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Development and Research on Innovative Vocational Education Skills

SENSOR FUSION EXPERT

SFE.U1.E1 FUNDAMENTAL CONCEPTS OF ELECTRICITY

Electronics and Electricity Principles

JUNE 2021, Version 1

Co-funded by the Erasmus+ Programme of the European Union

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LEARNING OBJECTIVES

The student is able to …

SFE.U1.E1.PC1	The student is able to represent electrical signals and knows how to perform the Fourier analysis.
SFE.U1.E1.PC2	The student understands and is able to explain Electric Charge, Electric Power, Electric Field and Electric Potential Energy.
SFE.U1.E1.PC3	The student knows the concepts of Voltage, Current, Power, Energy and Yield.
SFE.U1.E1.PC4	The student can distinguish and relate different fundamental concepts of electricity.
SFE.U1.E1.PC5	The student knows and understands rudiments of magnetism.

ELECTRIC SIGNAL DEFINITION

An electrical signal can be defined as "A signal that is conveyed by electricity (as by variations in voltage or frequency) or operated by electricity."

This signal can be artificially generated by an electronic circuit

1 - The **potential difference** variation, better known as voltage, between two points over time can be considered.

2 - Analyzing the current that passes through a conductor, the **variation of the current** over time is considered an electrical signal.

ELECTRIC SIGNAL TYPES

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There are two types of electrical signals, namely:

Direct Current (DC)

Alternating Current (DC)

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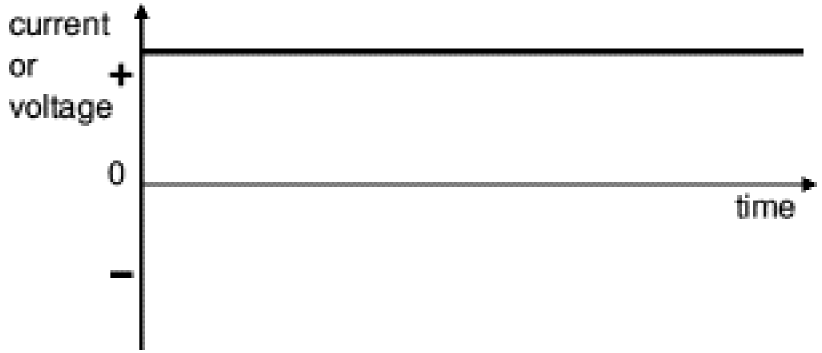
Direct Current (DC)

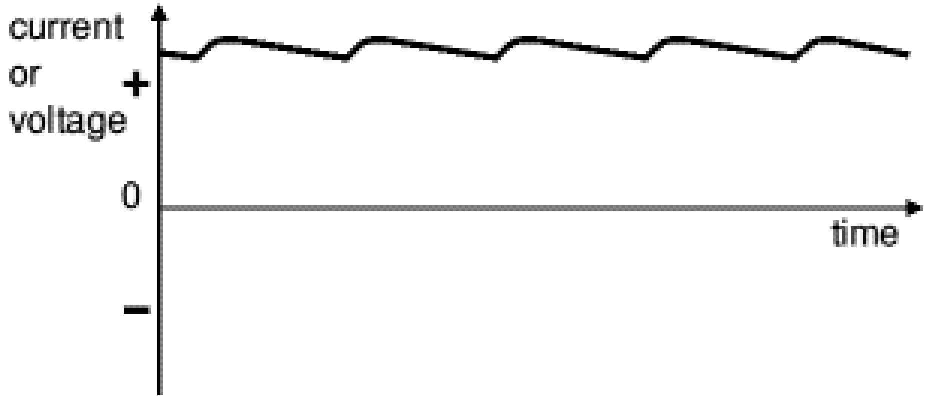
Direct Current is intended to create continuity in the supply of electrical energy.

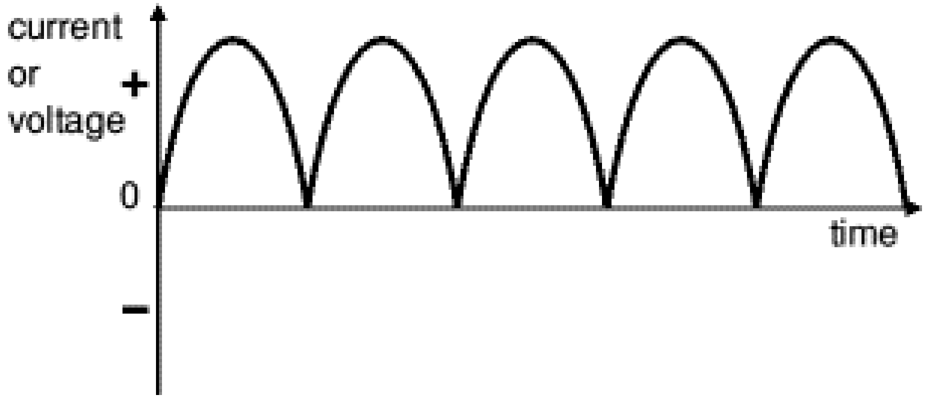
The electrons in a wire carrying direct current move slowly, but eventually they travel from one end of the wire to the other because they keep plodding along in the same direction.



Constant DC from a battery or regulated power supply is ideal for electronic circuits.

However, there are other variations of electrical signals that can include direct current, such as:





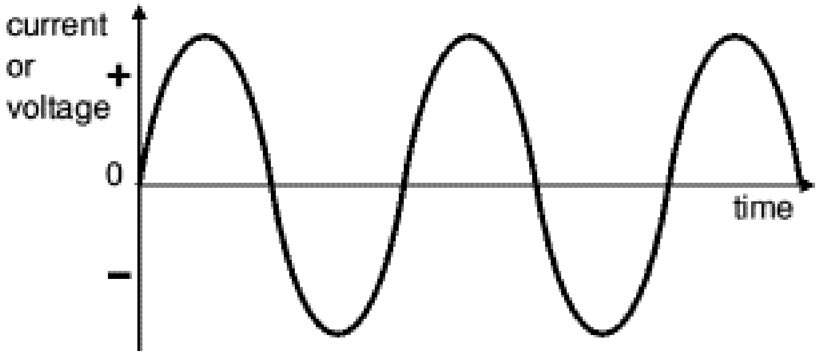
Smooth DC
from a smoothed power supply, suitable for some electronic equipment.

Varying DC
from a power supply without smoothing, this is not suitable for electronic equipment.

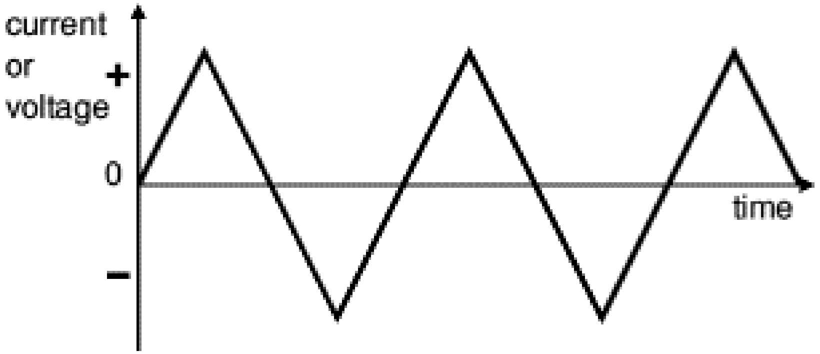
Alternating current (AC)

Alternating Current is intended to flow to one side and then to the other, continually reversing direction.

