JSR IAS ACADEMY

GENERAL SCIENCE
PHYSICS

Electricity - II

Cell

- A device **that converts chemical energy into electrical energy** is called a cell.
- A chemical solution which produces positive and negative ions is used as **electrolyte.**
- Two different metal plates are inserted into electrolyte as electrodes to form a cell.
- Due to chemical reactions, **one electrode gets positive charge and the other gets negative charge** producing a continuous flow of electric current.

Depending on the continuity of flow of electric current cells are classified in to two types.

Primary Cells

- They **can not be recharged**. So they can be **used only once.**
- Hence, the primary cells are usually produced in small sizes.

Examples cells used in **clocks, watches and toys etc.,**

DRY-cell (Primary cell)

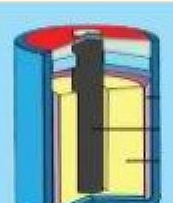
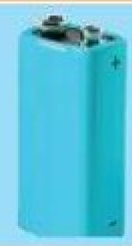
- It was **developed in 1887 by Yei Sakizo of Japan**.
- A dry cell is a **portable form of a leclanche cell.**
- It **consists of zinc vessel** which **acts as a negative electrode or anode.**
- The purpose of **zinc chloride is to maintain the moistness of the paste being highly hygroscopic.**
- The **ammonium chloride acts as an electrolyte.**
- The **carbon rod covered with a brass cap is placed in the middle of the vessel. It acts as positive electrode or cathode.**
- It is surrounded by a **closely packed mixture of charcoal and manganese dioxide (MnO_2) in a muslin bag.**
- Here **MnO_2 acts as depolarizer**.
- The **zinc vessel is sealed at the top with pitch or shellac.**
- **A small hole is provided in it to allow the gases formed by the chemical action to escape.**

> Electrolytes are substances that become ions in solution and acquire the capacity to conduct electricity.

Secondary Cells

- A cell that **can be recharged many times** is called secondary cell.
- These cells **can be recharged by passing electric current. So they can be used again and again**.
- The size of the secondary cells can be small or even large depending upon the usage.
- While the secondary cells used in **mobiles are in the size of a hand**, the cells **used in automobiles like cars and buses are large and very heavy.**

Examples: **Mobile phones, laptops, emergency lamps and vehicle batteries.**

Primary Cell	Secondary Cell			
Dry cell	Lithium cylindrical cells	Button cells	Alkaline cells	Automobile battery
				

Batteries

- Batteries are **a collection of one or more cells**
- All batteries are made up of **three basic components: an anode (the '+' side), a cathode (the '–' side), and some kind of electrolyte.**
- Electrolyte is a **substance that chemically reacts with the anode and cathode.**

Invention of the Battery

- One fateful day in **1780**, Italian physicist, physician, biologist, and philosopher, **Luigi Galvani, was dissecting a frog attached to a brass hook.**
- As he touched the **frog's leg with an iron scapel, the leg twitched.**
- **Alessandro Volta** hypothesized that the frog's leg impulses were actually caused by different metals soaked in a liquid.

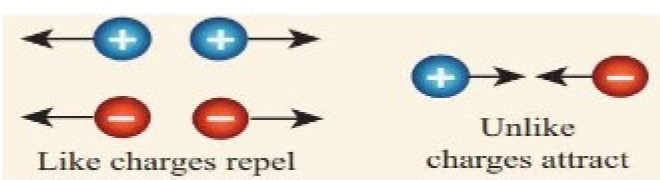
- Volta published his findings in **1791** and later created the first battery, **the voltaic pile**, in **1800**.

PRIMARY CELL	SECONDARY CELL
1. The chemical reaction inside the primary cell is irreversible	The chemical reaction inside the secondary cell is reversible
2. It cannot be recharged.	It can be recharged
3. Examples of secondary cells are lead accumulator, Edison accumulator and Nickel – Iron accumulator.	It is used to operate devices such as mobile phones, cameras, computers, and emergency lights.
4. Examples- simple voltalic cell, Daniel cell, and lechlanche cell and dry cell	Examples of secondary cells are lead accumulator, Edison accumulator and Nickel – Iron accumulator.

Electric force

The force existing between the charges is called as 'electric force'.

Among electric charges, there are two types of electric force (F): one is attractive and the other is repulsive.



- The like charges repel and unlike charges attract.
- These forces can be experienced even when the charges are not in contact.

Potential difference (v)

There is a work done on the charges to keep them together. This results in a quantity called 'electric potential'.

