EXPERIMENT 4
Electricity and Magnetism

1. Static Electricity

Static electricity is a familiar phenomenon in our daily life. Sometimes when you take off your clothes or touch the switch button, you will make a "pop" sound and may have felt a shock. In this section, we will discuss how static electricity is generated.

There are many different objects around us, such as metal, plastic, fiber, etc. Their compositions and structures are different. And these objects around us are all “charged”. No matter what object it is, it will have both positive and negative charges. We humans are the same. Usually, the object contains the same numbers of positive and negative charges which cause “uncharged” or neural so when we touch it, there will be no "pop" electric shock.

However, the forces of attracting a negative charge that is carried by electrons of objects are different. When two objects are moving over another, the electrons will move to the side that can accept more negative charges. The one whose negative charges are taken away will have more positive charges, and on the other hand, the one who has taken the negative charges will have more negative charges. It is said to possess an electric charge. The electrons can build up to produce static electricity

1). Formation of a Charge Imbalanced Object by Rubbing

The instructor will use one of the fabric pieces (wool, silk, flannel, and animal fur) to rub one of the other objects (hollow glass friction rod, hard rubber rod, and solid acrylic rod) back and forth for several seconds to build up a static charge. Then, the instructor will bring the charged object near the light-weight materials like scraps of paper.

Write down your observation. Can you explain what happened?

Question: Can water be affected by a charged rod? Explain.

2). The Van de Graaff Generator

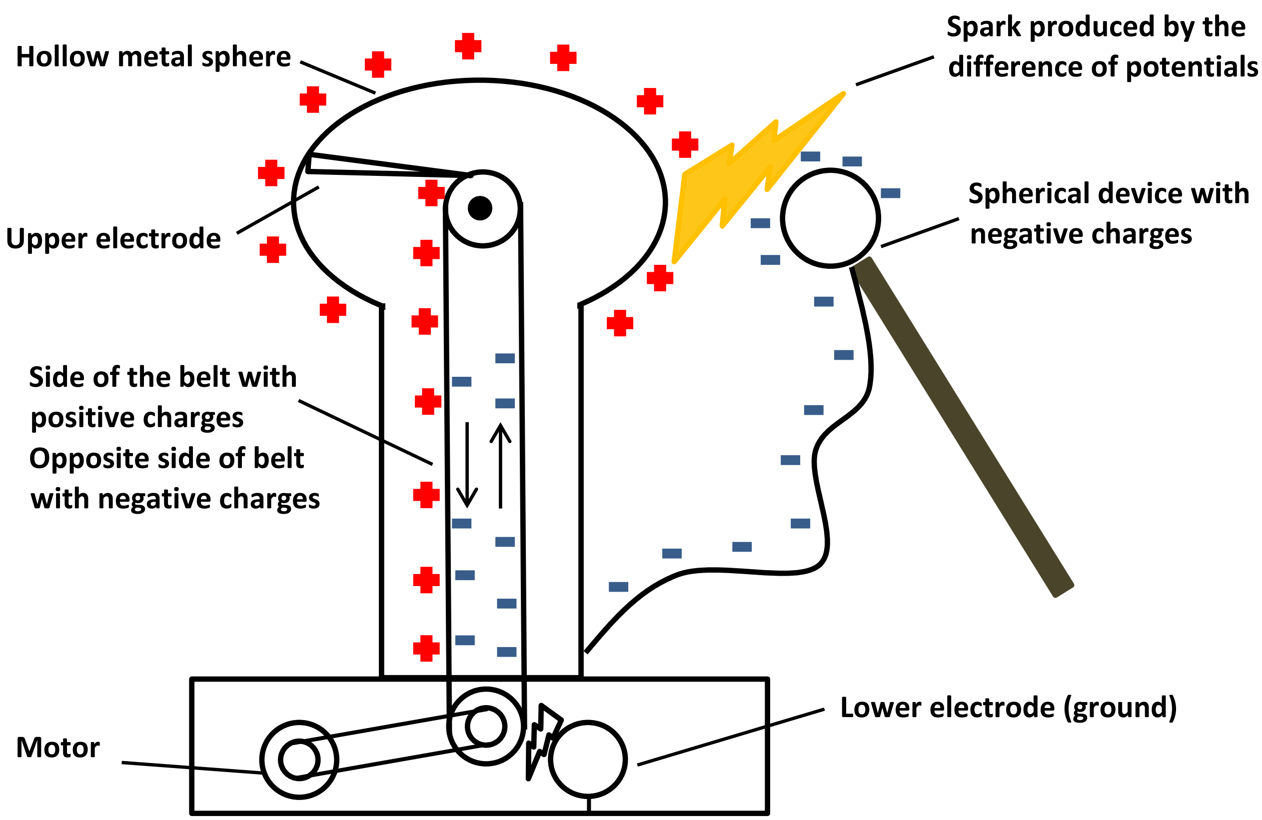


Figure 9.1 Schematic of the Van de Graaff generator

A volunteer with mid-to shoulder-length or longer hair is needed to show a charge imbalance.