In the most common form of alternating current, used in most power distribution systems around the world, the voltage reverses 50 or 60 times a second, depending on the country.



AC from a power supply
This shape is called a sine wave.



This triangular sign is AC because it changes between positive (+) and negative (-).

Fourier analysis is the study of how general functions can be decomposed into trigonometric or exponential functions with defined frequencies.

In recent years, he is one of the most influential theorists in science, and important in engineering calculations and in signal processing and in the analysis of electronic circuits.

Jean Baptiste Joseph Fourier

Source: Getty Images/Stock Montage

Its application areas are vast, but we present those that are better known, namely:

- Physics,
- Number theory,
- Signal processing,
- Digital image processing,
- Statistics,
- Cryptography,
- Numerical analysis,
- Sonar,
- Optics,
- Diffraction,

Fourier Analysis is divided into two parts:

Fourier Series Theory

Fourier Transform

During the study of thermal flow, Fourier found a periodic function that could be expressed as an infinite form of sinusoidal functions. Note that this function was not sinusoidal. This function was represented as follows:

$$f(t) = f(t + nT)$$

$f(t)$ Periodic Function

n Integer Number

T Function Period

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Applying this to electronic circuits, the procedure involves 4 steps:

1. Determine the expansion of the excitation Fourier series.
2. Transform the circuit from time domain to frequency domain.
3. Determine the response of DC and AC components in the Fourier series.
4. Sum the result of the individual DC and AC using the superposition principle.

1 Determine the expansion of the excitation Fourier series.

Let's take the following periodic voltage source as an example, shown in Figure 1:

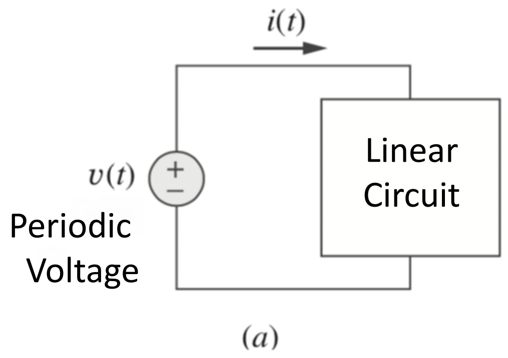

Figure 1

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1 Determine the expansion of the excitation Fourier series.

For the periodic voltage source, shown in Figure 1, the Fourier series can be expressed as follows:

$$v(t) = V_0 + \sum_{n=1}^{\infty} V_n \cos(n\omega_0 t + \theta_n)$$

2 Transform the circuit from time domain to frequency domain.

It can be seen that v(t) is formed by two parts: the component CC V_0 the component CA $\mathbf{V}_n = V_n \angle \theta_n$ with several harmonics.

This representation of the Fourier series can be considered as a set of sinusoidal sources connected in series.

Each of these sources has its own amplitude and frequency, as shown in Figure 2.

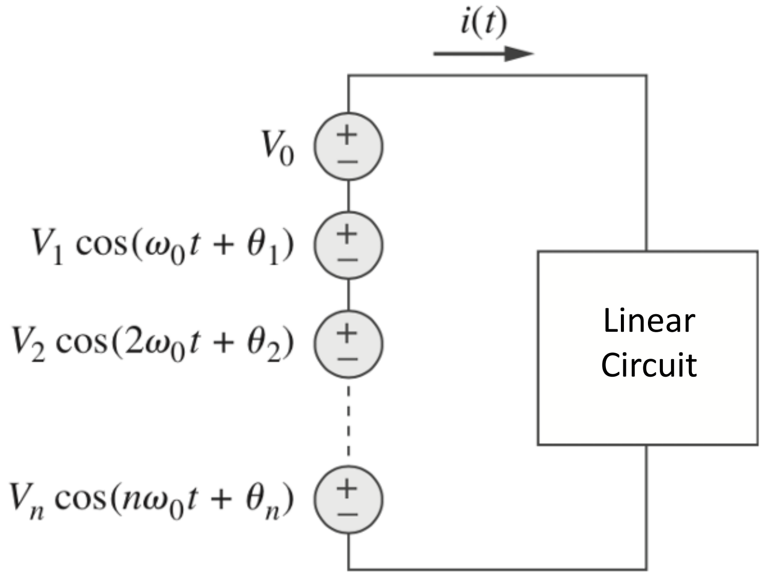

Figure 2

3 Determine the response of DC and AC components in the Fourier series.

The response to the DC component can be determined in the frequency domain.

It can be done $n = 0$ or $\omega = 0$ or in the time domain, replacing all inductors with short circuits and all capacitors with open circuits.

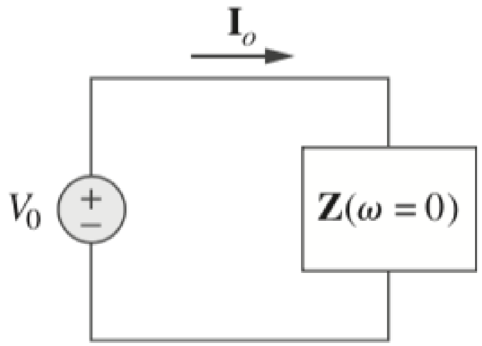

Figure 3

3 Determine the response of DC and AC components in the Fourier series.

The response to the AC component is achieved with the applicability of phasor techniques, as shown in Figure 4. The circuit representation is made by its impedance **Z**(n_w0) or admittance **Y**(nw_0). The input impedance is **Z**(nw_0), when all w is replaced by nw0 and **Y**(nw $_0$) is the inverse of **Z**(nw_0)

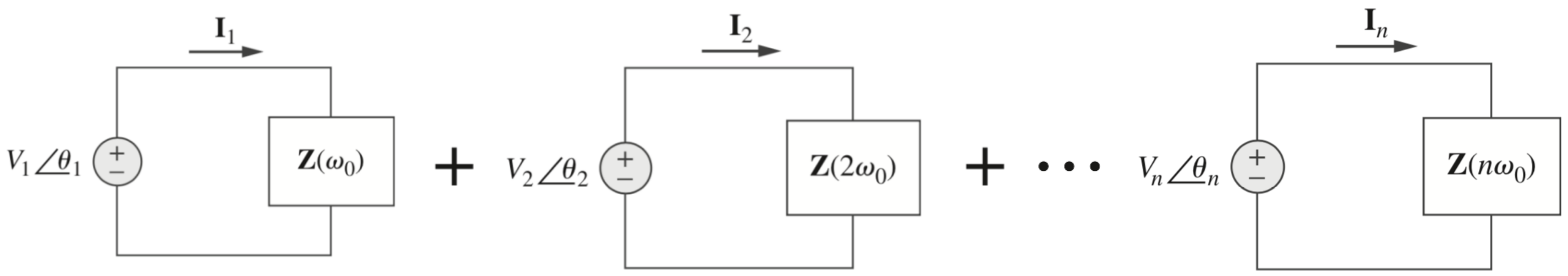

Figure 4

4 Sum the result of the individual DC and AC using the superposition principle.

Following the superposition principle, all individual responses are added.

