

Notes on: Electric Current

1.) Introduction

Introduction to Electric Current

Electricity is the flow of electric charge, which can be harnessed for various purposes such as lighting our homes, powering our gadgets, and propelling trains. In this introduction to electric current, we will explore the fundamental concepts that form the foundation of electricity and its associated phenomena.

Electric Charge:

At a basic level, everything in the universe has an innate property known as electric charge. This charge can be positive, negative or neutral. Neutral objects have zero net charge. Electrons, which are subatomic particles found in atoms, carry a negative charge ($-1e$). Protons, which are also subatomic particles found in nuclei, carry a positive charge ($+1e$). The electric force between oppositely charged objects is attractive while that between similarly charged objects is repulsive.

Voltage:

An electric potential difference, known as voltage or electrical potential, exists between two points due to an imbalance of electric charge. This potential energy can be transferred from one object to another through a conductor when a path for the flow of current is created by connecting the two objects using a wire. Voltage is measured in volts (V) and is analogous to altitude, where high voltage corresponds to a significant elevation above ground level.

Current:

An electric current is the rate at which electric charge flows through a conductor. It is measured in amperes (A). For example, if a certain number of electrons flow through a wire every second, this would correspond to an electrical current. The direction of current is determined by convention as the movement of positive charge, even though it's actually the negatively charged electrons that are moving through a conductor.

Resistance:

The property of a material that opposes electric current is known as resistance (R). This opposition to current results in heat generation, which is known as Joule heating. Resistances can be quantified in Ohms (Ω) and are dependent on the physical properties of the material. Some materials like copper have low resistances while others such as rubber have high resistances.

Electrical Circuits:

An electric circuit is a complete path through which current can flow between two points of different electrical potentials. A typical electric circuit consists of a source of voltage (a battery), a conductor (a wire) and a load (an appliance or device). The behavior of an electric circuit is governed by Kirchhoff's laws, which are two fundamental principles that help analyze and predict the behavior of circuits under various conditions.

Capacitors:

A capacitor is an electrical component that can store an electric charge. It consists of two conducting plates separated by a dielectric material. A capacitor can be charged or discharged by connecting it to a voltage source, which results in the transfer of electrons from one plate to another. The amount of charge that can be stored is proportional to the voltage and the capacitance (C) of the capacitor.

Electrical Power:

Electric power is the rate at which electrical energy is generated or consumed. It is measured in watts (W) and is equal to the product of voltage and current. Power can also be calculated by multiplying voltage by current and dividing the result by some unit of measure, such as ohms (Ω) for resistance. High power consumption leads to high electrical bills while low power consumption results in lower bills.

Electrical Energy:

Electric energy is the amount of work that can be done by an electric charge, measured in joules (J). It is equal to the product of voltage and charge. Electric energy is analogous to mechanical energy or potential energy in other systems. When a capacitor is charged, it stores electrical energy which can then be released when needed.

In summary, understanding the basic concepts of electric charge, voltage, current, resistance, circuits, capacitors, power, and energy is essential for comprehending electricity and its associated phenomena. These topics form the foundation upon which more advanced concepts are built, such as magnetic fields, transformers, alternating currents, and electronic devices. By mastering these fundamental principles, you will have a strong basis to explore further into the fascinating world of electricity.

2.) Electric Charge: Fundamental Concepts

Electric charge is one of the fundamental concepts in physics, specifically in the field of electricity and magnetism. It refers to the physical property of matter that causes it to attract or repel other charged objects. Charge can be positive, negative, or neutral. This lesson will explain electric charge in detail, including its history, unit of measurement, and how it is transferred between objects.

History:

The concept of electric charge was first introduced by the ancient Greeks, who observed that certain materials, such as amber, could attract lightweight objects like feathers when rubbed. This phenomenon became known as static electricity. Benjamin Franklin coined the terms positive and negative charge in the 18th century to describe the two types of charges he identified.