Question: How this charge imbalance was achieved?

The instructor will place several foil tart pans on top of the generator. When the generator is on, what did you observe? Explain why that happened.

2. Conductivity

In this section, the instructor will test a few samples (tap water, distilled water, solid sodium chloride, salt water solution, and sugar water solution) to determine whether they conduct electric current or not. The conductivity tester shown on the right is being used. When the conductivity tester is connected to a 110-Volt outlet and the sample inserts into both electrodes, the lamp will shine brightly for strong conductors, dimly for weak conductors, and will not shine at all for nonconductors.

Figure 9.2 Conductivity tester

Questions:

(1) Does distilled water conduct? Explain.

(2) Does tap water conduct? Explain.

(3) Does solid sodium chloride conduct? Explain.

(4) Does salt water solution conduct? Explain.

(5) Does sugar water solution conduct? Explain.

(6) For the samples that do conduct, what do they have in common?

3. Electrolysis of Water

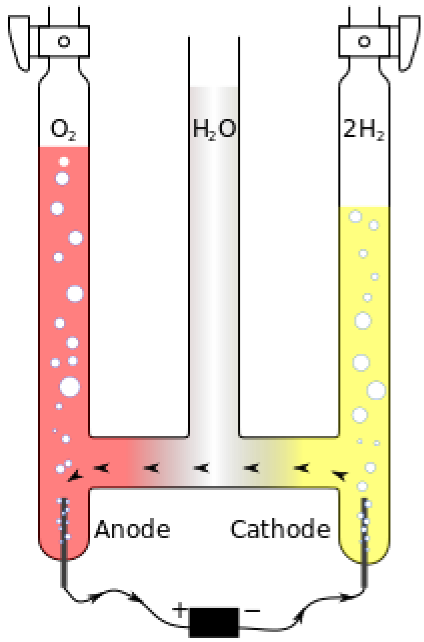


Figure 9.3 Schematic of the Hofmann voltameter.

Questions:

(1) What is the elemental make-up of water?

(2) What is the elemental ratio of water?

(3) Tests for the elements. Describe below.

4. Magnets and Magnetic Fields

Simple magnets are defined as containing both north and south poles. Magnetic monopole does not exit. When a magnet was cut in half, each piece will have its own north and south poles. When two north poles or two south poles are brought closed together, they will repel each other. However, when the north pole is near the south pole, they will attract each other. Those behaviors of magnets are now described as in terms of a magnetic field. The magnetic field is invisible. So, to detect the magnetic field of a magnet, iron filings will be used. Observe the magnetic field as the instructor sprinkling iron filings over a paper with a magnet under it.

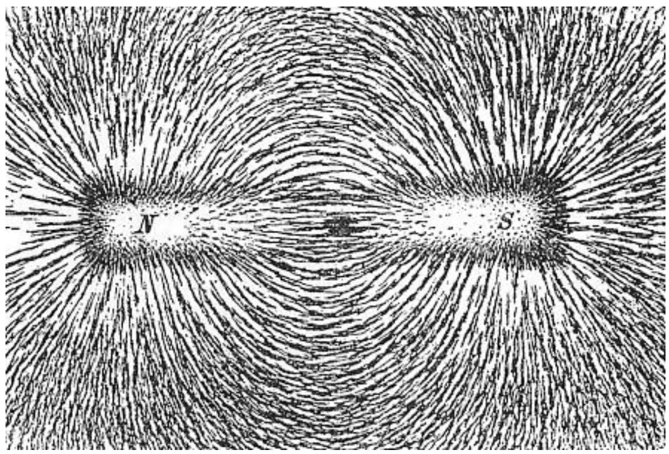
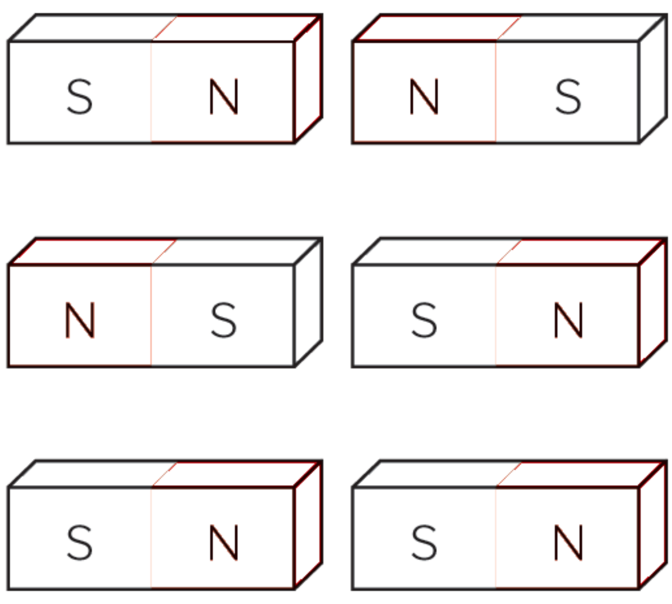


