التكنولوجيا التطبيقية
APPLIED TECHNOLOGY
وزارة التربية والتعليم والتعليم الفني

جمهورية مصر العربية
وزارة التربية والتعليم والتعليم الفني
وحدة تشغيل وإدارة مدارس التكنولوجيا التطبيقية

Student guide

Physics

Year 2

(STEM)

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week	Unit	Second secondary Second term 2023
Week 1	1	Lesson 1: meaning of static electricity
Week 2		Lesson 2 : coulomb's law
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Week 11		Lesson 3 ohmic resistance ,Resistivity and conductivity
Week 12		Lesson 4 : Electromotive force (emf) and internal resistance
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Week 14		lesson 6: Connections of resistors (series & parallel)(simple DC circuits)
Week 15		Lesson 7: unit test
Week16		**Lesson 8: Revision**

Unit one
Static electricity

Dear student, By the end of this lessons you should have the following skills and knowledges

Understand the concept of static electricity
State some types of attractive and repulsive forces.
Apply Coulomb's law.
Identify how to find the equivalent capacitance in series and parallel connection.
Identify the capacitor charging process.
Differentiate between attractive and repulsive forces.
Derive the international unit of proportionality constant in Coulomb's law
Deduce the factors affecting electrostatic force
Identify the electric field
Deduce the factors affecting the electric field intensity

Lesson 1
Meaning of static electricity

Introduction

ELECTRICITY:

Electricity is the flow of electrical charges or power. The charges could be in the form of electrons or ions. Electricity or electrical energy is a secondary energy source which means that we get it from the conversion of other sources of energy, like by burning coal, natural gas, oil or from nuclear power and other natural sources, which are called primary energy sources

Electric Charge

It was found that there is a physical quantity known as **electric charge** that can be transferred from one object to another. Charged objects can exert forces on other charged objects and also on uncharged objects. Finally, the electric charge classified into two types:

a) Positive charge
b) Negative charge.

Substances can be classified in terms of the ease with which charge can move about on their surfaces. **Conductors** are materials in which charges can move about freely; **insulators** are materials in which electric charge is not easily transported

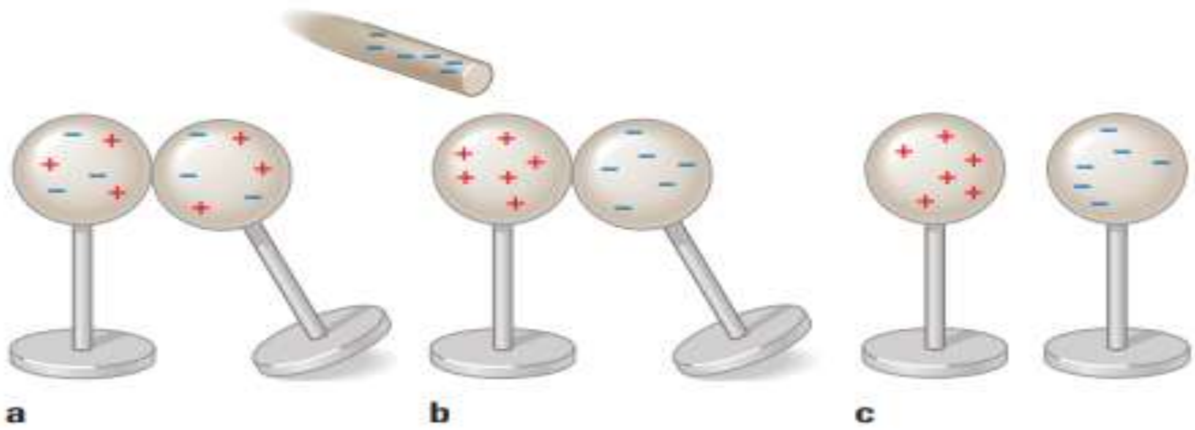
Electric charge can be measured using the law for the forces between charges (Coulomb's Law). Charge is a scalar and is measured in coulombs

STATIC ELECTRICITY:

- The electricity so produced by friction (rubbing) is called frictional electricity or static electricity.
- The word static means stationary or not moving since the charges do not flow through the conductor but only transfer from one substance to another.
- The material acquires positive or negative charge it is called charged or electrified bodies.
- The branch of physics that deals with the study of electrified or charged bodies, on which the electric charge is at rest, is called electrostatics physics.
- When a strip of polythene rod is rubbed with cloth it becomes negatively charged and when a strip of cellulose acetate rubbed with a cloth it becomes positively charged. See the table for different examples that create static electricity by rubbing
- It is the substance that is being used for rubbing that is responsible for inducing the positive or negative charge on the material and not the type of material used. For example if the glass rod is rubbed with flannel cloth, it becomes negatively charged, but when it rubbed with silk it becomes positively charged.
- Like charges + and + or – and – repel each other and unlike charges + and – attract each other.

Material	Rubbed with	Charge acquired	Behavior
Polythene rod	Woolen cloth	Negative	attract each other
Perspex or cellulose acetate	Woolen cloth	Positive	attract each other
Ebonite	Fur	Negative	attract each other
Glass	Silk cloth	Positive	attract each other
Glass	Flannel cloth	Negative	

Electrostatic induction:



The diagram above shows a process called "charging by electrostatic induction" in which a neutral metal sphere is supported on an insulating stand.

a) **Start with neutral spheres that are touching**

b) **When a negatively charged rod is** placed close to the neutral metal sphere the (negatively) charged electrons in the sphere are repelled to the far side of the sphere, leaving the atoms on the near side positively charged owing to their missing electrons. If we then connect a copper wire to the negative side of the sphere and an electrical ground some of the free electrons will flow into the ground. When we then remove the copper wire and the negatively charged rod what remains is a metal sphere with a uniform distributed positively charge. The attraction of an uncharged object by a charged object near it is due to electrostatic induction. The common example is the attraction between small pieces of aluminum foil and negatively charged polythene held just above them.

Dangers of static electricity:

1. Lightning is static electricity due to charges in clouds, and it can damage buildings and harm people.
2. Static electricity can damage sensitive electrical components, such as the parts inside computers. To prevent this, these parts are handled with anti-static bags and wrist straps, which drain the static charge off the person.
3. Static electricity can be responsible for the ignition of flammable gases, such as the vapors produced by petrol (gasoline) when you are filling your car at the petrol- station.
4. Dusts and germs are attracted by charged objects and so it is essential to ensure that equipment and medical personal are well earthed allowing electrons to flow to and from the ground e.g. by conducting rubber.

Some Uses of static electricity

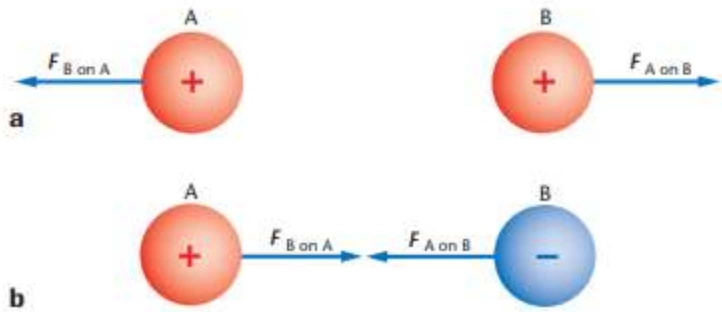
1. Static electricity is used to paint cars. Special powder paints that have been charged positively spread out to form a very even coating of paint on an earthed metal body of a car.
2. It is used in computer printers to distribute toner or ink to go at the right place.
3. Static electricity is also used to remove pollution from smoke-chimneys. Electrostatic plates are placed in the chimneys of the factories that attract all the polluted dust.

Lesson 2
Coulomb's law

When charges are at rest in, they exert electrostatic forces on each other. These forces are of great importance in chemistry and biology and have many technological applications. Electrostatic forces are governed by a simple relationship known as Coulomb's law and are most conveniently described by using the concept of electric field.

Coulomb's law

Coulomb found how the force between the two charged spheres, A and B, depended on the distance. First, he carefully measured the amount of force needed to twist the suspending wire through a given angle. He then placed equal charges



on spheres A and B and varied the distance, d, between them. The force moved A from its rest position, twisting the suspending wire. By measuring the deflection of A, Coulomb could calculate the force of repulsion. He showed that the force, F, varied inversely with the square of the distance between the centers of the spheres.

$$F \propto \frac{1}{d^2}$$

He found that the force varied directly with the charge of the bodies.

$$F \propto q_1 q_2$$

Coulomb's law

Coulomb's Law gives the force of attraction or repulsion between two point charges. If two point charges $\mathbf{q_1}$ and $\mathbf{q_2}$ are separated by a distance **r** then the magnitude of the force of repulsion or attraction between them is

$$F = K\frac{q_1 q_2}{d^2}$$

This equation gives the magnitude of the force that charge q_1 exerts on q_2 and also the force that q_2 exerts on q_1. These two forces are equal in magnitude but opposite in direction. You can observe this example of Newton's third law of motion in action when you bring two strips of tape with like charges together. Each exerts forces on the other. If you bring a charged comb near either strip of tape, the strip, with its small mass, moves readily. The acceleration of the comb and you is, of course, much less because of the much greater mass. **K** is the value of the proportionality constant in Coulomb's law

$$\boldsymbol{K = 9 \times 10^9\ N.m^2/C^2}$$

Solved problems

Two charges are separated by 3 cm. Object A has a charge of +6 µC, while object B has a charge of -3µ C. What is the force on object A?

The solution

$$F_{\text{B on A}} = K\frac{q_A q_B}{{d_{AB}}^2}$$

$$F_{\text{B on A}} = (9\times10^9\ \ \text{N}\cdot\text{m}^2/\text{C}^2)\frac{(6.0\ \mu\text{C})(3.0\ \mu\text{C})}{(3.0\times10^{-2}\ \text{m})^2}$$

$$\boldsymbol{F}_{\text{B on A}} = 1.8\times10^2\ \text{N},$$

What must be the distance between point charge q_1 = 26 µC and point charge q_2 = −47 µC for the electrostatic force between them to have a magnitude of 5.7 N?

$$F = K\frac{q_1\,q_2}{\text{d}^2}$$

$$5.7 = 9\times10^9\times\frac{26\times10^{-6}\times47\times10^{-6}}{\text{d}^2}$$

$$\text{d}^2 = 1.93\ m^2$$

$$\text{d} = 1.39\ \text{m}$$

Lesson 3
The repulsive and attractive forces

Introduction

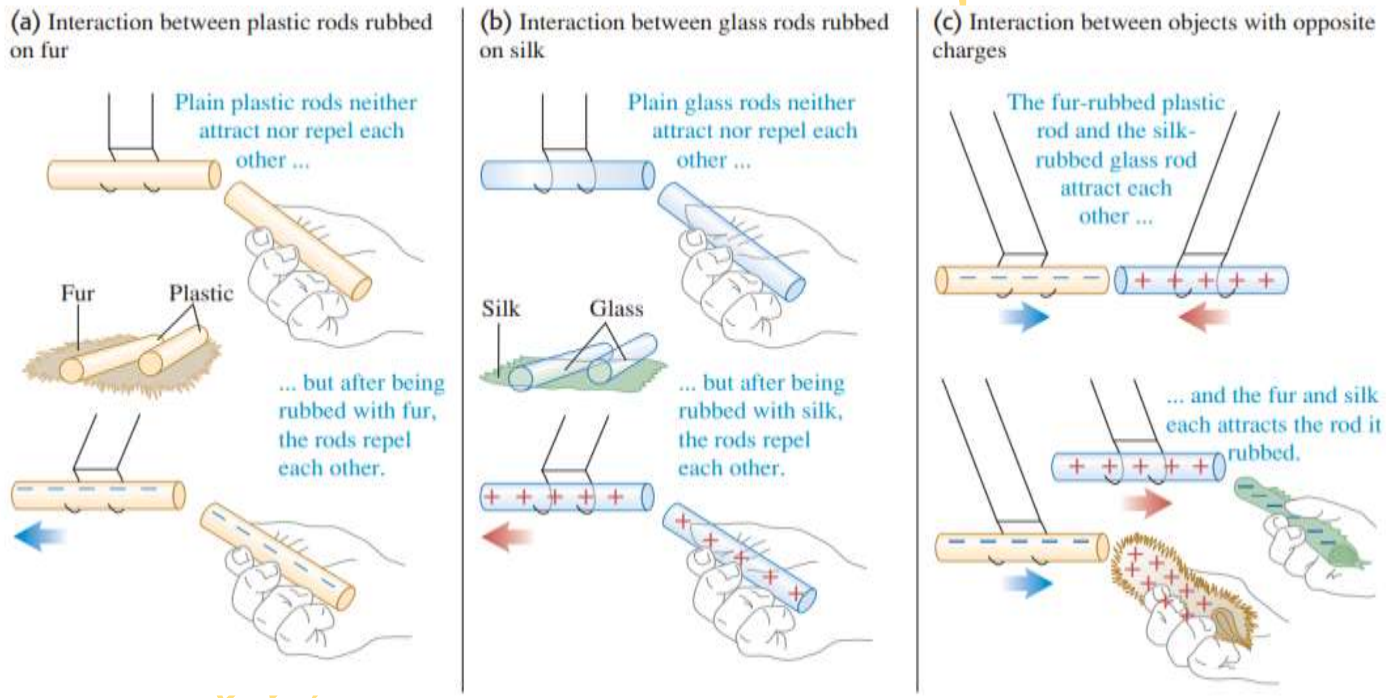
When you scuff your shoes across a nylon carpet, you become electrically charged, and you can charge a comb by passing it through dry hair. Plastic rods and fur (real or fake) are particularly good for demonstrating electrostatics, the interactions between electric charges that are at rest (or nearly so).

Figure (a) after we charge both plastic rods by rubbing them with the piece of fur, we find that the rods repel each other.

Figure (b) when we rub glass rods with silk, the glass rods also become charged and repel each other.

Figure (c) a charged plastic rod attracts a charged glass rod; furthermore, the plastic rod and the fur attract each other, and the glass rod and the silk attract each other.

These experiments and many others like them have shown that there are exactly two kinds of electric charge: the kind on the plastic rod rubbed with fur and the kind on the glass rod rubbed with silk



The attractive and repulsive forces

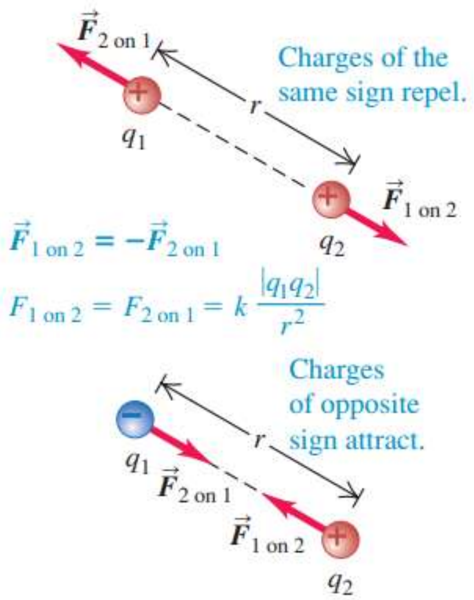
Two positive charges or two negative charges repel each other. A positive charge and a negative charge attract each other.

Electric attraction and repulsion

The attraction and repulsion of two charged objects are sometimes summarized as "Like charges repel, and opposite charges attract." But keep in mind that "like charges" does not mean that the two charges are exactly identical, only that both charges have the same algebraic sign (both positive or both negative). "Opposite charges" means that both objects have an electric charge, and those charges have different signs (one positive and the other negative).

$$F = K\frac{q_1\,q_2}{d^2}$$

If the charges q_1 and q_2 are of the same sign (both positive and both negative) then the force is mutually repulsive and the force on each charge points away from the other charge. If the charges are of opposite signs (one positive, one negative) then the force is mutually attractive and the force on each charge points toward the other one. This is illustrated in the opposite diagram

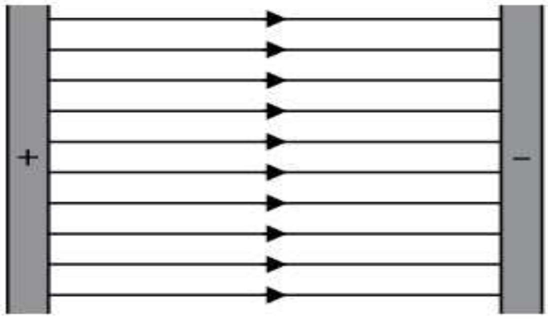


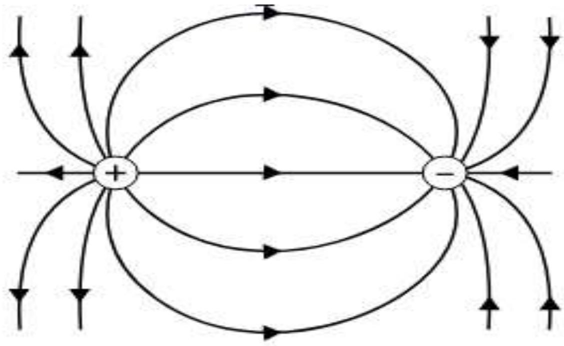
Lesson 4
The electric field

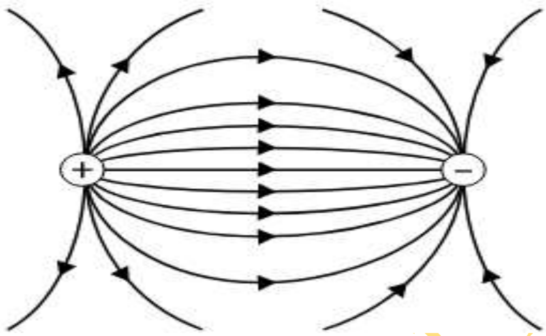
Introduction

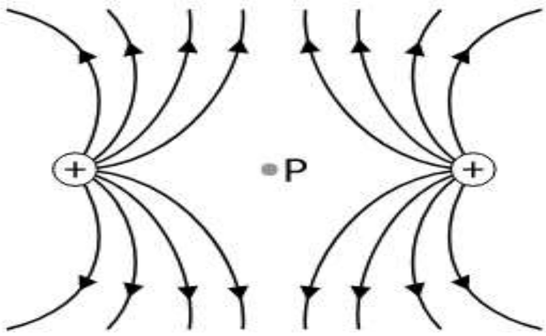
Electric fields arise from electric charges and changing magnetic fields.