Unit of Measurement:

Electric charge is measured in coulombs (C). A coulomb is defined as the amount of charge that passes through a point in an electric circuit when a constant current of one ampere flows for one second. For example, a typical household battery contains about 1.5 C of charge.

Transferring Charge:

Charge can be transferred between objects in several ways:

- Conduction: This occurs when charge moves through a material, such as when you touch a doorknob after walking on carpet and receive a mild shock.
- Induction: This happens when an object becomes charged by coming into contact with or being near another charged object. For example, if you rub a balloon on your hair, it will become negatively charged and stick to walls.
- Convection: This takes place when charge moves through a fluid, such as when lightning strikes during a thunderstorm.

Properties of Charge:

Charge can have several properties that affect its behavior:

- Magnitude: The amount of charge in coulombs.
- Sign: Positive (+) or negative (-).
- Distribution: The location of the charge within an object. For example, some objects have a uniform distribution of positive and negative charge, while others have a concentrated charge at one end (like a charged battery).
- Motion: Charge can move through a material, such as when you slide a glass rod across a fur cloth to

create static electricity. This motion generates an electric field around the object that attracts or repels nearby charged objects.

Real Life Examples and Observations:

- Rubbing two pieces of wool together will cause them to become charged, with one piece becoming positively charged and the other negatively charged.
- Lightning is a natural phenomenon caused by the buildup of charge in the atmosphere during thunderstorms.
- Electrical shock occurs when your body becomes charged and comes into contact with another charged object (like a doorknob or appliance).
- Charge can be transferred wirelessly through an electric field, as demonstrated by wireless chargers for smartphones.

Interesting Facts:

- The charge on an electron is approximately -1.6×10^{-19} C.
- Some materials, such as glass and plastic, are insulators that do not conduct electricity because they lack freely moving electrons.
- A lightning bolt can carry up to one billion volts of electrical potential energy, which is enough to light a city for an entire day!

In summary, electric charge is a fundamental concept in physics that refers to the physical property of matter that causes it to attract or repel other charged objects. Charge can be transferred between objects through conduction, induction, and convection, and has properties such as magnitude, sign, distribution, and motion. Understanding electric charge is crucial for many modern technologies, from smartphones to medical equipment.

3.) Definition of Electric Current

Electric current is the flow of electric charge through a material. This means that when there is a potential difference (voltage) between two points in a conductor, such as a wire, electrons will move from one point to the other. This movement of charges results in an electric current. Electric current is measured in amperes (A), which is defined as the flow of one coulomb of charge per second.

An analogy that can help visualize this concept is to compare it to a river. Just as water flows from a higher elevation to a lower elevation due to gravity, electric charges move from a region with a higher electrical potential (voltage) to a region with a lower electrical potential (also known as an electric field). The speed at which the charges flow depends on the resistance of the material through which they are passing. Just as the width and depth of a river affect its flow rate, the size and shape of the conductor also influence the electric current that can pass through it.

In real life, electric currents are used for a variety of purposes such as powering homes and businesses, running appliances, and transmitting information through wires or cables. For example, when you flip a light switch in your home, an electric current is triggered that travels through the wiring to turn on the bulb. Similarly, when you send an email or make a phone call, electric currents are used to transmit information over long distances via telephone lines or fiber optic cables.

An interesting fact about electric current is that it can also have negative effects, such as causing electrical shock or fires in extreme cases. To minimize these risks, safety precautions such as grounding and circuit breakers are implemented in electrical systems. Grounding involves connecting the electrical system to a large conductive object (such as a metal rod in the ground) to help disperse excess charge and reduce the risk of shock. Circuit breakers automatically shut off the flow of current in the event of an overload, protecting both the circuit and any people or objects that may be nearby.

In summary, electric current is the movement of electric charges through a material due to a potential difference (voltage). Understanding how electric currents work is important for safely using and managing electrical systems in everyday life. By following safety precautions and respecting the power of electricity, we can continue to harness its benefits while minimizing risks.