Figure 9.4 Iron filings in a magnetic field generated by a bar magnet (Newton Henry Black, 1913)

Questions: Sketch below your rendition of the magnetic lines of force.



5. Electromagnetic Induction

An electromagnet is a solenoid with an iron core inserted into it. If a current flows in the coil, a magnetic field is generated. All the randomly oriented domains of the iron core then align in the presence of the field of the solenoid. Thus, the core greatly enhances the strength of the electromagnet.

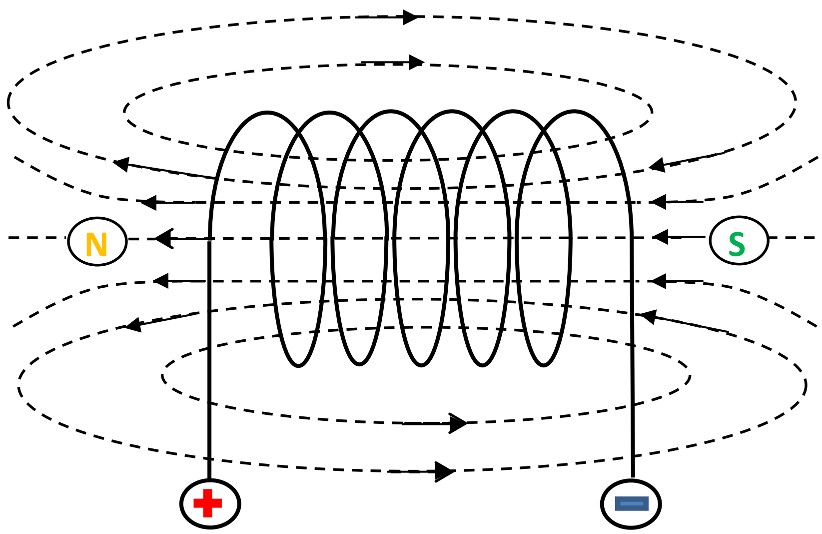


Figure 9.5 Schematic of electromagnet

Questions:

1. Describe some of the similarities and between the permanent and electromagnets.

2. Name some practical uses of electromagnets.

Now, what will happen if we disconnect the electrical current from the coil and instead of a core, we placed a bar magnet inside the core of the coil of wire?

The instructor will slowly insert and put out the permanent magnet into the green solenoid and you are to observe the galvanometer's needle.

Note - Galvanometer: a tool to detect, compare or measure small electric currents; Willem Einthoven developed a type of galvanometer that he evolved into the EKG/ ECG.

Questions:

(1) In which direction does the galvanometer's needle move?

(2) Can a current be "induced" in a wire by a stationary magnetic field?

Some Application of Electromagnetic Induction:

(I) Electric generator: It converts kinetic energy into electrical energy.

(II) Electric transformer: It changes the voltage and comes in two types – step up and step down. A step-up transformer increases the voltage, while a step-down transformer decreases the voltage.

A Tesla coil is a type of disruptive discharge transformer.

(III) Wireless power transfer

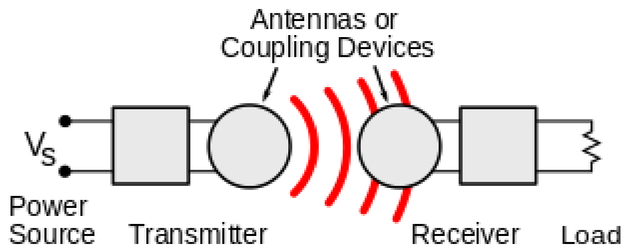


Figure 9.6 A generic block diagram of a wireless power system. (Chetvorno, 2014)

"Wireless power transfer" is a collective term for several different technologies which transfer power across space without wires using electromagnetic fields. A wireless power system consists of a "transmitter" device connected to a power supply such as mains power line, which converts energy to a time varying electromagnetic field, which transmits the energy across an intervening space to a "receiver" device, which converts it back to an electric current which powers a load.

