Electricity and Magnetism

Friday, March 08, 2013
9:23 PM

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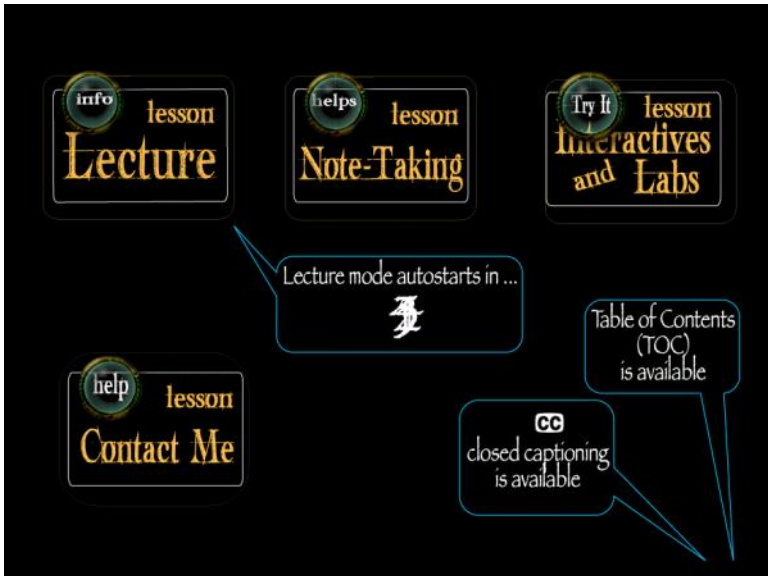
<tr><td>
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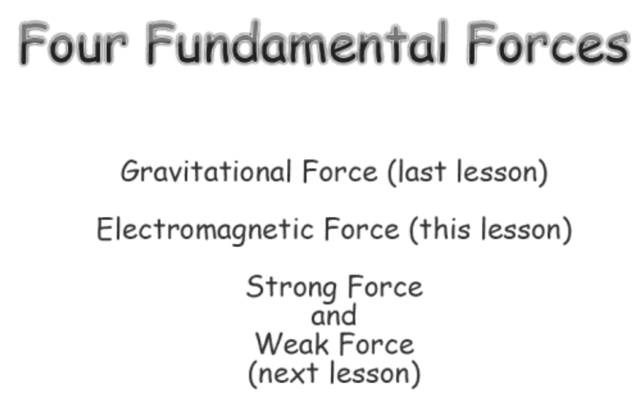
<tr><td>
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Let's see where we have been, where we will be this lesson, and where we are going. [read slide]</td></tr>
<tr><td></td><td>James Clark Maxwell:</td></tr>
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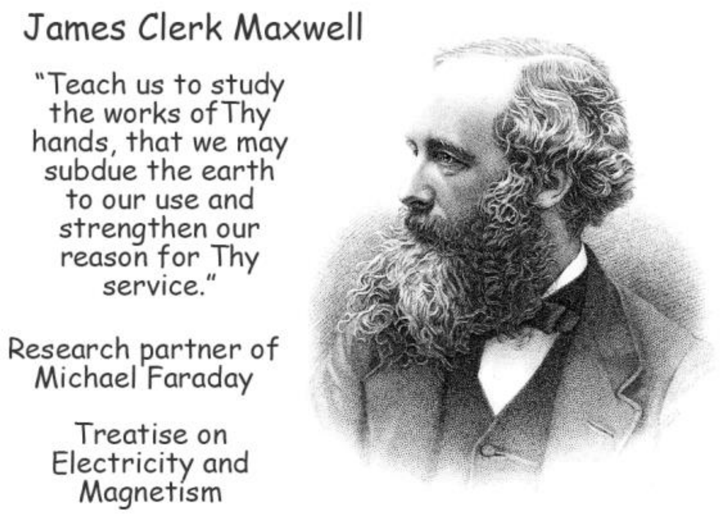
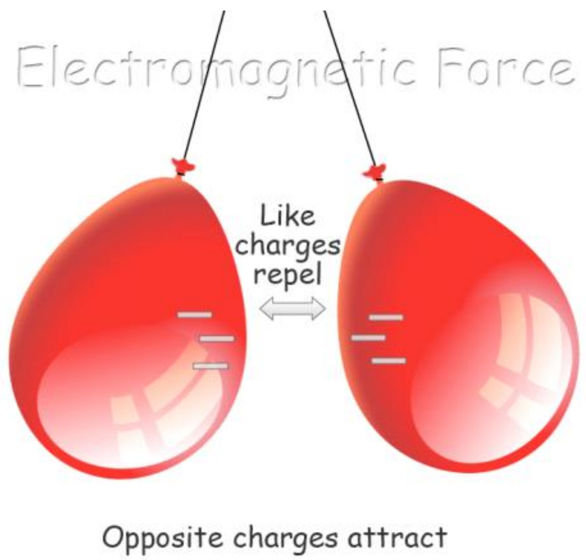


