws
4. Capacitors and Time Constants
5. Practice Problems and Review Quizlet

Basic Circuits, Ohm's Law, and Power

Below is a picture of a basic circuit.This circuit has direct current, which means all of the charge is moving in the same direction. The symbols for resistors and battery are labeled. Remember that the side of the battery that has the longer line represents the high voltage end and the side with the smaller line represents the low voltage end. If told the voltage across the battery we often assume the low voltage side has 0 volts and the high side has the rest of the voltage across the battery. Notice the volts and the amp meters. When doing problems remove these as no current flow through the wires attached to these meters and it will just confuse you! But the voltmeter measures the voltage across two points and the amp meter measures the current through that point.



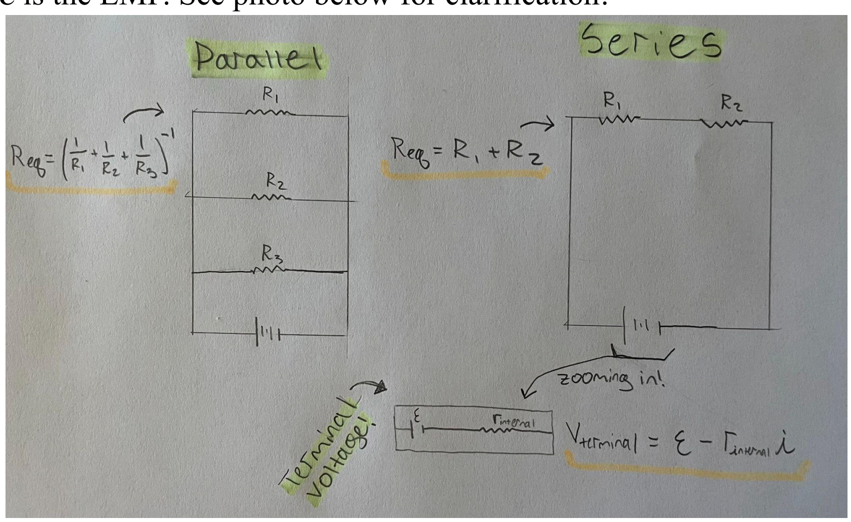
Charge moves through circuits and are defined as $\frac{\Delta q}{\Delta t}$, which makes their units coulombs per second, which we call Amps. Charge is represented by the symbol i. Current flow from high to low voltage.

<u>Ohm's Law</u>

The voltage across a resistor is proportional to the current going through it. From this comes the relationship $V = iR$ where V is the voltage, i is the circuit, and R is the resistance of the resistor. This is known as Ohm's law!

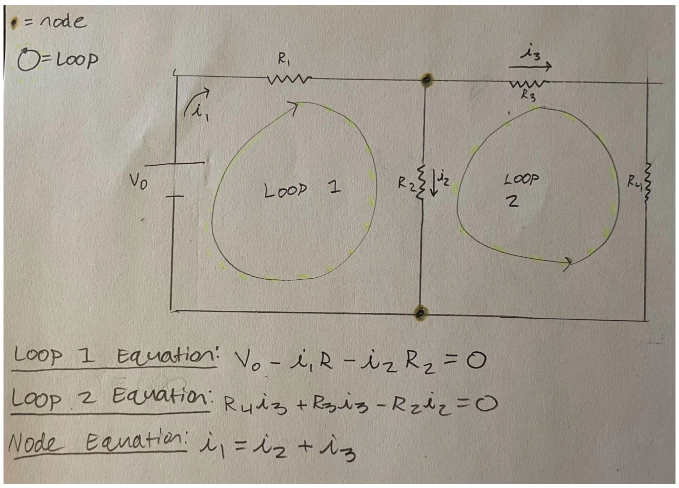
<u>Power</u>
The most general expression for a power rating is $P = iV$ where the i and V represent the voltage and current from the power supply. IF LOOKING SPECIFICALLY AT POWER THROUGH A RESISTOR use $P = i^2R$ or $P = v^2/R$ where the i and the v are the current and voltage across the resistor.

Resistors
Resistors limit current through a part of a circuit. If you have multiple resistors you can combine them to find the equivalent resistance. If the resistors are in parallel you can find equivalent resistance as follows: $Req = (\frac{1}{R1} + \frac{1}{R2} + ...)^{-1}$. If the resistors are in series you can find Req by doing the following: $Req = R1 + R2 + ...$. Look at the photos below to see what I mean by in parallel or in series!
There are a couple of things you need to know about resistors that are in series versus in parallel. When resistors are in series each element is connected to its neighbor in only one place, all of the resistors have the same current going through them, the Req > the largest R in the series combination, and if you add another resistor to the series the Req will increase but the i will decrease. When resistors are in parallel each element is connected in two places with its neighbor, all the resistors have the same voltage across them, the Req < the smallest R in the parallel combination, and if you add a resistor the Req will go down but the i will increase!
The final piece has to do with internal resistance. Sometimes a problem will give you the EMF (Ɛ). This is the voltage difference between the little battery inside the larger one and is accompanied by a small internal resistance. The Ɛ and the internal resistance make up the voltage across the whole battery, which is called the terminal voltage. The equation for terminal voltage is $Vterminal = \varepsilon - ir$ where i is the current given off by the battery, r is the internal resistance, and Ɛ is the EMF. See photo below for clarification!

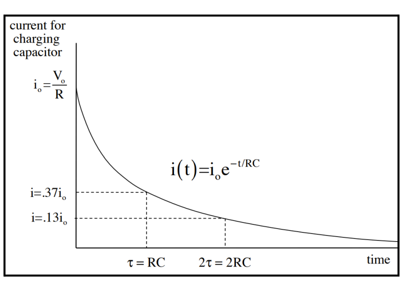


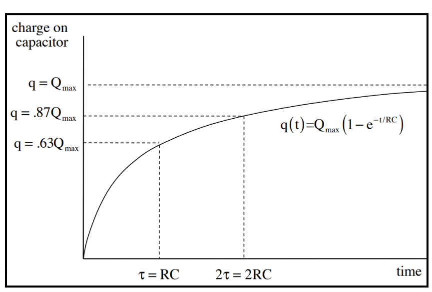
Kirchhoff's Laws: First in order to understand the laws you need to know some vocab. A node: A junction where current can split up or be added to. A branch: a section of a circuit in which the current is the same everywhere, go from junction to junction. A loop: Any closed path inside a circuit. Now that we have that down let's go into the first equation,
$\Sigma i\ going\ in = \Xi i\ going\ out$. This means that when the current goes to a place where the wires

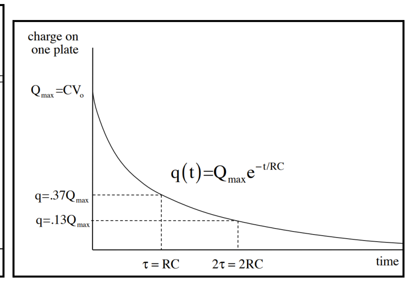
split in different directions the sum of the smaller currents that split off will equal the current that went into the place where they split (see photo). The next equation is, $\Xi\Delta V = 0$; this means that if you choose a point on a loop and go all the way around that loop back to that point it the sum of the voltage will be zero. When summing the voltage difference of each element along the circuit you make the voltage difference negative if it's going from high to low voltage and positive if it's going from low to high. The first equation mentioned is called a node equation and the second one mentioned is called a loop equation. You need enough node and loop equations to solve for the currents. You can do this algebraically or by making a matrix! This review is too short to go through that, so I encourage you to go look at the slide show to remember how to solve for current using a matrix!



Capacitors and Time Constants: There are three equations that are related to capacitors in a circuit you need to know. First, you need to know what the time constant is for a capacitor. The time constant (□) is the unit time it takes for the charge on the capacitor to reach 63% of its max or for the current to reach 37% of it's max. The equation for charge of a charging capacitor is $q(t) = Qmax(1 - e^{\frac{-t}{RC}})$. The equation for charge of a discharging capacitor is $q(t) = Qmax(e^{\frac{-t}{RC}})$. The equation for current of both a charging and discharging capacitor is, $i(t) = i_0\, e^{\frac{-t}{RC}}$. These equations give distinct graphs. Below are photos of all three of the graphs. NOTE THAT QMAX = CV!

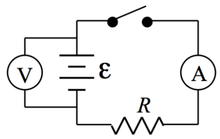






NOTE! Even though on the current graph it says for a charging capacitor it really means for both a charging and discharging capacitor.

Practice Problems: QUESTION 1



A battery $\mathcal{E}$ is connected to a load resistor R, with a voltmeter V and ammeter A connected as shown. Before the switch is closed, the voltmeter indicates a potential of 9 Volts across the battery. After the switch is closed, the Voltmeter indicates a potential of 8.4 Volts, and the ammeter indicates a current of 0.80 Amps. What is the internal resistance in the battery?

a. 0.6 Ω
b. 0.75 Ω
c. 1 Ω
d. 10.5 Ω
e. The answer cannot be determined without knowing the load resistor R.

SOLUTION: Given the equation $V = \varepsilon - ir$, which means that $r = \frac{v-\varepsilon}{-I} = \frac{8.4-9}{-0.8} = 0.75\Omega$

QUESTION 2:

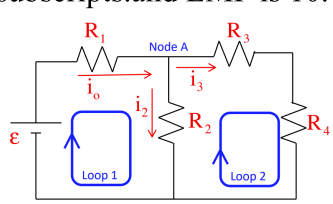
A capacitor C is charged to a potential V0, and placed in series with resistor R at time t = 0. If e represents the base of the natural logarithm, what is the charge on the plates of the capacitor at t = RC.

a. $Q = CV_0$
b. $Q = \frac{CV_0}{e}$
c. $Q = \frac{V_0}{R}$
d. $Q = CV_0 e$
e. $Q = CV_0\left(1 - \frac{1}{e}\right)$

SOLUTION: Given the formula that we talked about above, $q(t) = Qmax(e^{\frac{-t}{RC}})$ and knowing that Qmax=CV. Given this if we plug in RC we get $e^{-RC/RC}$, which equals e^{-1}. This means our end equation should be $Q = \frac{CV}{e}$ and so the correct answer is b.

QUESTION 3:

Given the following situation, what is i0, i1, and i3? Assume R values are equal to their subscripts.and EMF is 10.



SOLUTION:
First write out your look and node equations!
$\varepsilon - R_1 i_0 - R_2 i_2 = 0$ (LOOP 1) $- R_4 i_3 - R_3 i_3 + R_2 i_2 = 0$ (LOOP 2) $i_0 = i_2 + i_3$(NODE)
Rewrite so you can plug into a matrix:
$R_1 i_0 + R_2 i_2 + 0i_3 = \varepsilon$ (Loop 1) $0i_0 + R_2 i_2 - (R_3 + R_4) i_3 = 0$ (LOOP 2) $i_0 - i_2 - i_3 = 0$ (NODE)
PLUG INTO MATRIX! And you get… i_0=3.91 , i_2=3.04, i_3=0.87