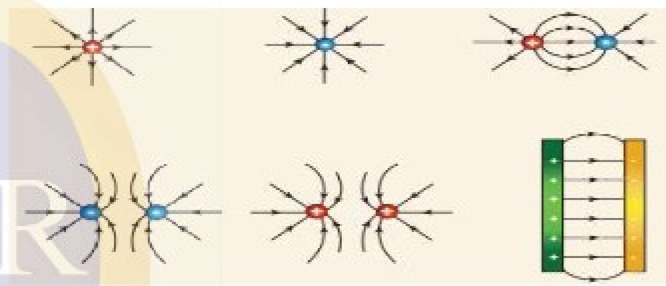
The electric current flow from the higher potential level to the lower potential level is just like the water flow.

The SI unit of potential difference is **volt (V)**

Electric field

The region in which a charge experiences electric force forms the **'electric field'** around the charge.

- Often electric field (E) is represented by lines and arrowheads indicating the direction of the electric filed
- the lines representing the electric field are called 'electric lines of force'.
- an isolated positive charge the electric lines of force are radially outwards and for an isolated negative charge they are radially inwards.



- A positive charge will experience force in the direction of electric field and a negative charge will experience in the opposite direction of electric field.

Electromotive force (e.m.f)

The e.m.f of an electrical energy source is the work done (W) by the source in driving a unit charge (q) around the complete circuit.

$\varepsilon = W/q$ where, W is the work done.

The **SI unit of e.m.f** is joules per coulomb **(JC^{-1}) or volt (V).**

the e.m.f of an electrical energy source is one volt if one joule of work is done by the source to drive one coulomb of charge completely around the circuit.

Potential difference (p.d)

The potential difference is represented by the symbol **V.**

$V = W/q$ where, W is the work done, i.e.,

The **SI unit for both e.m.f and potential difference** is the same i.e., **volt (V).**

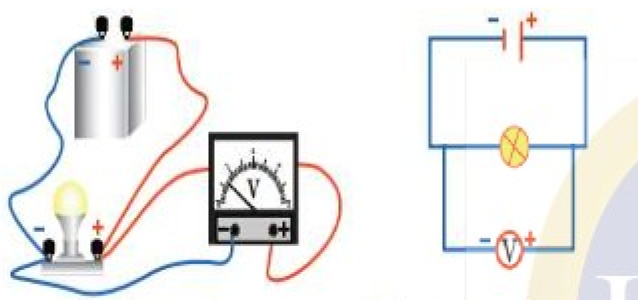
A charge of 2×10^4 C flows through an electric heater. The amount of electrical energy converted into thermal energy is 5 MJ. Compute the potential difference across the ends of the heater.

Solution:

V = W/q that is 5×10^6 J / 2×10^4 C = 250 V

Voltmeter is an instrument **used to measure the potential difference.**

To measure the potential difference across a component in a circuit, the **voltmeter must be connected in parallel to it.**



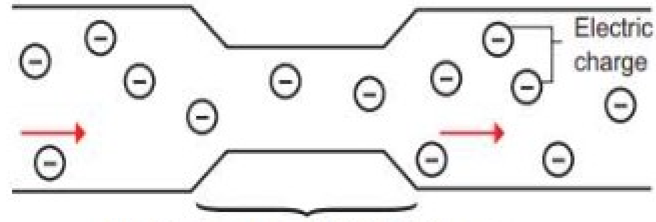
(a) Actual setup (b) Circuit diagram

Note: Difference between e.m.f and potential difference:

As both e.m.f and potential difference are measured in volt, they may appear the same. But they are not. The e.m.f refers to the voltage developed across the terminals of an electrical source when it does not produce current in the circuit. Potential difference refers to the voltage developed between any two points (even across electrical devices) in an electric circuit when there is current in the circuit.

Resistance (R)

The Resistance (R) is the measure of opposition offered by the component to the flow of electric current through it.



Electrical component with resistance

- Greater the ratio of V to I, the greater is the resistance
- Metals like **copper, aluminium** etc., have **very much negligible resistance.** That is why they are called **good conductors.**
- On the other hand, materials like **nicrome, tin oxide** etc., **offer high resistance to the electric current**. We also have a category of materials called **insulators; (glass, polymer, rubber and paper).**

The **SI unit of resistance** is ohm with the symbol **(Ω).**

components used for providing resistance are called as **'resistors'.**

The **resistors can be fixed or variable.**

Fixed resistor Variable resistor Rheostat

Electrical conductivity (σ)

- Electrical conductivity or specific conductance is the measure of a material's ability to conduct an electric current.
- It is commonly represented by the Greek letter **σ (sigma)**
- The S.I Unit of electrical conductivity is **Siemens/meter(S/m)**

Conductance

- The conductance of a material is mathematically defined as the **reciprocal of its resistance (R).**
- Hence, the **conductance 'G'** of a conductor is given by **G = 1/R**
- Its unit is **ohm–1**. It is also represented as **'mho'.**

Electrical Resistivity ρ (rho)

the resistance of any conductor **'R'** is directly proportional to the length of the conductor **'L'** and is inversely proportional to its area of cross section **'A'**.