James Clerk Maxwell was a home educated Christian. His geometric curves paper that he wrote at only 14 years of age caught the attention of scientists at Edinburgh University. He was admitted, but he quickly outgrew the experimental facilities there and transferred to Cambridge University in England.

After graduating, he took a post at King's collegel where he met Michael Faraday, the inventor of the electrical generator and the electrical transformer. Clarks gift with calculus was far superior to Faraday's ability with math, so they partnered in research with James focusing on the mathematical side of their explorations of electricity and magnetism.

When Clark was 42, he published Treatise on electricity and Magnetism. He used 40 mathematical equations to prove that magnetism and electricity were indeed the same force. It wasn't fully accepted until Heinrich Rudolph Hertz's work also showed the same connection. It eventually became the guiding force of electromagnetic study. With time, the number of equations dropped to just 4, but they still bear his name "Maxwell's Equations". The math will be above your ability right now. Indeed, you would need 2 to 4 years of post calculus mathematics to be able to understand them.

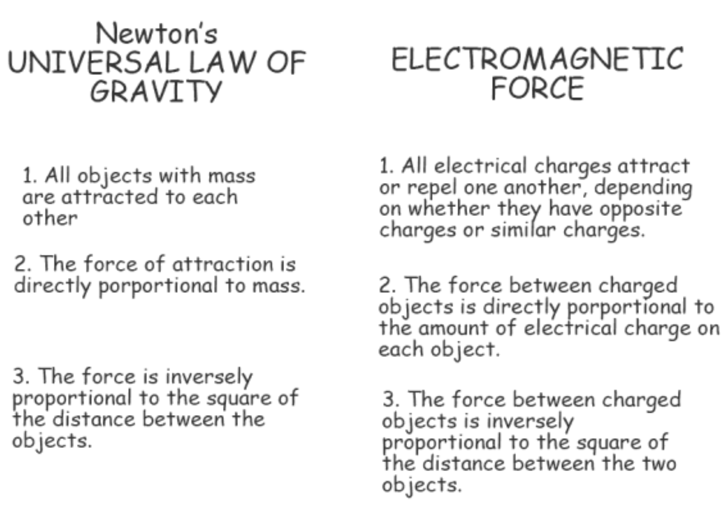


Positive and Negative Charges

Synthetic material when rubbed against a natural fiber will build up charges. If you rub balloons on your hair for instance, the balloons will collect electrons from your hair making your hair positively charged and the balloons negatively charged.

When the charges are the same on two objects, such as a negatively charged balloon next to another negatively charged balloon, they try to get away from one another. Like charges repel.

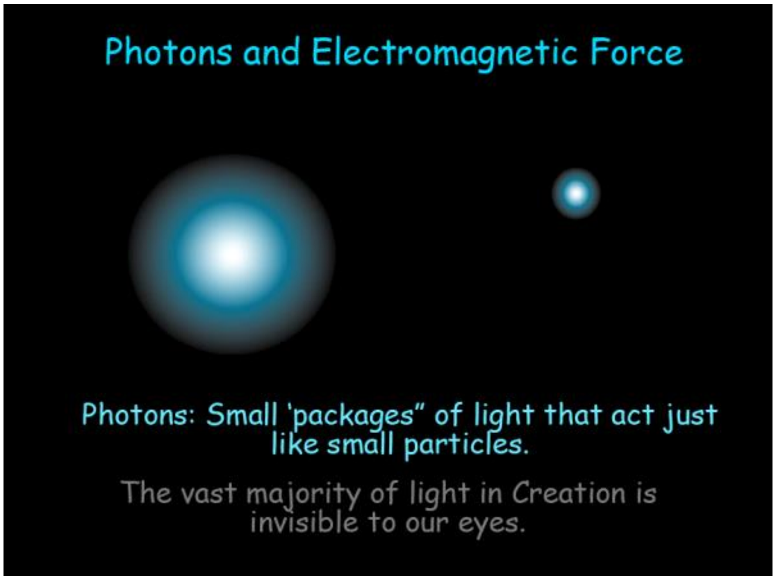
If you take the balloon to the wall, the positive charges on the wall will draw near the balloon and the balloon will be attracted to the wall and seem to magically stick to it. You can also bring the ballon near to your hair and it will pull the strands toward it and make it look like you are having a really bad hair day. Opposite charges attract.



Electromagnetic Force

Remember Newton's Universal Law of Gravity that you studied in the last lesson? Look how similar it is to the Electromagnetic Force Laws. Coincidence? Maybe not. Scientists have seen the similarity too and they think that gravity and electromagnetic force may be the same phenomenon.

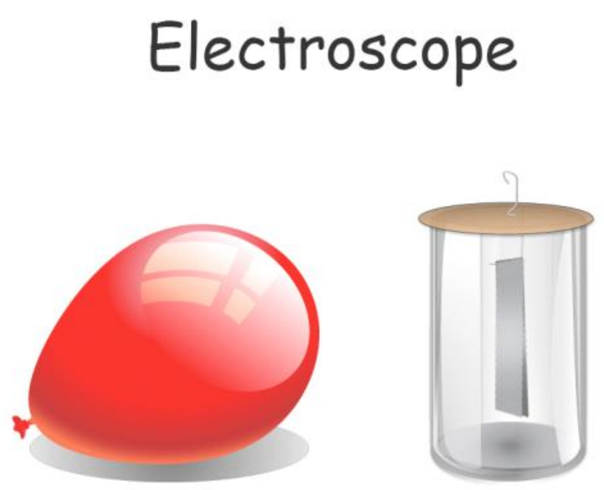
Since you already did the math in the last lesson, we will not need to do math equations in this lesson since the math is the same for both.



Protons and Electromagnetic Force

Electromagnetic force is actually produced from the exchange of photons. Photons are small packages of light that act just like a small particle. You may wonder why then you don't always see light. Actually, it is always there when they are exchanged, but our eyes can only see it when there is extra photons available to be sent out in the visible spectrum so that our eyes have the ability to see them.

You can also see how the inverse proportionality of distance plays out. If you were blindfolded and you were supposed to throw a ball and hit someone with it, you would have a higher chance of hitting them if they were close to you. The further away they are, the harder it would be to hit them.



Electroscope

An electroscope is a pretty easy device to build. A glass, a lid cut our of a butter tub top, a bent paper clip, and strip of aluminum foil is all you need for the device itself. A charge can be built up using a balloon or a plastic comb that is rubbed against clean, dry hair or other natural fiber.

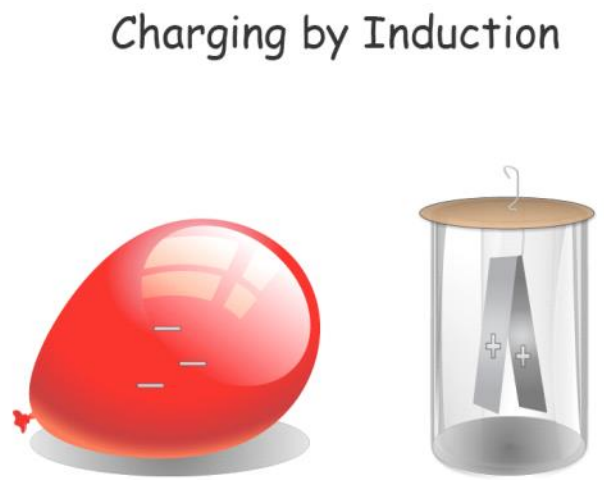
When you bring the charged balloon close to but not touching the bent paper clip the positive and negative charges in the foil and paper clip go from being random to arranging themselves so that the positive charges are as close to the balloon as possible and the negative charges are as far away as possible. When you pull the balloon away again, they go back to being largely random in arrangement.

How Objects Become Charged _ Conduction

Repeat the process but this time, let the balloon touch the bent paperclip. Some of the balloon's negative charges moved to the paperclip and the electroscope now has a flood of negative charges making the foil leaves now permanently negatively charged. Now the leaves stay repelled.

When you charge an object in this way, it is called charging by conduction. In conduction, you end up with the object being the same charge as the object that was used to charge it. The balloon was negatively charged and now the electroscope is too.

Charging an object by allowing it to come into contact with an object which already has an electrical charge. conduction



Induction:

What if you need the foil to be repelled but you need the charge to be the opposite in the electroscope than in the balloon? This can be accomplished and all you need is something to drain the electrons away.

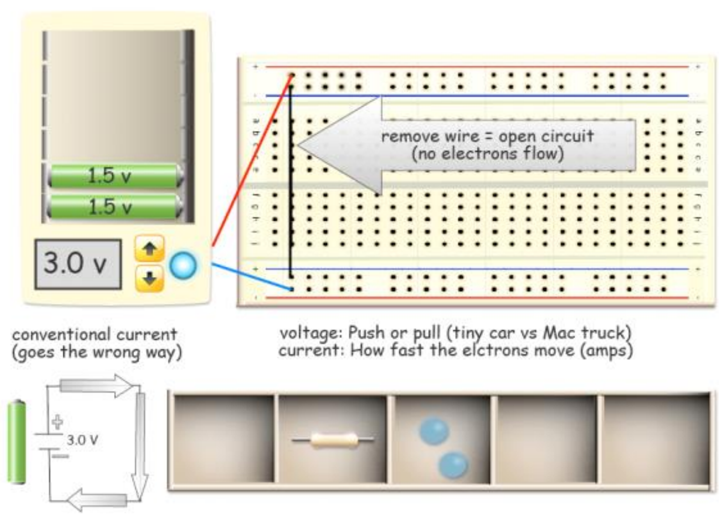
Bring the balloon near but not touching the bent paperclip. The electrons are trying to stay away from the balloon as far as they can get. But, if you give them a path to get even further away they will take it. Do that by touching your finger to the bent paperclip. They will rush through your finger to get further away. When you pull your finger and the balloon away, now the electroscope has too few electrons and so it will be positively charged. The positive charges in the foil try to get away from each other and they repel each other but this time it is because of a positive instead of a negative charge.

This is charging by induction and the result is that the electroscope has the opposite charge of the balloon which charged it because electrons left the object.

Charging an object by forcing some of the charges to leave the object — induction

A physicists charges an object with a positively-charged rod. If the object develops a negative charge, how did the physicist charge the object?

Choose one answer.
- ○ a. conduction
- ◉ b. induction



Electrical Circuits and Switches and Circuits

Now let's turn our attention to electrical circuits. The funny thing with the columns of holes is called a breadboard and it is a great tool for making temporary or experimental circuits.

The columns are connected almost as if there were a wired inside the plastic running from top to bottom.

We also have a battery holder. This one will let us combine batteries to get a variety of voltages. You may already have noticed that those AA batteries are marked as 1.5 volts. If you need 3.0 volts, you could just put two in because they would add up to 3.0 volts. Voltage is the push or pull that sends the electrons around the circuit.