Figure 5 demonstrates that each component In with frequency nw0 was transformed to the time domain to obtain $i_n(t)$ and ψ_n is the argument of I_n

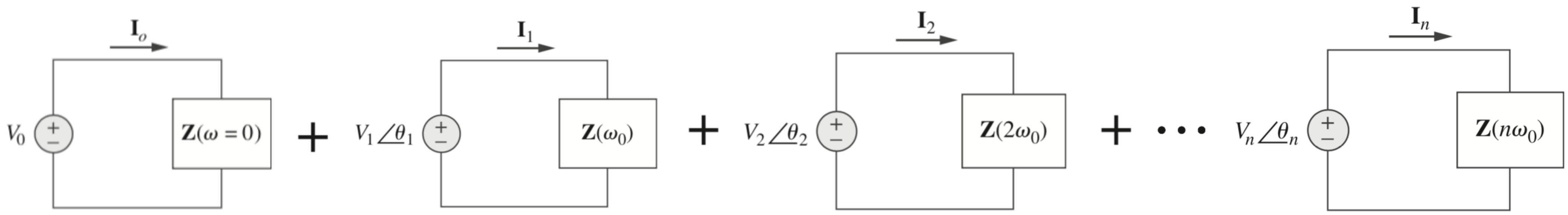

Figure 5

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The Fourier Transform:

- It consists of transforming integrals of $f(t)$ from the time domain to the frequency domain;
- Develops the phasor technique for non-periodic functions;
- It is applied to circuits with non-sinusoidal excitations with the same method that the phasor; techniques apply to circuits with sinusoidal excitations.

Thus it can be concluded that Ohm's law is still valid.

$$V(w) = Z(w)\, I(w)$$

V(w) and **I(w)** are the Fourier transforms of voltage and current
Z(w) is the impedance

The expressions for the impedances are obtained in the same way used in phasor analysis.

The impedances to be obtained are for:

- Resistors,
- Inductors,
- Capacitors.

$$R \Rightarrow R$$

$$L \Rightarrow j\omega L$$

$$C \Rightarrow \frac{1}{j\omega C}$$

Figure 6

After the transformation of functions for circuit elements for the frequency domain, Fourier transforms of excitations are extracted.

Circuitry techniques can be used to find the answer (current or voltage).

The techniques that can be used are:

- Voltage Division,
- Font Transformation,
- Mesh Analysis,
- Nodal Analysis or Thevenin's theorem

Finally, one has to extract the inverse Fourier transform in order to obtain the answer in the time domain.

Although the Fourier transform method generates an answer that exists for $-\infty < t \infty$, Fourier analysis is not able to treat the circuits with initial conditions.

The transfer function is defined again as the ratio between the output response Y(w) and the input excitation X(w), that is:

$$H(\omega) = \frac{Y(\omega)}{X(\omega)}$$

Figure 7

The input-output relationship within the frequency domain is represented in Figure 8.

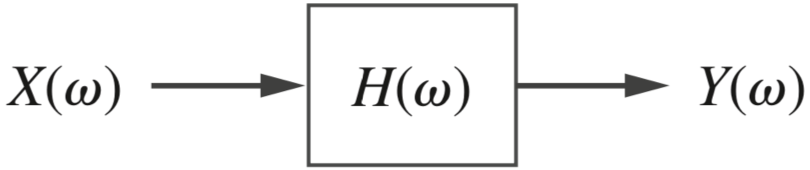


Figure 8

Below is an equation that demonstrates that if we know the transfer function and the input, we can readily determine the output.

$$Y(w) = H(w)\, X(w)$$

The relationship in the Equation below (Figure 7) is the main reason we use Fourier transforms in circuit analysis.

$$H(\omega) = \frac{Y(\omega)}{X(\omega)}$$

Figure 7

Note that H(w) is identical to H(s) with s = jw.

Likewise, if the input is an impulse function [ie, x(t) = d(t)], then X(w) = 1.

Thus the answer is Y(w) H(w) F[h(t)] indicating that H(w) is the Fourier transform of the impulse response h(t).

ELECTRIC CHARGE

An electrical charge can be defined as "basic property of matter carried by some elementary particles that governs how the particles are affected by an electric or magnetic field. Electric charge, which can be positive or negative, occurs in discrete natural units and is neither created nor destroyed."

The International System of Unit of electric charge is the coulomb (C) in honor of the physicist Charles Augustine de' Coulomb.

The electric charge is the smallest charge that exists in nature.

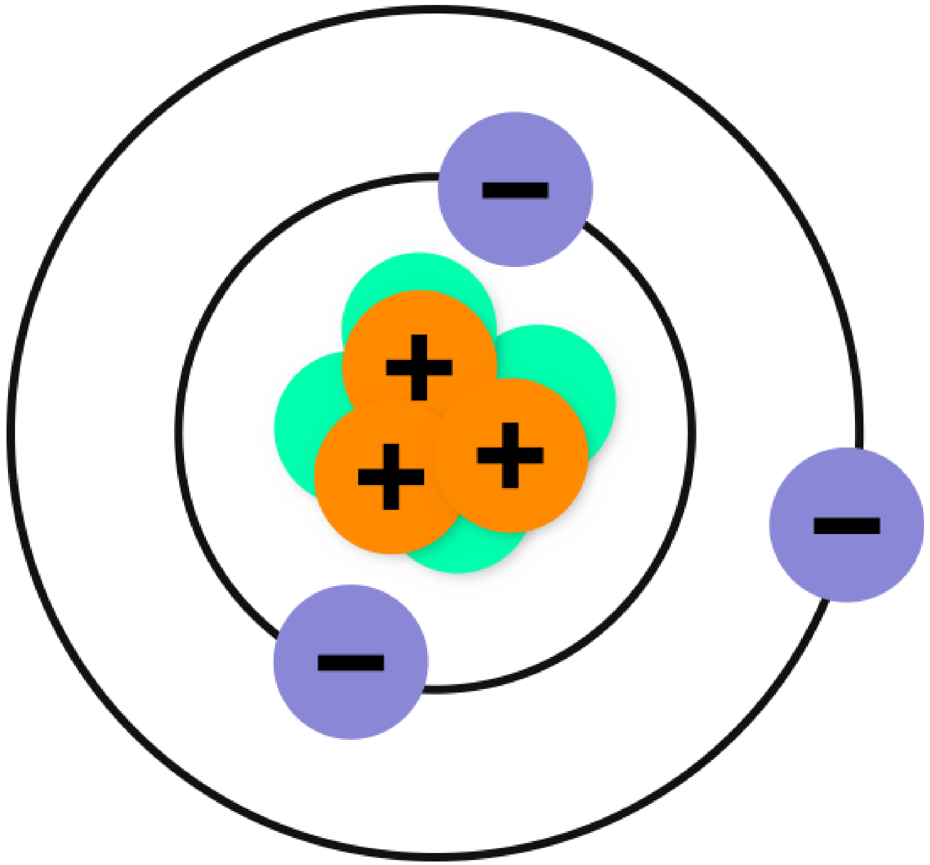
Understanding Electric Charge

Based on the aforementioned definition, the electrical charge is composed of:

Electrons

Protons

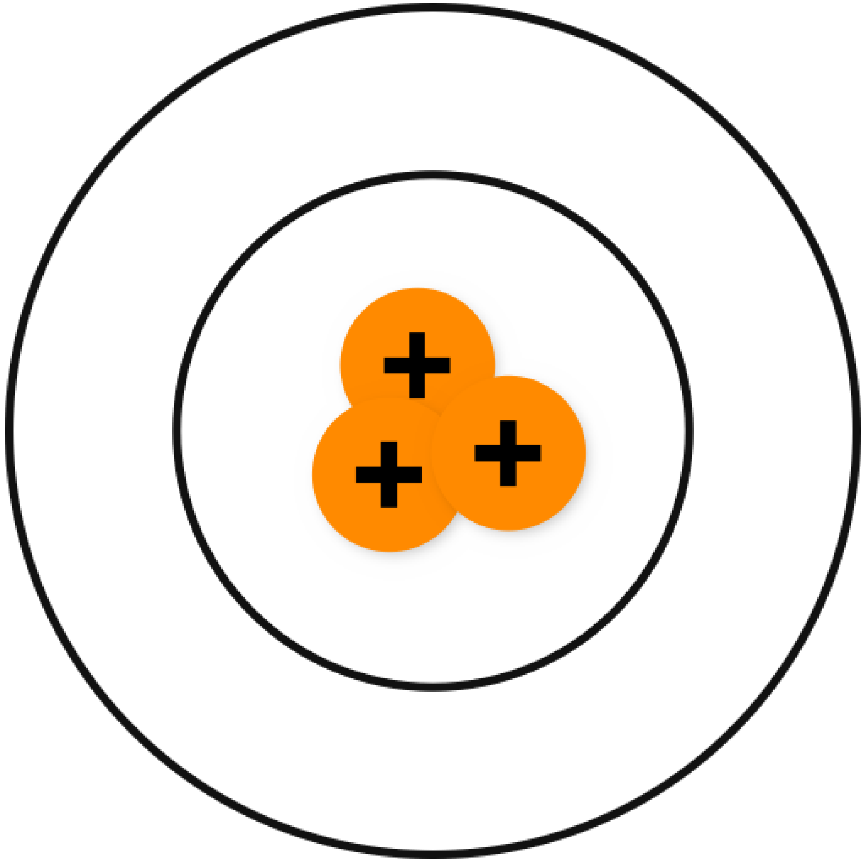
Neutrons



Understanding Electric Charge

Protons

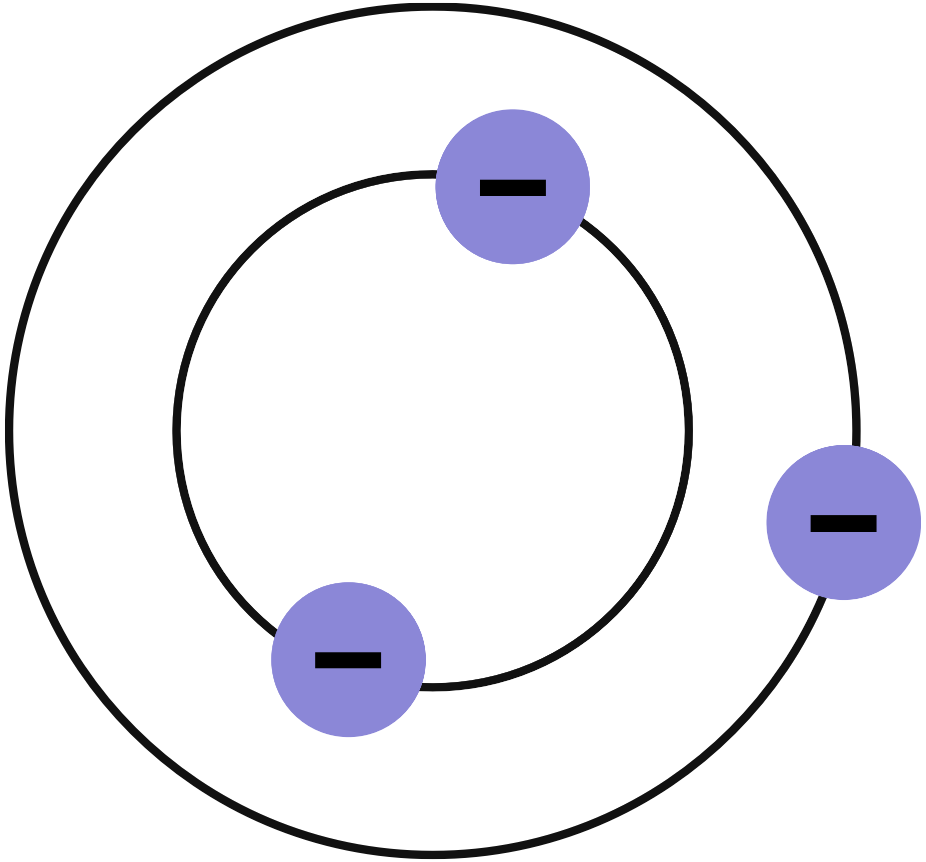
- They are located in the nucleus of the atom
- They have a positive electric charge



Understanding Electric Charge

Electrons

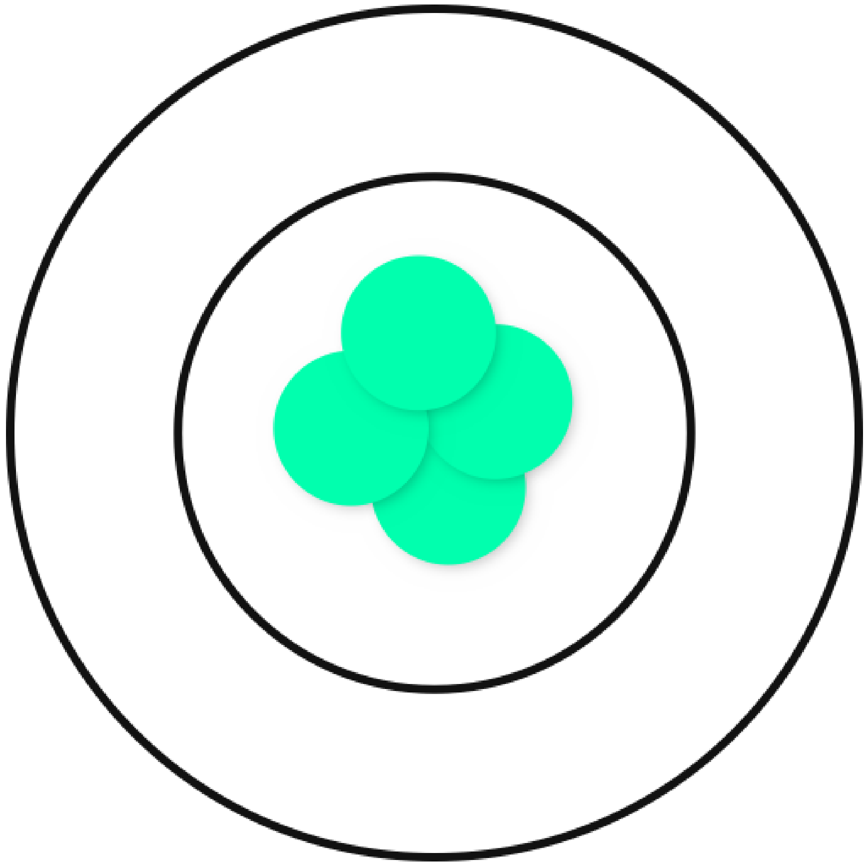
- Are located in the electrosphere
- Has negative electrical charge