6. Types of Current

A direct correct (DC) indicates that the flow goes from the positive to the negative side of the voltage source.

An alternating current (AC) indicates the flow goes in both directions intermittently.

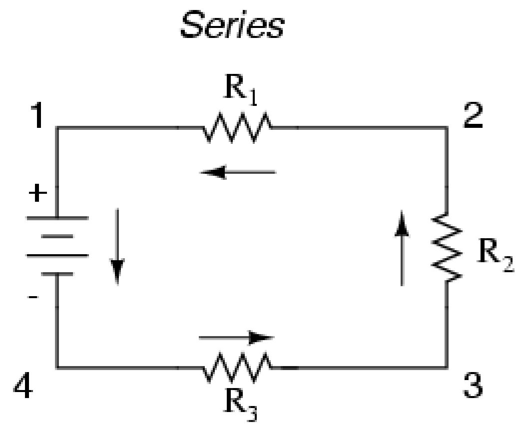
Questions:

(1) Which type is the most common in our home, DC or AC?

(2) Which type of current does the electric generator produce in power plants nowadays? What are the advantages?

7. Series and Parallel Circuits

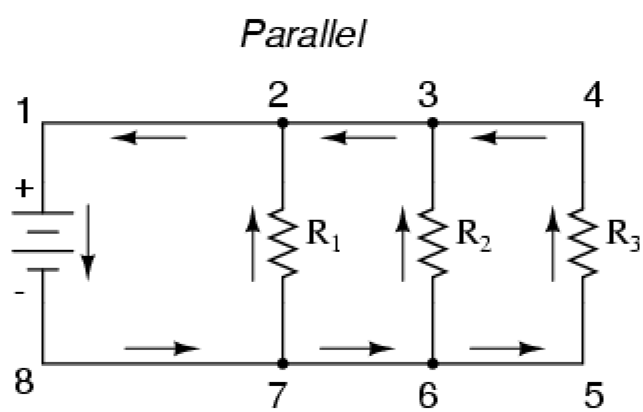
A series circuit is considered a dependent circuit on all the components being in operation at the same time.



Here, we have three resistors (labeled R1, R2, and R3), connected in a long chain from one terminal of the battery to the other. (It should be noted that the subscript labeling -- those little numbers to the lower-right of the letter "R" -- are unrelated to the resistor values in ohms. They serve only to identify one resistor from another.) The defining characteristic of a series circuit is that there is only one path for electrons to flow. In this circuit the electrons flow in a counter-clockwise direction, from point 4 to point 3 to point 2 to point 1 and back around to 4.

Question: Give an example of series circuit that you use at home.

A parallel circuit is one in which each component is independent of the other components.



Again, we have three resistors, but this time they form more than one continuous path for electrons to flow. There's one path from 8 to 7 to 2 to 1 and back to 8 again. There's another from 8 to 7 to 6 to 3 to 2 to 1 and back to 8 again. And then there's a third path from 8 to 7 to 6 to 5 to 4 to 3 to 2 to 1 and back to 8 again. Each individual path (through R1, R2, and R3) is called a branch. The defining characteristic of a parallel circuit is that all components are connected between the same set of electrically common points. Looking at the schematic diagram, we see those points 1, 2, 3, and 4 are all electrically common. So are points 8, 7, 6, and 5. Note that all resistors as well as the battery are connected between these two sets of points.

Questions:

(1) Give an example pf a familiar parallel circuit.

(2) Explain some of the advantages or disadvantages of using a series and parallel circuit.

8. Ohm's Law and Equivalent Resistance

1) Ohm's Law

In circuit analysis, three equivalent expressions of Ohm's law are used interchangeably:

$$\boldsymbol{I = \frac{V}{R}} \text{ or } \boldsymbol{R = \frac{V}{I}} \text{ or } \boldsymbol{V = IR}$$

Where I is the current through the conductor in units of amperes; V is the voltage measured across the conductor in units of volts, and R is the resistance of the conductor in units of ohms.

Questions:

(1) When a current of 10.0 A flows through a 50.0-Ω resistor in a circuit, what is the voltage of that circuit?

(2) A 9-V battery is hooked up to a 3-Ω resistor. What current is flowing through this circuit?

2) Equivalent Resistance

In a series circuit, all components are connected end-to-end, forming a single path for electrons to flow. So, the equivalent resistance of a series circuit is given as:

$$R_s = R_1 + R_2 + R_3 + \cdots R_n$$

In a parallel circuit, all components are connected across each other, forming exactly two sets of electrically common points. So, the equivalent resistance of a parallel circuit is given as:

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots \ \frac{1}{R_n}$$

Question:

Find the equivalent resistance in the given circuit below: