Electricity & Magnetism

All of it

For EM all you need to know is what happens then with + or - charges, what happens when they get close and what happens when they move. That's it! For all of non-quantum EM there are only 5 formulas you need. The 4 Maxwell Equations and the Lorentz equation describe all of electricity, magnetism, light, sound, radiation, most of physics. I suggest that those under the age of 18 brace themselves as these can be a bit intense the first time you see them;

$$\oint E.dA = \frac{Q_{inside}}{\varepsilon_0}$$

$$\oint B.dA = 0$$

$$\oint E.dl = -\int \frac{\partial B}{\partial t}.dA$$

$$\oint B.dl = \mu_0 I + \mu_0 \varepsilon_0 \int \frac{\partial E}{\partial t}.dA$$

$$F = q(E + v \times B)$$

How bad can a topic be if you can describe it all with just 5 equations, you could probably fit them all on the back of a beermat. Now that you've seen the conclusion we can go to the beginning and read the whole story in detail. Unless you're doing a university course you can get away with not knowing exactly what the equation mean or do, but this site will explain them later, first lets get back to basics.

The Basics

Charge comes in 2 types, positive and negative and is measured in Coulombs (C). If you have a charge on its own it emits a field in all directions. The field from a charge is represented by E as in E lectricity. If you put another charge in the field it experiences a force. Like charges repel and unlike charges attract. The bigger the charge the stronger the force and the further away the charges the weaker the force, exactly what you'd expect. This relationship can be represented by Coulombs Law;

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

and

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r^2}$$

The q's are the two charges and r2 is the distance between them squared. The other bit is just a constant which roughly equals 9000000000. (The exact derivation of this law can be found here). From these you can see that the force is just the field times by whatever charge you put in, F=qE. Using this you can work out the field or force between particles or atoms or anything with charge provided they're not moving. Once you start a charge moving other things happen

Stuff Moving

As soon as a charge starts to move it produces another field. Why? How? Who cares, it just does. The new field is magnetism and is represented by B as in B agmatism well as in nothing ok? B doesn't stand for anything, it just is. So now your particle or atom or whatever has 2 fields coming out. The full equation to describe how both fields act on a particle is

$$F = q(E + v \times B)$$

Which is known as the Lorentz force. This can also be written as

$$F = qE + qv \times B$$

But we can already describe one of these bits, qE is just Coulombs Law

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

so only half the work left to do.

This is where its gets a little harder. You see that times sign in between the v and the B, that's no ordinary times sign, its a cross product. Its basically a short way of writing "B times v times the sine of the angle between". This is because the B field pushes at 90° to which ever direction its pointing AND which ever direction you are moving in. Now unless you're doing EM past A-level you can forget all about the directions and angles and just write

$$F = qE + qvB$$

Also, at A-level or below the situation will probably be simplified so you only have to consider the E and B fields separately. So you will probably only have to use one of the following two formulas,

Obviously F is the force and q is charge, E and B are the two fields previously described and v is the velocity of the moving charge. The electric field is measured in the SI units of Newtons per coulomb (N C-1) or, equivalently, volts per meter (V m-1). The magnetic field has the SI units of Teslas (T), equivalent to Webers per square meter (Wb m-2) or volt seconds per square meter (V s m-2)

$$F = qE$$

$$F = qvB$$

Circuits

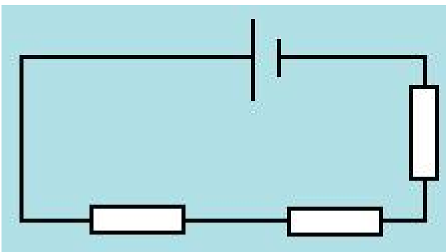
Now I'm not a big fan of circuits, never have been, now hopefully I'll be professional enough that my disliking of them won't come across in this section but if it does I apologise in advance. If I really start to struggle with my hate I may have to call in a second writer

A circuits is basically just a series of moving charges with the occasional object or device in the way that affects the flow. Now when I say the electrons are moving around most people will think that their speeding around at close to the speed of light, but this is wrong. The actual electrons are moving EXTREMELY slowly, it's the wave that travels fast. As stated above like charges repel, so put one electron next to another and they will move apart. With a current in a wire you basically have a tube of electrons and you're adding one to one of the ends, this causes the next electron to move down which in turn pushed the next one and so on. So you have a Mexican wave like effect that moves quickly, but the electrons themselves are only moving slowly.

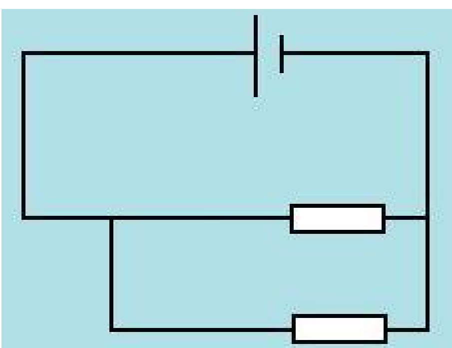
Circuits usually contain all sorts of different objects and devices depending on what they're for, and depending on how you set them all up in the circuit depends how you do all of you calculations.

Which is Which?

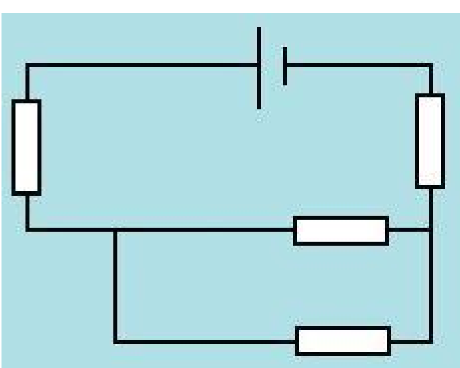
If you set up all your component in a closed loop like so



then we say that all the components are in Series. If you set them up with branching paths like so



then we say that the components are in Parallel. You can also make circuits that are a mixture of series and parallel section like so



Amps, Volts and Ohms (Oh my!)

We call the moving charges a Current, and it is measured in the SI unit of Amps (A). Amps are equivalent to the amount of charge passed in a certain time, so 2 coulombs in 6 seconds will be equivalent to 0.3A. This, like most things in physics can be expressed in a nice formula for you to learn

$$I = \frac{Q}{t}$$

Another important idea in circuits is Voltage or Potential Difference (p.d). Volts are basically the difference in the Electric potential at two different points. Electric potential is given as

It's basically field times distance. Instead of being Coulombs law with an r2 it's just with an r.

Another important idea when it comes to circuits is resistance. Resistance is basically a measure of how much resistance opposes an electric current. Almost all objects or devices in a circuit cause resistance and to calculating the total resistance in a circuit you use one or more of these rules

$$R_{Series} = R_1 + R_2 + R_3 + \cdots$$
$$\frac{1}{R_{Parallel}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$$

One of the most important and fundamental equations in circuits is Ohm's law, and it relates current, voltage and resistance.

$$V = IR$$

Source: http://www.physicsforidiots.com/em.html