R α L , R α 1/A

R α L/A Hence , **R = ρ L/A**

Where, **ρ (rho)** is a constant, called as **electrical resistivity or specific resistance of the material** of the conductor.

ρ = (RA)/L

L = 1 m, A = 1 m² then, **ρ = R**

Hence, the electrical resistivity of a material is defined as the resistance of a conductor of unit length and unit area of cross section.

Its unit is **ohm metre.**

Material	Resistivity (ρ) (Ω m) at 20°C	Conductivity (σ) (S/m)at 20°C
Silver	1.59×10^{-8}	6.30×10^{7}
Copper	1.68×10^{-8}	5.98×10^{7}
Annealed Copper	1.72×10^{-8}	5.80×10^{7}
Aluminum	2.82×10^{-8}	3.5×10^{7}

NATURE OF THE MATERIAL	MATERIAL	RESISTIVITY (Ω m)
Conductor	Copper	1.62×10^{-8}
	Nickel	6.84×10^{-8}
	Chromium	12.9×10^{-8}
Insulator	Glass	10^{10} to 10^{14}
	Rubber	10^{13} to 10^{16}

Conductivity

The **reciprocal of electrical resistivity** of a material is called its electrical conductivity.

$$\sigma = \frac{1}{\rho}$$

Its unit is **ohm–1 metre–1.** It is also represented as **mho metre–1**.

Electrical conductivity of a conductor is a measure of its ability to pass the current through it.

Conductivity is more for conductors than for insulators.

But, the resistivity is less for conductors than for insulators.

The resistance of a wire of length 10 m is 2 ohm. If the area of cross section of the wire is 2×10^{-7} m², determine its (i) resistivity (ii) conductance and (iii) conductivity

Solution:

Given: Length, L = 10 m, Resistance, R = 2 ohm and Area, A = 2×10^{-7} m²

$$\text{Resistivity, } \rho = \frac{RA}{L} = \frac{2 \times 2 \times 10^{-7}}{10}$$

$$= 4 \times 10^{-8}\ \Omega\ \text{m}$$

$$\text{Conductance, } G = \frac{1}{R} = \frac{1}{2} = 0.5 \text{ mho}$$

$$\text{Conductivity, } \sigma = \frac{1}{\rho} = \frac{1}{4 \times 10^{-8}}$$

$$= 0.25 \times 10^{-8} \text{ mho m}^{-1}$$

DO YOU KNOW? Nichrome is a conductor with highest resistivity equal to $1.5 \times 10^{-6}\ \Omega$ m. Hence, it is used in making heating elements.

There are 3 main effects of electricity

1.Heating effect

When electric **current passes through a conductor, there is a considerable 'friction' between the moving electrons and the molecules** of the conductor.

During this process, electrical energy is transformed to heat energy. This is known as heating effect of electric current.

This conversion of electrical energy into heating energy is called **'Joule heating'**

as this effect was extensively studied by the **scientist Joule**

The heat produced depends on the amount of resistance offered by the wire.

- **Copper wire** offers very little resistance and does not get heated up quickly.
- On the other hand, thin wires of **tungsten or nichrome** which are used in bulbs offer high resistance and gets heated up quickly.
- This is the reason why **tungsten wire is used in the filaments of the bulbs** and **nichrome wire is used as a heating element in household heating appliances**.
- In heating appliances, the **heating element is made up of materials with high melting point**.
- An example of such a material is **nichrome (an alloy of nickel, iron and chromium).**

Factors affecting Heating Effect of current

1. Electric Current
2. Resistance
3. Time for which current flows

Electric Fuse

Fuse is a strip of alloy wire which is **made up of lead and tin with a very low melting point.**

The fuse wire is **made up of a material whose melting point is relatively low.**

- Electric fuse has a **body made of ceramic**
- The **fuse wire melts whenever there is overload of the current in the wire**.
- This **breaks the circuit and helps in preventing damage** to costly appliances and to the wiring.

- In electrical devices, **a glass fuse** is often used.
- This is a **small glass tube**, **in which lies the fuse wire.**

MCBs (Miniature Circuit Breaker)

MCBs have been replacing electric fuse from wirings at most of the places.

- The electric **fuse has a big practical problem.**
- Whenever **the wire fuses, one needs to replace the wire to resume electric supply.**
- More often than not, **this proves to be a cumbersome task.**
- Miniature circuit breakers **break the circuit automatically**.
- One just needs to switch it on to resume the electric supply.
- Many models **of MCBs have a built in mechanism by which the electric supply is automatically resumed.**

Caution: The heating effect and the chemical effect experiments have to be performed only with a dc cell of around 9V. Students at any cost **should not use** the main domestic electric supply which is a 220V ac voltage. If it is used it will give a heavy electric shock leading to a severe damage to our body.