Understanding Electric Charge

Neutrons

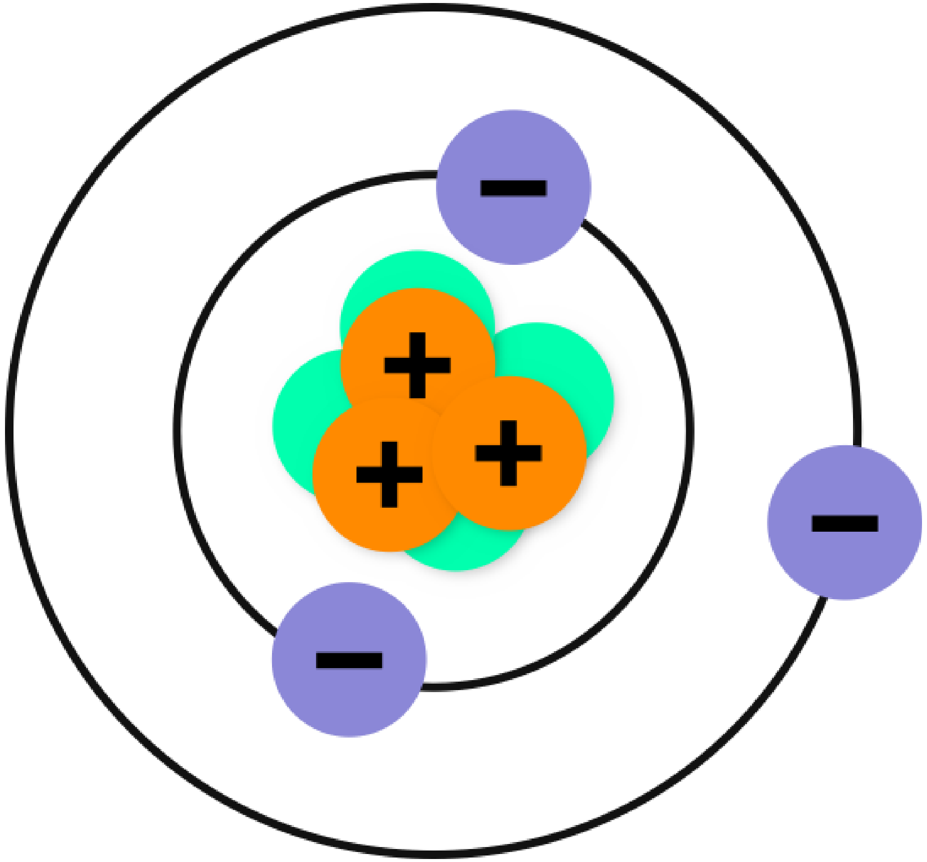
- They are located in the atomic nucleus
- Do not have electric charge



Understanding Electric Charge

Thus, a given body can be electrified in two ways:

- **Negatively**
  - If you have more electrons than protons
- **Positively**
  - If you have more protons than electrons



ELECTRIC POWER

The electrical power can be defined as "energy generated through the conversion of other forms of energy, such as mechanical, thermal, or chemical energy. Electric energy is unrivaled for many uses, as for lighting, computer operation, motive power, and entertainment applications. For other uses it is competitive, as for many industrial heating applications, cooking, space heating, and railway traction."

The International System of Unit of electric charge is the Watt (W) which is equal to one Joule per second.

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Understanding Electric Power

- Briefly, the time in which this energy is transferred in an electrical circuit is called electrical power.

- It can be supplied by electric lines or batteries to power homes and businesses.

Understanding Electric Power

Below is the formula that explains how electrical power can be measured:

$$P = \frac{W}{t} = \frac{W}{Q}\,\frac{Q}{t} = VI$$

Power

Time

Electric Charge

Electric Potential (Voltage)

Electric Current (amperes)

An electrical field can be defined as *“an electric property associated with each point in space when charge is present in any form. The magnitude and direction of the electric field are expressed by the value of E, called electric field strength or electric field intensity or simply the electric field. Knowledge of the value of the electric field at a point, without any specific knowledge of what produced the field, is all that is needed to determine what will happen to electric charges close to that particular point.”*

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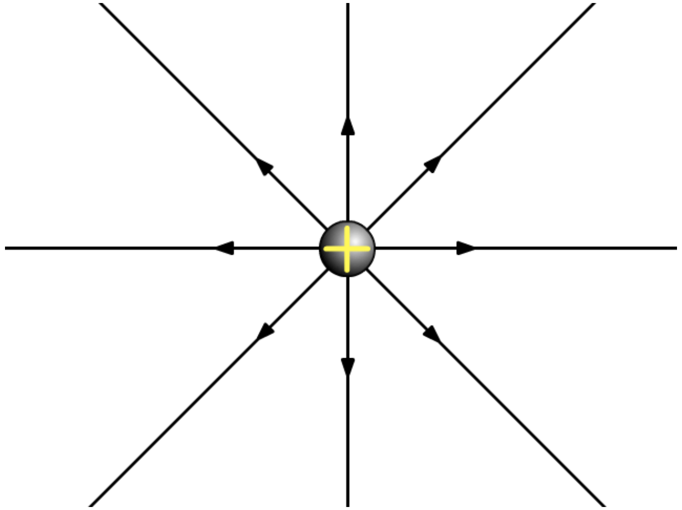
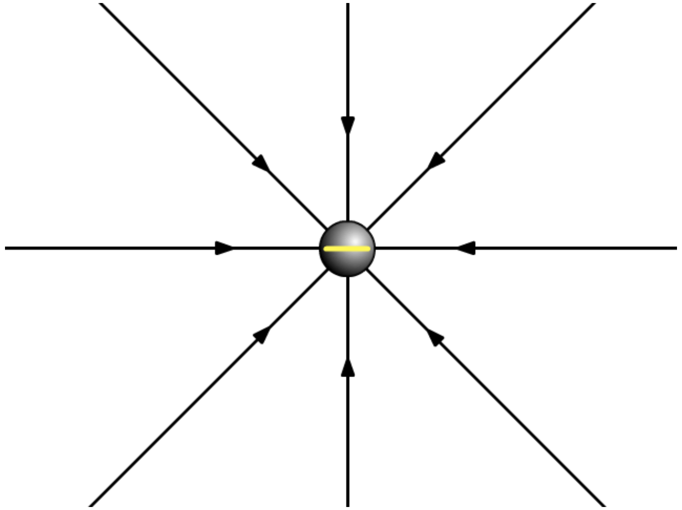
Understanding Electric Field

- Briefly, the electric field measures the impact a charge has on its surroundings.
- Thus, the closer two charges are, the greater the electrical force they will produce.