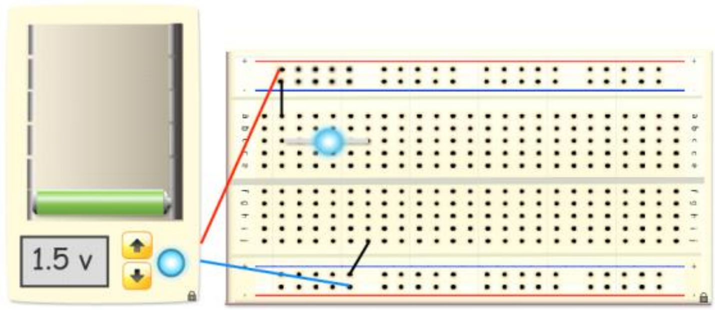
Electrical current is the amount of charge traveling through the circuit in one second. Its units are amps.

The circuit diagram is there in the lower left. All we have in this circuit is just a battery and the wires. The short and long line is the symbol for a battery. Batteries have a positive side and a negative side.

We have something called Conventional Current because of Benjamin Franklin. He thought that the positive plate had too many electrons and traveled to the side with too few (negative plate). It took about 20 years to correct the misconception, but scientists decided to keep it the wrong way in circuit diagrams! That is conventional current.

If you pull one of the wires out from the hole, you would create an open circuit. It would be the equivalent of turning the switch off. No electrons could flow through the circuit because one side of the battery isn't connected to the other side of the battery.

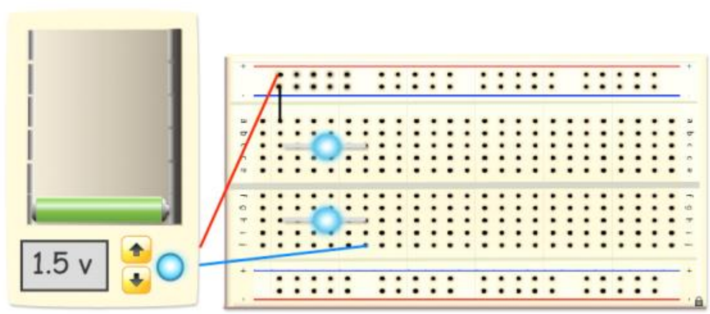
Current that flows from the positive to the negative side. This is the way we draw circuit diagrams even if it is wrong.	conventional current
The amount of charge that travels through an electrical circuit each second	electrical current
A circuit that does not have a complete connection between the two sides of the battery. As a result, current does not flow.	open circuit



Series Circuits

Now, that last circuit wasn't really doing much of anything useful. It was merely draining the battery without doing something that needed to be done. Let's give the circuit something to do such as lighting up a light bulb. Now look at the circuit diagram and see that there is a funny triangle with arrows. That is the symbol for a light emitting diode. You may know it better as an L.E.D. light.

The electrons can flow through the wires and the breadboard columns and through the LED and the LED light will light up.



Parallel Circuits

Now, that last circuit was pretty useful for giving an indication that electricity was flowing, but sometimes those little bulbs burn out. Have you ever notices that in some old Christmas tree lights that if one bulb burns out, the whole string of lights go out. This is because a burned out buld is really an open circuit where the metal burned enough to no longer be connected all the way through the bulb. You have to check every bulb on the string to find the one that is burned out and replace it with a new bulb.

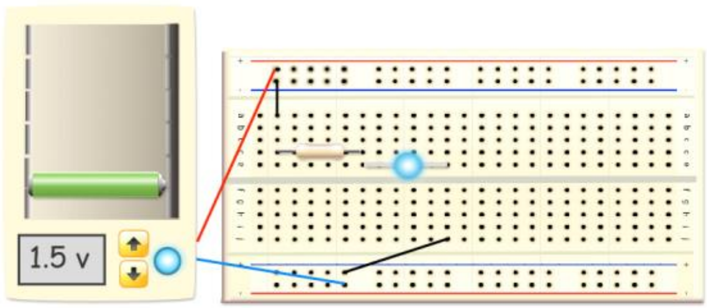
There is a solution though, a parallel circuit. Notice the circuit diagram now. The lights are in two separate branches. Lets pretend that one bulb burns out. Do you see how the electricity can still flow through the other leg of the circuit keeping the other bulb lit? Now, you can easily see which bulb is burned out because it will be the one not glowing while all the others are still lit. Parallel circuits are very handy.

One light bulb burned out but the rest of them in the set stayed on.