An electric charge, or a collection of charges, will have an associated electric field. Any charged object placed in this field will experience an electrostatic force as the field interacts with the charge of the object. Field lines represent the force a positively charged particle would experience if it were in the field at that point.









The electric field

- The electric field is defined as **(the area around a charge in which the effect of that charge can be felt)**

OR

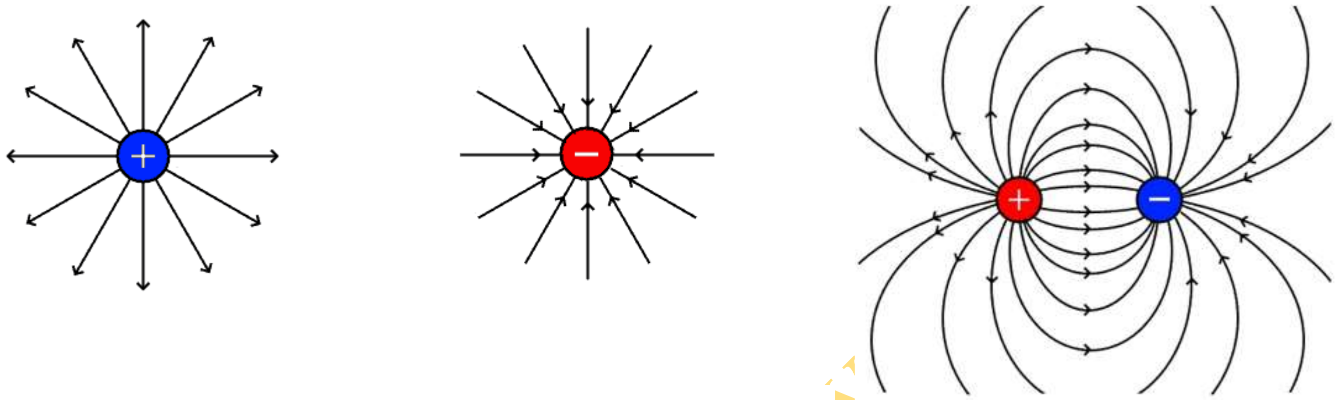
- The electric field is a field defined by **the magnitude of the electric force at any given point in space**

- The electric field exerts force on other charges.

- The electric field has magnitude and direction. Hence, it is **a vector quantity**

- The instrument used for measuring the electric field is known as **Electrometer**. Whereas the strength of the field cannot be determined on its own but it takes another charge to measure it

- An electric field is either generated surrounding an electric charge (positive or negative) or by varying a magnetic field with respect to time.
- The electric field line generated by a stationary charge originates from a positive charge and terminates at negative charge. Therefore, a stationary positive charge has electric field lines pointing outwards while a stationary negative charge has electric field lines pointing inwards. While the electric field between two positive & negative charge originates from a positive charge & terminates on a negative charge.



*Two same charges will repel each other as their electric field lines will repel each other. While two opposite charges attract each other as their electric field lines attract each other.
*The electric field intensity is the electric field lines per unit area. It varies with the amount of charge & decreases with the square of the distance from the source charge.
*The force acting on an electric charge inside an electric field depends on the amount of charges & the distance between them.

Formula of Electric field

The symbol E expresses the electric field intensity, and it is measured in Newton/Coulomb (N/C).

Electric field intensity = Force/Charge

$$E = \frac{F}{q} = \frac{K\,q}{d^2}$$

Solved problem

A force of 2 N is acting on the charge 4 µ C at any point. Calculate the electric field intensity at that point.

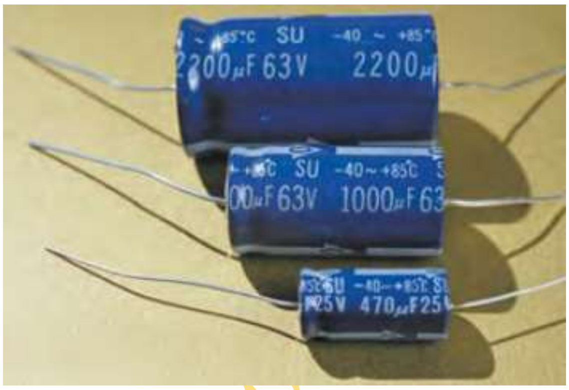
Solution:

$$E = \frac{F}{q}$$

$$E = \frac{2}{4 \times 10^{-6}} = 5 \times 10^{5}\ N/C$$

Lesson 5
The capacitor

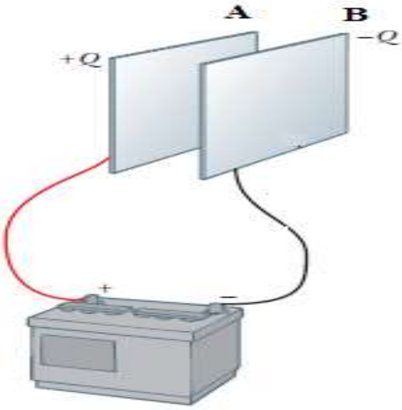
The electric capacitor



Capacitors are commonly used in a variety of electric circuits. For instance, they are used to tune the frequency of radio receivers, as filters in power supplies, to eliminate sparking in automobile ignition systems, and as energy-storing devices in electronic flash units.