- Potential Difference (Voltage): This is the difference in electrical potential between two points in a circuit. It is measured in volts (V). When there is a voltage between two points, it creates an electric field that causes charges to move from one point to the other, resulting in an electric current.
- Resistance: This is the measure of how much a material opposes the flow of electric current through it. It is measured in ohms (Ω). The higher the resistance, the more difficult it is for charges to pass through that material and the lower the current will be.
- Electric Conductivity: This is the ability of a material to allow electric current to flow through it. Some materials are good conductors, such as copper or silver, while others are poor conductors, such as rubber or plastic. The level of conductivity is related to the number of free electrons in the material and their ability to move freely.
- Direct Current (DC): This refers to an electric current that flows in one direction only. It is typically produced by a battery or other DC power source.
- Alternating Current (AC): This refers to an electric current that alternates direction, typically due to the use of AC power sources such as power plants. The frequency of the alternation is measured in hertz (Hz), with common household AC power having a frequency of 60 Hz in the United States and 50 Hz in many other countries.
- Kirchhoff's Current Law (KCL): This is a fundamental principle of electrical circuits that states that the total current entering a junction (where multiple wires meet) must equal the total current leaving that junction. This helps to ensure that electric charges are conserved and prevents issues such as shorts or overloads in complex electrical systems.
- Kirchhoff's Voltage Law (KVL): This is another fundamental principle of electrical circuits that states that the sum of all voltages around a closed loop in an electrical system must equal zero. This helps to ensure that there are no inconsistencies or discrepancies in the potential differences between various points in a circuit, and can help to identify issues such as voltage drops due to resistance in the wiring.
- Electrical Power: This is the rate at which electric energy is being converted into other forms of energy, such as light, heat, or motion. It is measured in watts (W). The power

4.) Conventional Current vs. Electron Flow

Conventional Current vs. Electron Flow

In the study of electricity, two different ways of describing the movement of electrical charge have been proposed; these are conventional current and electron flow. In this lesson, we will explore both concepts in detail and discuss their differences.

1) Conventional Current (CC)

Conventional current is a term used to describe the net flow of electric charge through a wire or any other electrical conductor. It is defined as the amount of charge passing through a given point per unit time. This definition assumes that positive charges are flowing from one end of the wire to the other, even though in reality electrons move in the opposite direction.

CC can be thought of as water flowing through a pipe. In this analogy, the pipe represents the conductor, and the water represents electric charge. The flow rate (volume per unit time) is analogous to CC, while the velocity of the water is similar to the speed at which electrons move in an electrical circuit.

Example: 10 C of charge flows through a wire in one second. This corresponds to a conventional current of 10 Amperes (A).

2) Electron Flow (EF)

Electron flow, on the other hand, refers to the movement of electrons in an electrical circuit. Unlike CC, which assumes that positive charges are moving, EF takes into account the fact that electrons actually

move from one place to another.

EF can be compared to the movement of cars on a highway. In this analogy, the highway is like a wire or conductor, and the cars represent electrons. The number of electrons traveling along the wire per second is analogous to EF, while the velocity of the cars represents the speed at which electrons move.

Example: 6×10^{18} electrons pass through a wire every second. This corresponds to an electron flow of 1.2 mA (milliAmperes).

Differences between CC and EF:

- Direction of Charge Movement: The main difference between CC and EF is the direction in which charge flows. In CC, it's assumed that positive charges move from one end of a conductor to the other; this is also known as conventional current. On the other hand, EF takes into account that electrons actually move in the opposite direction.

- Units: CC and EF are measured in different units because they describe two different aspects of electrical charge movement. CC is measured in Amperes (A), while EF is measured in Amperes per meter squared (A/m^2) or milliAmperes (mA).

- Applications: Both CC and EF are important concepts to understand, but they serve different purposes. CC is commonly used to describe the flow of electric charge through a wire or conductor, while EF helps us understand how electrons move within an electrical circuit.

In conclusion, both CC and EF are essential concepts in the study of electricity, as they help us understand how electric charges behave in different contexts. While CC is useful for describing the net flow of charge through a wire or conductor, EF helps us understand the movement of individual electrons within an electrical circuit. By understanding these two concepts separately, we can develop a more detailed and nuanced understanding of electricity as a whole.

5.) Drift Velocity of Electrons

The Drift Velocity of Electrons

In the last blog post, we discussed how electric current is defined as the flow of electric charge through a conductor. We also introduced the concept of conventional current, which is the direction that an electric charge would travel if it were moving through the wire from higher to lower potential energy. But what about the electrons themselves? Where are they going, and why do they move in the opposite direction of conventional current?

To understand this, we need to take a closer look at the behavior of electrons in a metal wire. When an electric charge is applied to one end of the wire, it creates an electric field that pushes the electrons in the opposite direction. This force is known as the electric force or Lorentz force, and it is given by the formula:

$$F = qE$$

where F is the force acting on the electron, q is its charge (-1.6×10^{-19} C), and E is the strength of the electric field (V/m). Since the direction of the electric force is opposite to the direction of conventional current, we can say that the electrons are being pushed in the opposite direction of conventional current.

However, this doesn't mean that the electrons are moving randomly or chaotically. In fact, they follow a regular pattern known as drift velocity. Drift velocity is the average speed at which electrons move through a wire when an electric charge is applied. It is calculated using Ohm's law:

$$V = IR$$

where V is the voltage (potential difference) across the ends of the wire, I is the current flowing through the wire, and R is the resistance of the wire.

To understand how drift velocity works, let's consider an example. Let's say we have a 10-ohm resistor connected to a 9V battery. If we apply Ohm's law, we can calculate the current flowing through the wire:

$$I = V / R$$

$$I = 9V / 10 \text{ ohms}$$

$$I = 0.9 \text{ amperes (A)}$$

Now that we know the current, we can use it to calculate the drift velocity of the electrons in the wire. First, we need to find out how many electrons are passing through the wire every second:

$$N = I / q$$

where N is the number of electrons, I is the current flowing through the wire (in amperes), and q is the charge on each electron ($-1.6 \times 10^{-19} \text{ C}$).

Next, we need to find out how far these electrons are traveling during this time:

$$d = V / E$$

where d is the distance traveled by the electrons (in meters) and E is the strength of the electric field inside the wire. Since the electric force acting on each electron is given by $F = qE$, we can use Newton's second law of motion to find out how fast they are moving:

$$F = ma$$

where F is the force acting on the electron (in newtons), m is its mass ($9.1 \times 10^{-31} \text{ kg}$), and a is its acceleration (in meters per second squared).

Now, let's put it all together. Suppose we have a wire with a diameter of 2 mm and a length of 1 meter. The resistance of this wire is 5 ohms. When a voltage of 6V is applied to the ends of the wire, how many electrons pass through the wire every second, and what is their average speed?

First, we need to find out the strength of the electric field inside the wire:

$$E = V / L$$

where E is the strength of the electric field (in volts per meter), V is the voltage across the ends of the wire (in volts), and L is the length of the wire (in meters).

Next, we need to find out how many electrons are passing through the wire every second:

$$N = I / q$$

where N is the number of electrons, I is the current flowing through the wire (in amperes), and q is the charge on each electron ($-1.6 \times 10^{-19} \text{ C}$).

Now that we know how many electrons are passing through the wire every second, we can calculate their average speed:

$$v = d / t$$

where v is their average speed (in meters per second), d is the distance traveled by the electrons (in meters), and t is the time it takes for them to travel this distance.

To find out how far they are traveling, we can use Ohm's law again:

$$V = IR$$

where V is the voltage across the