Understanding Electric Field

- In order to better understand the electric field, two animations are presented below:





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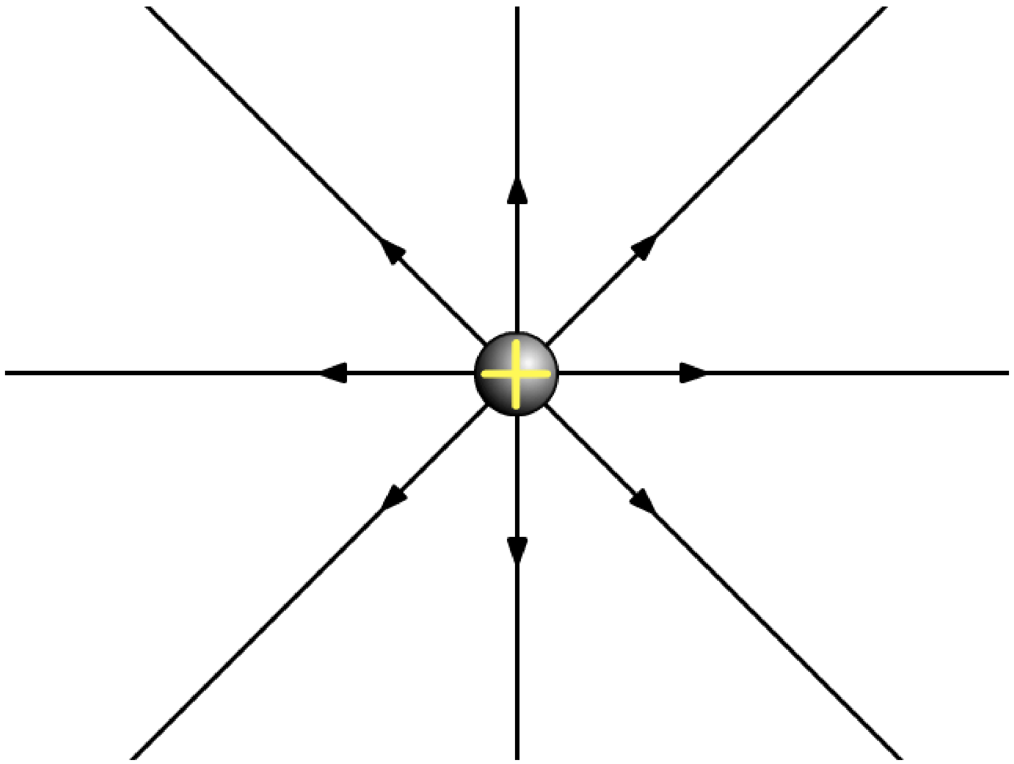
Understanding Electric Field

- The lines that you can see in the animation indicate the direction and direction of the electric field.
- These lines are called power lines.



ELECTRIC FIELD

Understanding Electric Field

- The electric field is calculated as follows:

$$\vec{E} = \frac{K_0 . Q}{d^2}$$

Electrostatic Constant

Electric Charge

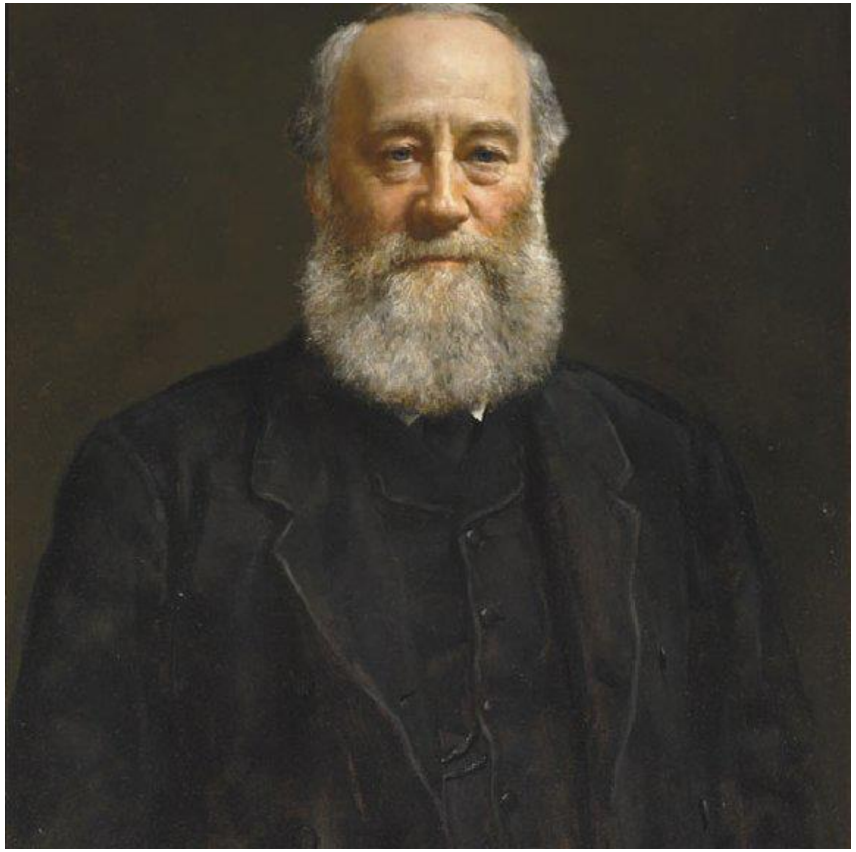
Electric Field

Distance from Point to Generating Load

Understanding Electric Potential Energy

Electrical potential energy can be defined as *”the result of work performed between two electrified loads”.*

- The unit of measure for Electric Potential Energy is the Joule in honor of James Prescott Joule.