2.Magnetic Effect of electricity

In **1819, Hans Christian Oersted** discovered the electricity that has a magnetic effect.

Application of magnetic effect of electric current

Electromagnets.

- Electromagnet Magnetic effect of electric current has been **used in making powerful electromagnets**.
- Electromagnets are also used **to remove splinters of steel or iron** in hospitals dealing with eye injuries.
- **electric bell, cranes and telephone**.

Telephone

In telephones, a changing magnetic effect causes a thin sheet of metal **(diaphragm)** to vibrate.

The diaphragm is made up a metal that can be attracted to magnets.

1. The diaphragm is attached to spring that is fixed to the earpiece.

2. When a current flows through the wires, the soft – iron bar becomes an electromagnet.

3. The diaphragm becomes attracted to the electromagnet.

4. As the person on the other end of the line speaks, his voice cause the current in the circuit to change. This causes the diaphragm in the earpiece to vibrate, producing sound.

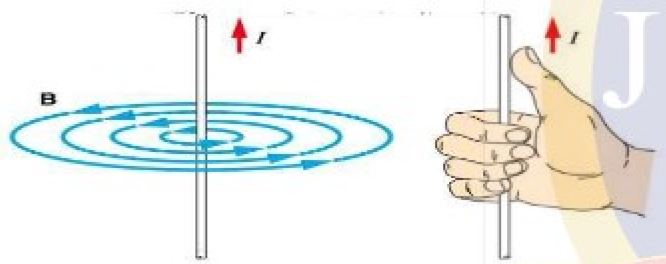
Magnetic effect of electricity

A wire or a conductor carrying current develops a magnetic field perpendicular to the direction of the flow of current.This is called magnetic effect of current.

The discovery of the **scientist Oersted**

Right hand thumb rule

Direction of current is shown by the right hand thumb and the direction of **magnetic field is shown by other fingers of the same right hand**



3.Chemical Effects of Electricity

Chemical reactions happens, when electricity passes through various conducting liquids.

Chemical Effect of Current

Electrolysis

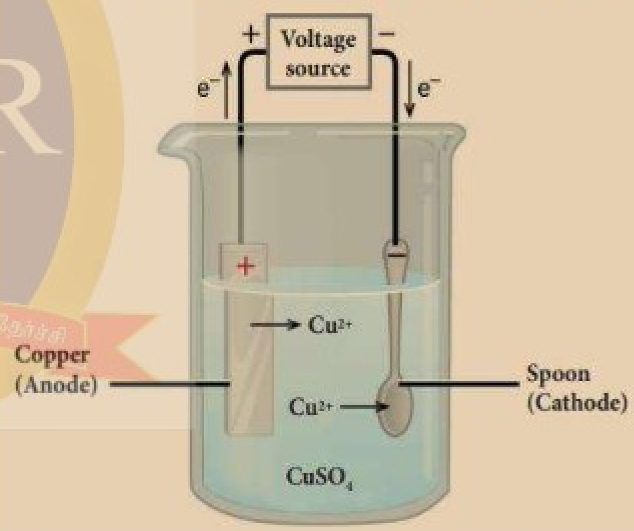
- The decomposition of molecules of a solution into positive and negative ions on passing an electric current through it, is called electrolysis.
- It is used in extraction and purification of metals. The most general use of electrolyte is electroplating.

Electroplating

The **process of depositing a layer of one metal over the surface of another metal** by passing electric current in called electroplating.

- a **coating of zinc is deposited on iron to protect it from corrosion and formation of rust.**
- **Chromium** has a **shiny appearance**. It does **not corrode.** It **resists scratches**. But, **chromium is expensive** and it may not be economical to make the whole object out of chromium.
- So, the objects such as car parts, bath taps, kitchen gas burners, bicycle handlebars, wheel rims are made from a cheaper metal and only a coating of chromium is deposited over it.

Take a glass jar and fill it with copper sulphate solution. Take a copper metal plate and connect it to the positive terminal of battery. Connect an iron spoon to the negative terminal of the battery. Now, dip them in the copper sulphate solution. When electric current is passed through the copper sulphate solution, you will find that a thin layer of copper metal is deposited on the iron spoon and an equivalent amount of copper is lost by the copper plate.



DO YOU KNOW?

Extremely weak electric current is produced in the human body by the movement of charged particles. These are called synaptic signals. These signals are produced by electro-chemical process. They travel between brain and the organs through nervous system.