Definition

(Two parallel metal plates separated by an insulator)

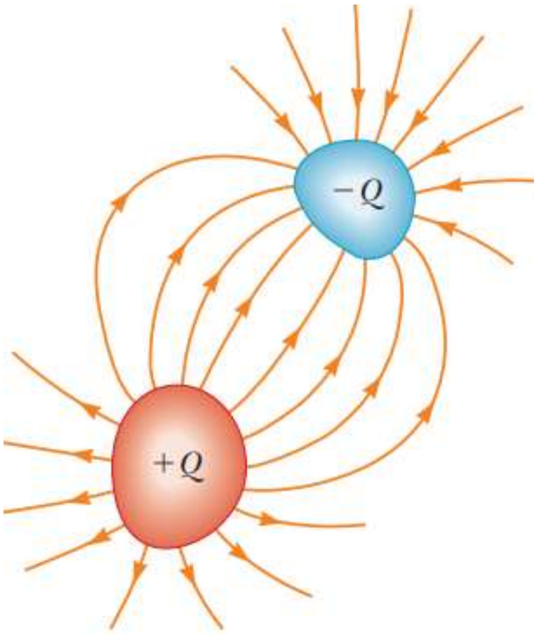


When the capacitor is charged, the conductors carry charges of equal magnitude and opposite sign.

When the capacitor is charged, one plate is charged positively whereas the other is charged negatively creating a potential difference (V) between them

If the **quantity of charge (**in Coulombs) on one of its plates is **(Q)** and **the capacitance** (in Farads)of capacitor is **(C),** the relation between them is given by

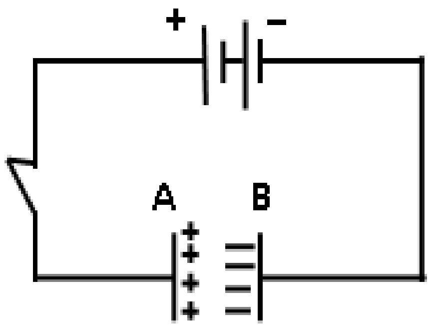
$$C = \frac{Q}{V}$$



The capacitance C of a capacitor

(It is the ratio of the magnitude of the charge on either conductor to the magnitude of the potential difference between the conductors)

The capacitor in a DC circuit



When the capacitor is connected to the terminals of a battery, electrons transfer between the plates and the wires so that the plates become charged.

When a capacitor is connected to a battery where the plate (A) is connected to the positive pole of the battery while the plate (B) is connected to the negative pole as shown in figure, a negative charge (free electrons) passes from the negative pole to the plate (B), lowering its potential. This negative charge on plate (B) pushes the negative free charges in plate (A) towards the positive pole of the battery charging the plate (A) with a positive charge, and raising its potential. **The transfer of charge stops when the potential difference across the plates equals the potential difference of the battery.**

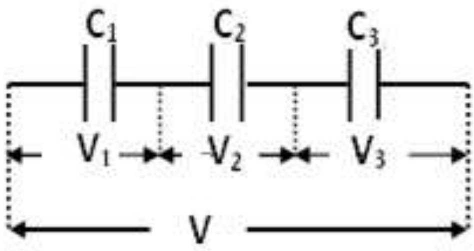
This means that a momentary current flow through the circuit then vanishes, meanwhile the capacitor is charged.

Quantity of charge on plates = **C**apacitance of capacitor ×**V**oltage across plates

$$\mathbf{Q = C\,V}$$

Connection of Capacitors:

Series connection



If capacitors are connected in series as shown in figure

a) The quantity of charge (Q) is the same for all capacitors

$$\mathbf{Q = Q_1 = Q_2 = Q_3}$$

b) The potential difference is split.

$$V_t = V_1 + V_2 + V_3$$

c) The equivalent capacitance is given by

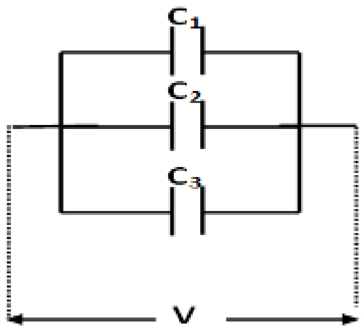
$$\frac{Q}{C_{eq}} = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$$

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

If the capacitance for all capacitors is **equal**

$$C_{eq} = \frac{C}{n}$$

Parallel connection



1) If capacitors are connected in parallel

a) The voltage across each capacitor is the same

$$\mathbf{V_t = V_1 = V_2 = V_3}$$

b) The quantity of charge is split.

$$Q_t = Q_1 + Q_2 + Q_3$$

c) The equivalent capacitance is given by

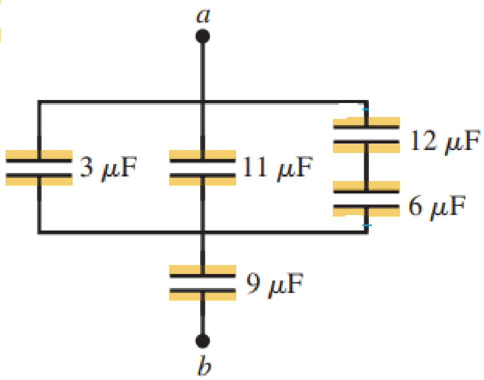
$$C_{eq}V = C_1V + C_2V + C_3V$$

$$\mathbf{C_{eq} = C_1 + C_2 + C_3}$$

If the capacitance for all capacitors is the same

$$\mathbf{C = n\,C_1}$$

Solved problem

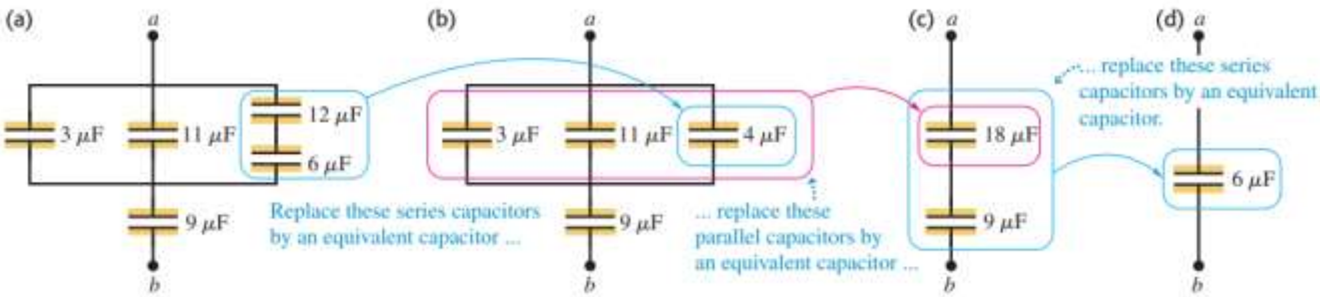


Find the equivalent capacitance of the five-capacitor network shown in the opposite Figure.