Choose one answer.

- ○ a. This is a series circuit
- ◉ b. This is a parallel circuit

Resistance



Sometimes you need to slow down the flow of electrons. Sometimes it is because some parts of the circuit are not able to handle the flow of electrons without it being slowed down. Resistors can do that job.

Resistors do just as their name implies. They resist the flow of electrons. They can get pretty hot in dong this job because it is very similar to friction. When you rub your hands together, The skin is providing friction to resist the motion and it generates heat.

If you take aluminum foil and connect it from one end of a battery to the other as you see in the picture, you will feel the heat in the foil as it resists the electrons. They do still flow, just as your hands still move against one another when you rub them together, but they give the heat and slow the movement.

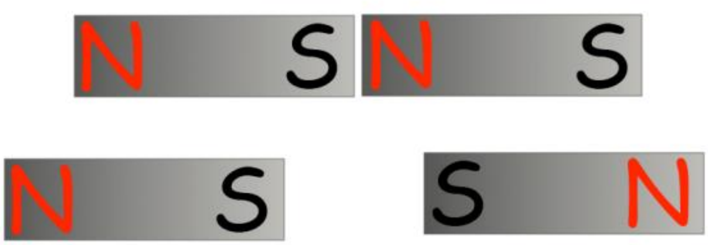
Resistors have color bands that show how much resistance they supply. This one doesn't have any bands of color yet. If we wanted a 470 ohm resistor, we would need bands of yellow (4), purple (7), black (0) and then a little space with another black (x1). [add the colors in to the slide if you want].

That 470 ohms is the resistance of the resistor. Resistance is the measure of how much a metal impedes the flow of electrons. The thickness of the metal plays a role in resistance. If the wire is thin, it is like a lot of traffic all crammed into a tiny little road and this will get hotter because stuff is bumping in to each other a lot more. A thick wire will not get as hot because it is like many lanes on a road where there is enough room to keep traffic from colliding as much as the electrons travel.

A measure of how much a metal impedes the flow of electrons — resistance

Two power cords get the same amount of current. The first cord is cooler than the second.

Choose one answer.
- (•) a. The first cord is thicker
- ( ) b. The second cord is thicker



How fast the elctrons are moving.Magnetism

Remember how the positive and negative charges in the electroscope behaved? If the charges were alike they repelled and when they were different they were attracted to each other. It is the same with magnets except the positive and negative are called north and south poles. Sometimes we just use N for north and S for south. They behave the same as the charges though.

If two south poles are brought near they repel. The force of that repulsion is going to be the inverse of the distance squared just like you learned in the force of gravity equations. If the distance is doubled so that they are farther apart you will decrease the force by 2 squared. That is 2 times 2, so the total force is decreased by 4 times when the distance is doubled.

The poles are because the atoms in the iron line up when they are magnetized. They line up so that the positive and negative charges are orderly instead of random as they would be if the iron were not magnetized.

If you cut the magnet in half, the atoms would stay lined up. It would just give you two magnets, each with one north and one south pole.

Though you cannot see them with your eyes, there are magnetic field lines coming out of the magnet. If you sprinkle iron filings on the table and give the surface a gentle tap or two, the filings will start making the field lines visible because the filings line up with the lines.

So, now you have had a chance to see how the forces of electricity and magnetism are from the same basic phenomenon and how they have commonalities even with gravitational forces. We have put these forces to use to invent new technologies that make our lives a lot different than they were even 20 years ago.

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like charges	repel
opposite charges	attract

The force between the south pole of one magnet and the south pole of another magnet is measured. If the distance between those magnets is suddenly doubled, how will the new force compare with the old one? Will it be repulsive or attractive?

Choose one answer.
- ○ a. decreased by 2, attractive
- ◉ b. decreased by 4, repulsive
- ○ c. decreased by 4, attractive
- ○ d. decreased by 2, repulsive

The atoms in an object are aligned. Is the object a magnet?

Choose one answer.
- ○ a. no
- ◉ b. yes

You cut a magnet in half. How many north poles do you have now?

Choose one answer.
- ◉ a. two
- ○ b. one