James Prescott Joule.
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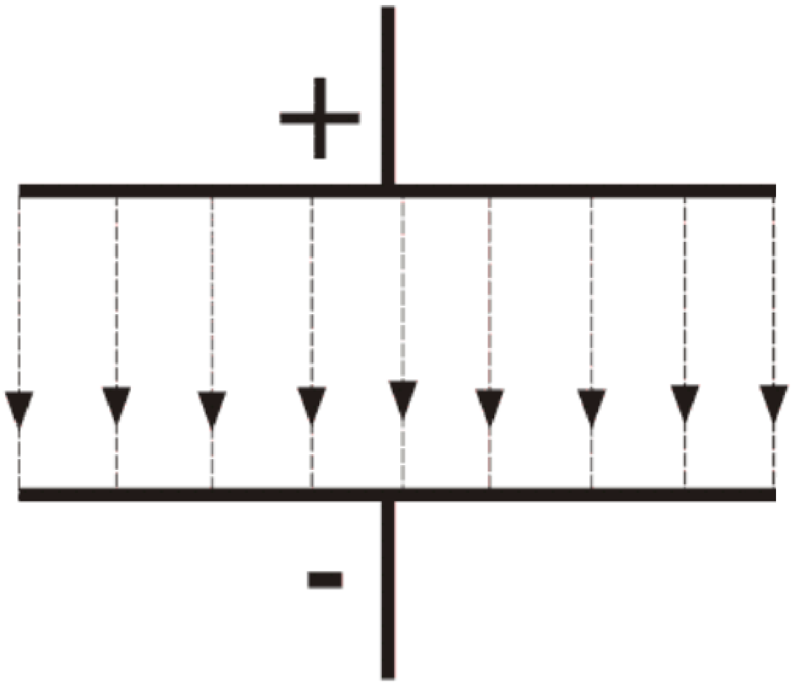
Understanding Electric Potential Energy

- Let's imagine two electrified plates and they both have opposite magnetic fields, so they create a magnetic field.

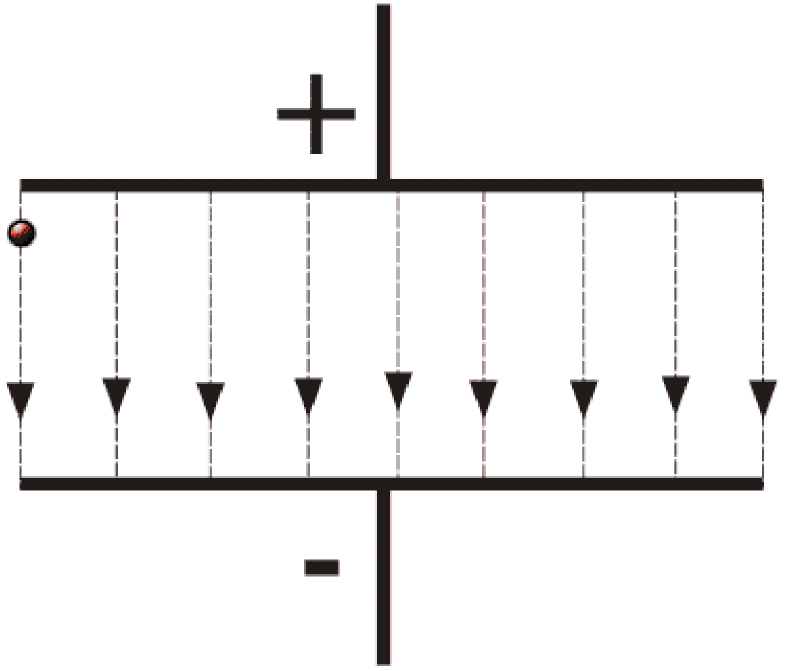


Understanding Electric Potential Energy

- As soon as a point-shaped electrical charge is placed in the middle of the plates, this charge will move between point A and Point B through the electrical force.

- At point A, the load is in rest mode, however, when it reaches point B, it will have speed and energy.

Movement of positive charged particle in uniform electrical field

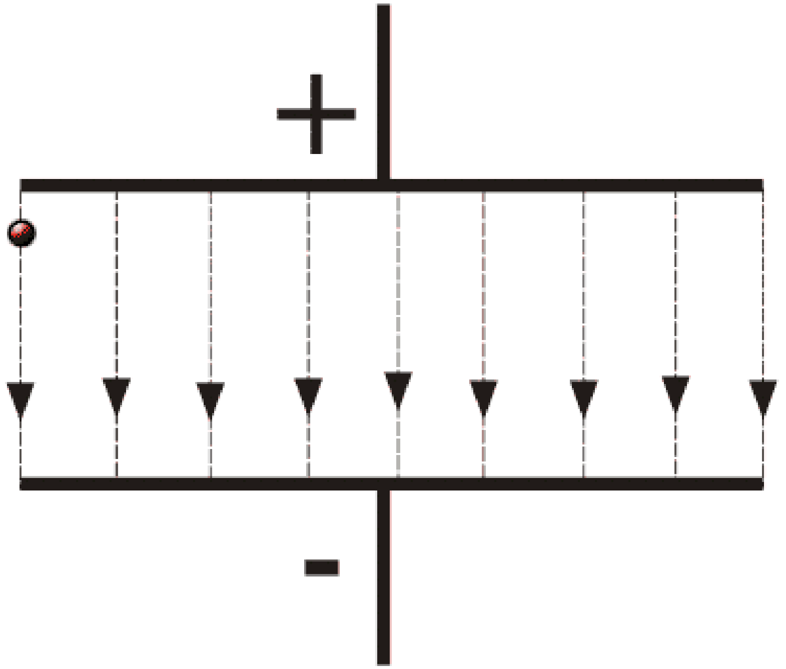


Understanding Electric Potential Energy

- Thus, at point A, the load has the potential energy associated with it with respect to point B.

- This energy is called electrical potential energy.

Movement of positive charged particle in uniform electrical field



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Understanding Electric Potential Energy

- The formula to calculate the Electric Potential Energy is presented bellow:

Electrostatic Constant

Electric Charge

$$E_p = \frac{K.Q.q}{d}$$

Electric Potential Energy

Distance

Electric Proof Charge

Understanding the Concept of Voltage

- Voltage is the physical magnitude that creates the impulse to electrons in an electrical circuit.

- Briefly, it is the work per unit of charge exerted in an electric field on a particular so that it creates a movement from one side to the other.

Understanding the Concept of Current

- The name electric charge is given to the physical property that certain particles have existing in magnetic fields.
- These particles are subatomic;
- They arise through the window of repulsion and attraction that exist between them through electromagnetic fields;
- In summary, the flow of electrical charges that travel through a given circuit is called an electrical current.

Understanding the Concept of Power

- Power is the product (result of the multiplication) of the potential difference between the ends of a load and the current that circulates there.
- In other words the amount of energy of a force effected by a unit of time.

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Understanding the Concept of energy

- The main concept of energy is transforming or putting something in motion.
- It originates from electrical potential energy and allows the establishment of electrical current between two points.

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Understanding the Concept of Yield

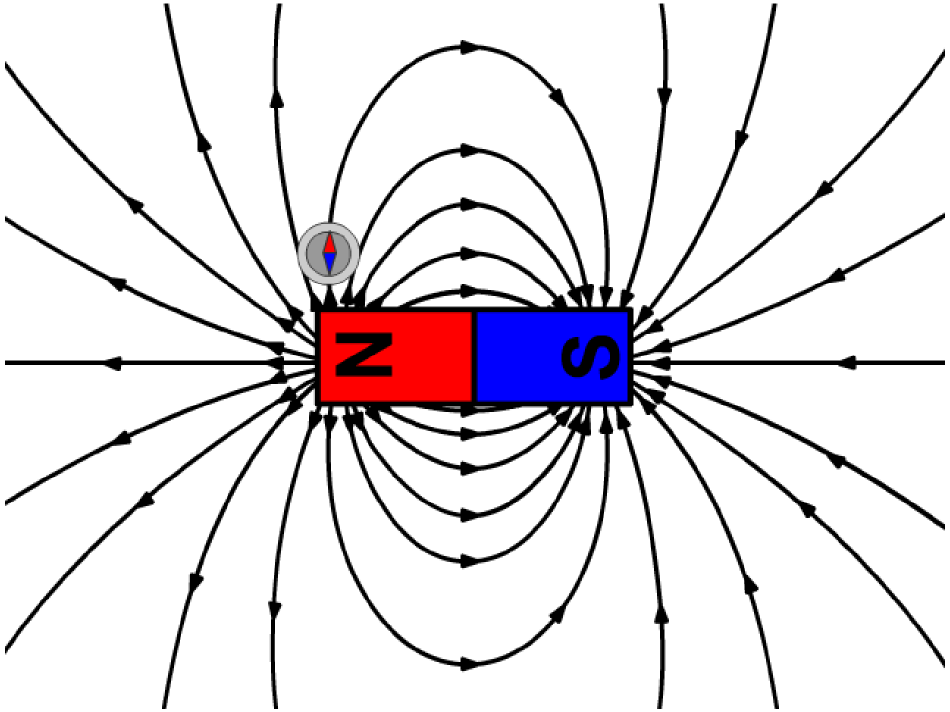
- Yield is the ratio between useful electrical energy and consumed electrical energy.
- It is presented as a percentage;
- To calculate just divide the amount of energy generated by the amount of energy needed.

The Rudiments of Magnetism are composed of:

- Force and magnetic field;
- Flux and magnetic flux density;
- Magnetic materials;
- Inductance;
- Electromagnetic induction phenomenon.

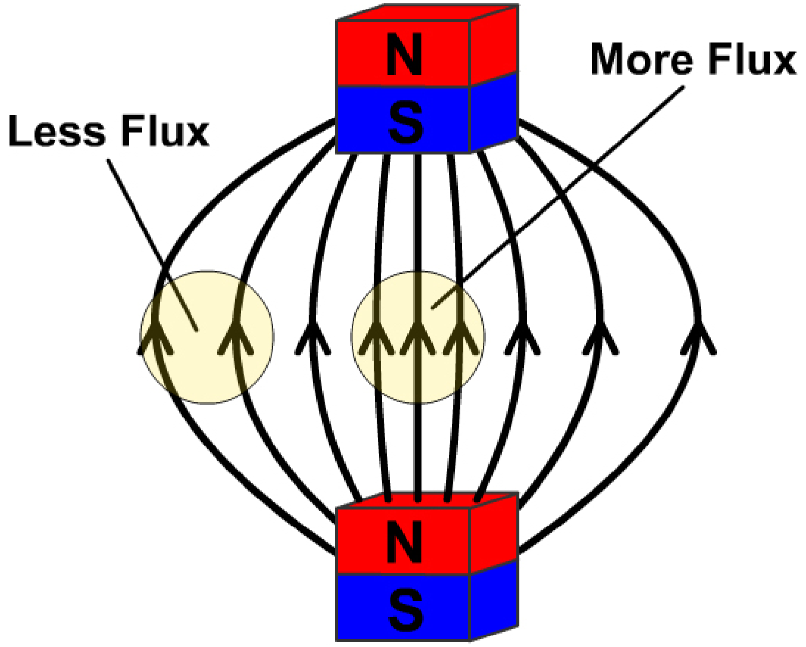
The Rudiments of Magnetism are composed of:

- Force and magnetic field:
    - Magnetic force is a type of force between ferromagnetic objects;
    - The magnetic field is formed by forces on magnetic materials.



The Rudiments of Magnetism are composed of:

- Flux and magnetic flux density
    - Magnetic flux is a measure of the total magnetic field that passes through an area.
    - The magnetic flux density is the magnitude of the magnetic field.
    - Flow is measured in webers and density in tesla.



The Rudiments of Magnetism are composed of:

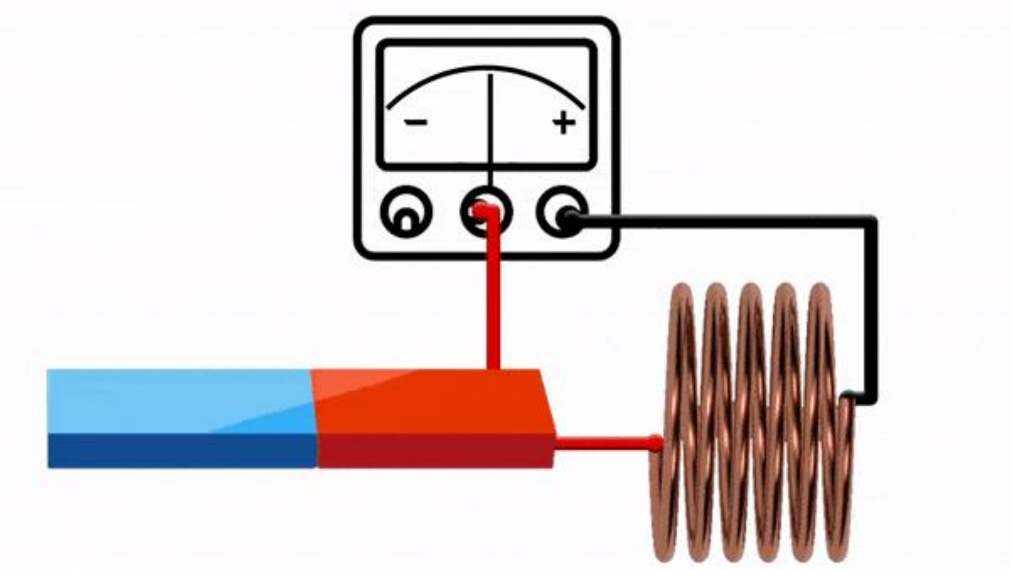
- **Magnetic Materials.**
  - Diamagnetic material
    - The external magnetic field is paired, and these repel magnetism
  - Para magnetic material
    - Does not return to original state when magnetized
  - Ferro magnetic material
    - They will maintain magnetism until removal of the magnetic field

The Rudiments of Magnetism are composed of:

- **Inductance**
    - Inductance is the phenomenon that happens when a certain electrical conductor opposes the change in the electrical current flowing through it.

The Rudiments of Magnetism are composed of:

- **Electromagnetic induction phenomenon**
  - Electromagnetic induction happens when a conductive material is immersed in a magnetic field and they are enabled to change the flux of the magnetic field that passes through them.



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Thank you for your attention

DRIVES project is project under **The Blueprint for Sectoral Cooperation on Skills in Automotive Sector**, as part of New Skills Agenda.

The aim of the Blueprint is **to support an overall sectoral strategy and to develop concrete actions to address short and medium term skills needs.**

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