$$\frac{1}{C'} = \frac{1}{12\ \mu\text{F}} + \frac{1}{6\ \mu\text{F}} \qquad C' = 4\ \mu\text{F}$$

$$C'' = 3\ \mu\text{F} + 11\ \mu\text{F} + 4\ \mu\text{F} = 18\ \mu\text{F}$$

$$\frac{1}{C_{eq}} = \frac{1}{18\ \mu\text{F}} + \frac{1}{9\ \mu\text{F}} \qquad C_{eq} = 6\ \mu\text{F}$$



Unit two
Dynamic electricity

Dear student, by the end of this chapter you should have the following skills and knowledges

Differentiate between methods of connections.
Apply ohm’s law to calculate intensity of electric current, potential difference and electric resistance
Apply ohm’s law for closed circuit
Identify the color code of resistor
Identify the electric resistivity and conductivity
Understanding the concept of emf and internal resistance of a cell
Identify the concept of electric power

Lesson 1
Some concepts of dynamic electricity

Introduction

Materials are classified into 3 types according to their electrical conductivity:

1) Conductors
* They are the materials which allow electricity to flow easily through it
* Metals are conductors, such as copper, silver and gold.
* They contain large number of free electrons (rich in free electrons).

2) Insulators
* They cannot allow electricity to flow easily through it.
* Examples: wood, paper, plastics, and ceramics.
* They contain very few numbers of free electrons (poor in free electrons).

3) Semiconductors
* They are materials with conductivities somewhere **between conductors and insulators.**
* Examples are silicon and germanium

Electric current

(It is the amount of charge flowing through a conductor)
(the flow of electric charges through any cross section of the conductor).

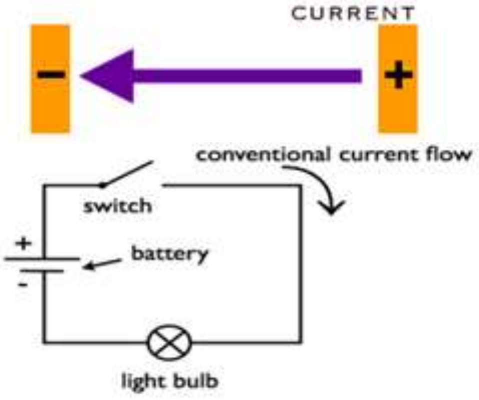
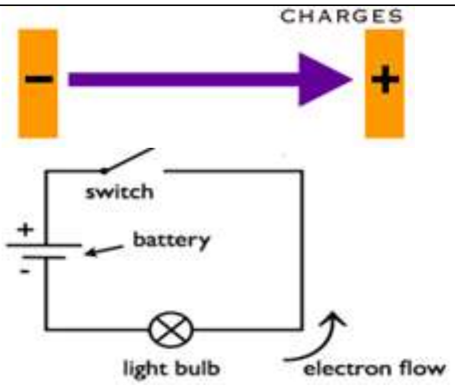
OR

It's the quantity of electricity (charges) in coulombs passing through any cross section of the conductor

summary

the electric current is due to the movement of free electrons (charged particles) in a conductor

Direction of current Flow

1) Conventional (Traditional) Current	2)The electron current
It is the flow of positive charges from the positive to the negative terminal of a cell in a circuit	It is in opposite direction to the conventional current
	

Important physical quantities in Electricity

1) the electric current intensity (I)

(It is the amount of electric charges flowing per second through a conductor)
(the rate of flow of electric charges through any cross section of the conductor)
OR
(It's the quantity of electricity (charges) in coulombs passing through any cross section of the conductor in one second).

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

I : the electric current intensity
t : time of flow
Q: the quantity of charges (the total number of electrons passing a given point)
N: the total number of electrons passing a given point
e: the electron charge (1.6×10^{-19}C)
The electric current intensity measured in Ampere (A) = coloumb per second (C/s) and measured by the ammeter
Ampere: (It is the current intensity if the quantity of electricity passing through any cross section of the conductor in **one second** is **1 coulomb)**
OR
(It is the current flowing in a circuit if the rate of flow of charge 1C/s)

2) Potential Difference between two points (V)

(It is the work done in joules to transfer a unit charge (1C) between the two points)

$$V = \frac{W}{Q}$$

V : potential difference between two points
W : the work done (energy)
The potential difference measured in Volt (V) = Joule/coloumb (J/C) and measured by the voltmeter
Volt: (It is the potential difference between two points if the work done required to transfer a unit charge (1C) between the two points is 1 Joule)

3) The electric resistance (R):

(It's the opposition of the conductor to the flow of electric current due to the friction)
(it's the ratio between the potential difference (voltage) across the conductor and current intensity passing through it at certain temperature)

$$R = \frac{V}{I} \quad \textit{(At constant temperature)}$$

V : Potential difference between ends of conductor (volt) (V)
I : current intensity (amperes) (A)
R: electric resistance (Ohm) (Ω)
The electric resistance measured in Ohm(Ω)=Volt/ampere (V/A) and measured by the ohmmeter
Ohm : (It's the electric resistance of conductor that carries current of 1 A when potential difference between its two ends is 1 V)

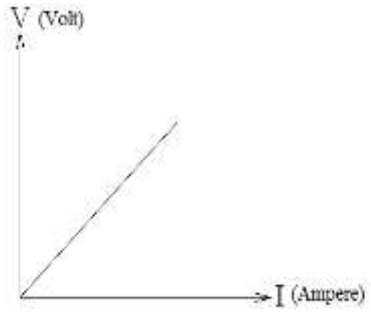
Lesson 2
Ohm's law

Ohm's Law deals with the relationship between the electric current intensity in a conductor and potential difference across it

Ohm's Law

The current intensity flowing through a conductor is directly proportional to the potential difference across it at constant temperature

$$V=IR$$



The graphical representation

$$V = I\,R$$

$$R = \frac{V}{I}$$

$$\text{Slope } = \frac{V}{I} = \text{constant} = R$$

Notes

1) There are **some materials obey Ohm's law** (verifying the linear relation (straight line) between the voltage and the current intensity) ($\frac{V}{I} =$ constant)

2) many materials do not obey Ohm's Law (The relationship is not linear) ($\frac{V}{I} \neq$ onstant)

Try to think:

The following table gives the current I (in amperes) through two devices for several values of potential difference V (in volts). From these data, determine which device does not obey Ohm's law.

Device 1	
V	I
2	4.5
3	6.75
4	9

Device 2	
V	I
2	1.5
3	2.2
4	2.8

Electric power (P_w)

The mathematical relation

$$Pw = \textit{electric energy consumed}/\ \textit{time} = W/\ t = VIt/\ t = V\ I$$

The power dissipated in a resistor can be obtained by the use of Ohm's Law

$$\mathbf{Pw = V\ I = I^2 \times R = V^2\ /R}$$

Definition:

(It is the rate of electrical energy consumed in the electric conductor)

The measuring unit

Watt (W) ≡ Joule per second (J/sec) ≡ Volt .Ampere (V.A)

Solved problems

An electrical element which has a resistance of 60 Ω is connected across a 24 V power supply. Calculate the current drawn from the power supply

100W heating element is connected to a 25 V power supply voltage. Calculate

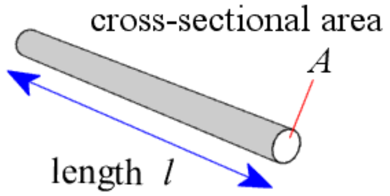
a) the resistance of the element when it is hot

b) the current drawn from the supply

Lesson 3
The ohmic resistance

The Factors affecting the Electric Resistance (at constant temperature)

$$\mathbf{R = \rho_e \frac{\mathit{l}}{A}}$$



where

R: the resistance of conductor
l : the length of conductor
A: the cross sectional area of conductor
$\boldsymbol{\rho_e}$: the resistivity of the conductor (specific resistance)

Electric resistivity (Specific resistance) of a material ($\boldsymbol{\rho_e}$)

(It is the resistance of a conductor of length 1m and of cross sectional area $1m^2$ at constant temperature)

It is a measure of how strongly a material opposes the flow of electric current. A low resistivity indicates a material that readily allows the movement of electrical charge.

The SI unit of electrical resistivity is the ohm meter (Ω . m).

Note that

Every ohmic material has a characteristic resistivity that depends on the properties of the material and on temperature.

Electric conductivity of a material (σ_e)

(It is the reciprocal of the resistivity)

$$\boldsymbol{\sigma = 1/\rho}$$

The unit of electrical conductivity is ohm^{-1} $meter^{-1}$ (Ω^{-1}. m^{-1})

Solved example (1)

A copper wire 30 m long and 2×10^{-6} m^2 cross sectional area has a potential difference of 3V across. Calculate the current if the copper resistivity is 1.79×10^{-8} Ω.m

The solution

$$R = \rho_e \frac{l}{A} = \frac{1.79 \times 10^{-8} \times 30}{2 \times 10^{-6}} \qquad R = 0.2564 \text{ ohm}$$

$$V = I\,R \qquad 3 = I\,(0.2564) \qquad I = 11.17 \text{ Amp.}$$

Solved example (1)

A metallic wire is 1 m long and $1mm^2$ in cross -sectional area. It carries a current of intensity 4A when a 2V potential difference is applied between its ends. Calculate the conductivity of the metallic wire

The solution

$$V = I\,R \qquad 2 = 4\,(R) \qquad R = 0.5 \text{ ohm}$$

$$R = \rho_e \frac{l}{A} \qquad 0.5 = \rho_e \times \frac{1}{(1 \times 10^{-6})}$$

$$\rho_e = 5 \times 10^{-7} \text{ohm . m}$$

$$\sigma_e = \frac{1}{\rho_e} = \frac{1}{5 \times 10^{-7}} = 2 \times 10^{6} \Omega^{-1} m^{-1}$$

Lesson 4
Ohm's law for closed circuit

Introduction

In an electric circuit there must be a device somewhere in the loop that acts like the water pump in a water fountain. The influence that makes current flow in the circuit is called **electromotive force** (abbreviated **emf)**. This is a poor term because emf is not a force but an energy-per-unit-charge quantity

Electromotive force of the cell (emf)

(The total work done inside and outside the cell to transfer an electric charge of 1C in the whole electric circuit)

Internal resistance (r) of the cell

Ideal source

The potential difference across an ideal source in a circuit is equal to the emf because there is no internal resistance

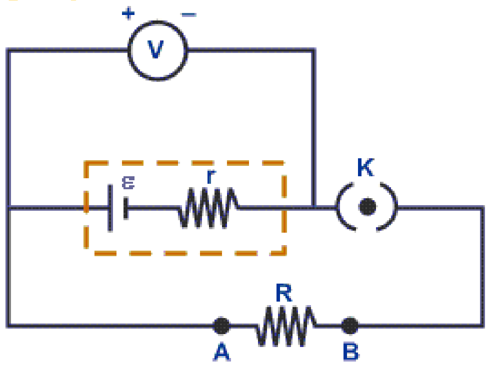
Real source

The potential difference across a real source in a circuit is not equal to the emf because there is an internal resistance that consumes part of energy due to movement of charges through material of the source; therefore it experiences an associated drop in potential equal to Ir.

The electric circuit

A simple electric circuit consists of

1) A battery (source of electrical energy)
2) Connecting wires
3) Fixed resistors ORvariable resistor (rheostat)
4) Switch (to allow or avoid the passage of current)



$$V_B = I\,R_{eq} + I\,r = I\,(R_{eq} + r)$$
$$I = V_B / (R_{eq} + r)$$

The last equation known as **Ohm's law for a closed circuit**, from which we find that the current intensity in a closed circuit is the emf of the total source divided by the total (external plus internal) resistance of the circuit.

$I\,R_{eq}$ =V = the terminal voltage

I r = the potential drop across the internal resistance

Note

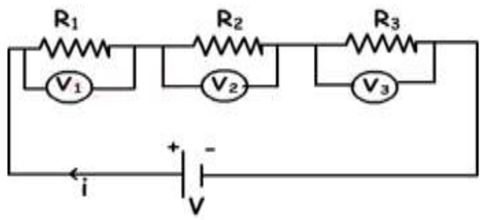
For real source the terminal voltage is less than the emf of the source due the potential drop across the internal resistance

Lesson 5
Connection of resistors

Introduction

- There are two ways to connect multiple resistors to a voltage source one is called series and the other is called parallel
- Resistors are connected in series to obtain a higher resistance out of a group of large resistances
- Resistors connected in parallel to obtain a small resistance out of a group of large resistances

Resistors in Series



1) The current through all the resistors is the same
($I = I_1 = I_2 = I_3$)

2) The potential difference is split
($V_t = V_1 + V_2 + V_3$)

3) The equivalent resistance is greater than the greatest resistance

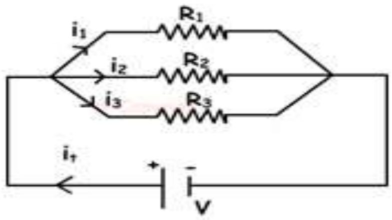
$$\mathbf{R_{eq} = R_1 + R_2 + R_3}$$

If there are (N) equal resistances connected in series each equal to (R) **(R_{eq} = NR)**

Note that

The higher the resistance, the higher the potential difference (V α R at constant the current)

Resistors in Parallel



1) The potential difference across each of them is the same.

$V = V_1 = V_2 = V_3$

$I_t R_{eq} = I_1 R_1 = I_2 R_2 = I_3 R_3$

2) The current is split.

$I_t = I_1 + I_2 + I_3$

3) The equivalent resistance is smaller than the smallest resistance

$$\mathbf{R_{eq} = \frac{1}{\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}}} \quad \textbf{OR} \quad \mathbf{\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

If there are (N) equal resistances are connected in parallel each equal to (R) $\mathbf{R_{eq}} = \mathbf{\frac{R}{N}}$

Note that

The higher the resistance, the lower the current that is flowing through it (I α 1/R at constant the potential difference)

Solved examples

Example (1)

A 45V potential difference is placed across a 5 Ω resistor and a 10Ω resistor connected in series. Calculate

a) the equivalent resistance of the circuit b) the current through the circuit

c) the voltage drop across each resistor

The solution

$R_{eq} = R_1 + R_2$ $R_{eq} = 5+10 = 15\ \Omega$

$V_t = I_t R_t$ $45 = I_t (15)$ $I_t = 3A$

$V_1 = I_t R_1$ $\quad$ $V_1 = (3)(5) = 15V$

$V_2 = I_t R_2$ $\quad$ $V_2 = (3)(10) = 30V$

Example (2)

Three resistors of 60Ω, 30Ω, and 20 Ω are connected in parallel across a 90V difference in potential. Calculate

a) the equivalent resistance of the circuit $\qquad$ b) the current in the circuit

(c) the current through each branch of the circuit.

The solution

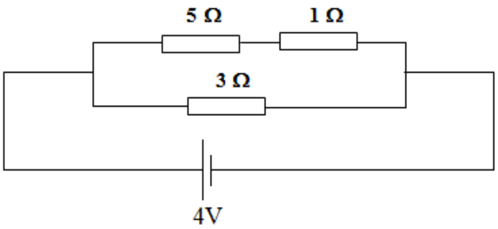
$$R_t = \frac{1}{\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}} = \frac{1}{\frac{1}{60}+\frac{1}{30}+\frac{1}{20}} = 10\ \Omega$$

$V_t = I_t R_t$ $\qquad$ $90 = I_t(10)$ $\qquad$ $I_t = 9A$

$$I_1 = \frac{V}{R_1} = \frac{90}{60} = 1.5\ A \qquad I_2 = \frac{V}{R_2} = \frac{90}{30} = 3\ A \qquad I_3 = \frac{V}{R_3} = \frac{90}{20} = 4.5\ A$$

Example (3)

The opposite figure shows a simple electric circuit, calculate:



a) The total resistance of the circuit

b) The total current flowing through the battery, assuming the battery has no internal resistance.

c) The current flowing through 1 Ω resistor

The solution

5 Ω and 1Ω are in series $\quad R = 5 + 1 = 6\ \Omega$

6 Ω and 3 Ω are in parallel $\quad R_{parallel} = \frac{R_1 \times R_2}{R_1 + R_2}$ $\quad R_{parallel} = \frac{6\times 3}{6+3} = 2\ \text{ohm}$

$V_t = I_t R_t$ $\qquad$ $4 = I_t(2)$ $\qquad$ $I_t = 2A$

$I_t R_{parallel} = I_1 R_1$ $\qquad$ $\mathbf{2\times 2 = I_1 \times 6}$ $\qquad$ $I_1 = 4/6 = 2/3 = 0.667A$

Solved example

A battery has an emf of 12 V and an internal resistance of 0.05 Ω Its terminals are connected to a load resistance of 3Ω

a) Calculate the current in the circuit and the terminal voltage of the battery.

b) Calculate the power dissipated by the load resistor.

The solution

$$\mathbf{I = \frac{V_B}{R_t + r} = \frac{12}{3 + 0.05} = 3.93A}$$

$V = V_B - I\,r$

$V = 12 - (3.93)\,(0.05) = 11.8V$

$P = I^2\,R = (3.93)^2 \times 3 = 46.33$ watt