WEEK-3 SECONDARY CELLS AND BATTERIES.

DEFINITION OF CELL AND BATTERY:

CELL: A cell is a device that converts chemical energy into electrical energy and provides electric current to a circuit.

* It consists of two electrodes (positive and negative) immersed in an electrolyte, which produces a potential difference between the electrodes.

Example: Dry cell, Daniell cell.

BATTERY: A battery is a combination of two or more cells connected together to provide a higher voltage and/or greater current capacity than a single cell.

* Batteries are used as a source of electrical energy in circuits.

Example: Car battery, mobile phone battery.

*A cell or battery works on the principle of electrochemical reactions.

- Chemical energy is converted into electrical energy due to oxidation and reduction reactions taking place at the electrodes.

Electrolysis is the chemical decomposition of an electrolyte (liquid or molten compound) by passing electric current through it.

FARADAY'S LAWS OF ELECTROLYSIS: Faraday's Laws Of Electrolysis describe the relationship between the electric charge passed through an electrolyte and the mass of substance deposited or liberated at the electrodes.

There are two Laws:

First Law of Electrolysis

The mass (m) of a substance deposited or liberated at an electrode is directly proportional to the quantity of electricity (Q) passed through the electrolyte.

$$m \propto Q \text{ or } m = ZQ$$

Where:

- m= mass deposited
- $Q = It$(current × time)
- Z= electrochemical equivalent of the substance

Second Law of Electrolysis

When the same quantity of electricity passes through different electrolytes, the masses of substances deposited are directly proportional to their chemical equivalent weights.

$$\frac{m_1}{m_2} = \frac{E_1}{E_2}$$

Where:

- m= mass deposited
- E= equivalent weight

Difference Between Cell and Battery:

Feature	Cell	Battery
Definition	A single electrochemical unit	One or more cells grouped together
Function	Converts chemical to electrical energy	Provides required voltage/current output
Configuration	Standalone unit	Multiple cells in series or parallel
Voltage/Capacity	Limited to single cell values	Higher total voltage or capacity
Resistance	It has high internal resistance	It has a low internal resistance
Cost	Its initial cost is cheap	Its initial cost is high
Design	Its design is smaller and lighter	Its design is more complex and heavier

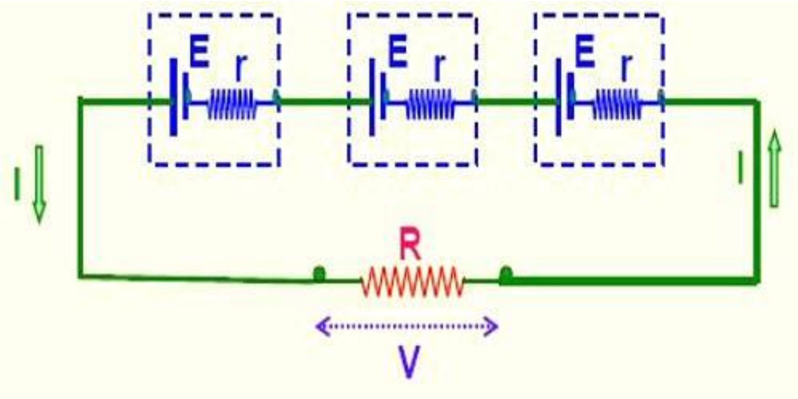
Difference Between Primary and Secondary Batteries:

Primary Battery	Secondary Battery
Cannot be recharged	Can be recharged
Chemical reaction is irreversible	Chemical reaction is reversible
Used once and discarded	Used multiple times
Light and cheap	Heavier and costly
Example: Dry cell	Example: Lead-acid battery

Grouping of Cells

Cells can be grouped in three ways to meet the required voltage and current demands:

1. **Series Grouping**



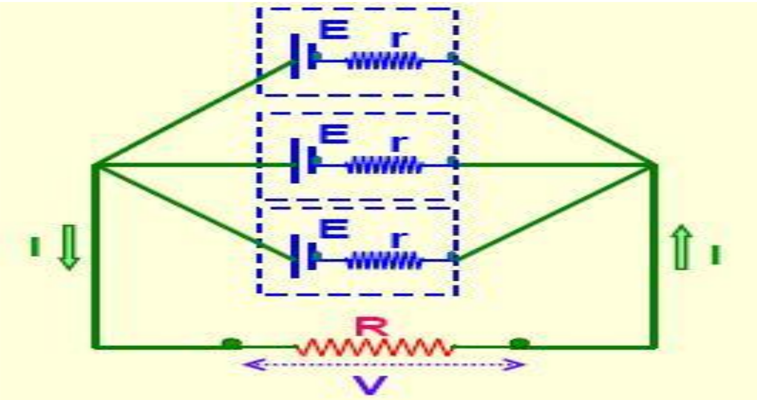
○ Positive terminal of one cell is connected to the negative of the next.

○ Total voltage = sum of individual voltages

○ Current = current of one cell

○ Used when a higher voltage is needed.

(2) Parallel Grouping



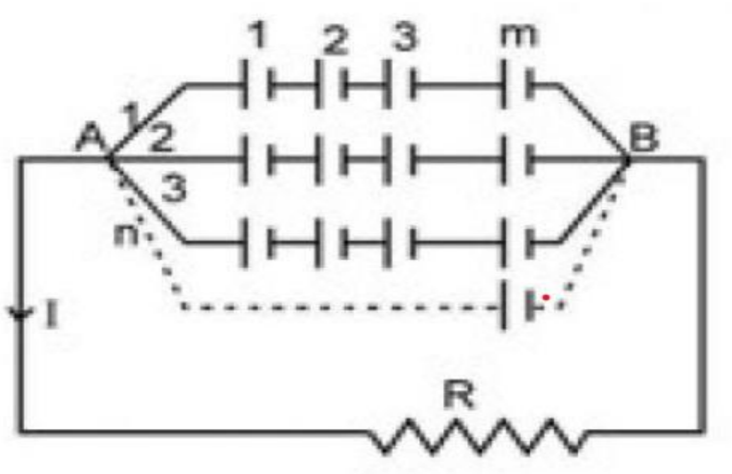
○ All positive terminals are connected together, and all negative terminals together.

○ Total voltage = voltage of one cell

○ Current = sum of individual cell currents

○ Used when a higher current is needed.

(c) Series–Parallel Grouping



Used when **both voltage and current** are needed

A combination of the above two to get the required voltage and current.

- Used in complex applications like UPS and EVs.

Numerical Problem : Problems with Grouping of Cells

Problem 1: 3 cells of 2V, 1.5A are connected in series. Find total voltage and current.

Solution:

● Total Voltage = 2 + 2 + 2 = 6V

● Total Current = 1.5A (same as one cell)

Problem 2: Three cells of emf 2 V each are connected in series.
Find total voltage.

Solution:

$$V = 2 + 2 + 2 = 6 \text{ V}$$

Answer: 6 V

Problem 3

Three identical cells each of emf **2 V** and current is **0.5 A** are connected in series. Find:

1. Total emf

Solution:

Total EMF 2+2=4V
Current:0.5A

Problem 4: When 3 cells of 2 V, 1.5A are connected in parallel. Find total voltage and current.

Solution:

● Total Voltage = 2V

● Total Current = 1.5 + 1.5 + 1.5 = 4.5A

Problem 5: When 4 cells of 5V, 1.5A are connected in parallel. Find total voltage and current.

Solution:

Total voltage:5v

Total current:1.5+1.5+1.5+1.5=6A

Special problem : Series-Parallel Grouping 6 cells, each of 2V, 1.5A. 3 sets of 2 cells in series, and then all sets in parallel. Find total voltage and current.

Solution:

● Each set voltage = 2 + 2 = 4V

● Each set current = 1.5A

● Total = 3 sets → ○ Voltage = 4V

○ Current = 1.5 + 1.5 + 1.5 = 4.5A

Classification of Secondary Batteries Based on Their Uses

Secondary batteries (rechargeable batteries) are classified according to **where and how they are used**. This classification is **important for exams** and practical understanding.

1. Automotive Batteries

Use: Starting, lighting, and ignition (SLI) in vehicles

Common Type:

- **Lead–acid battery**

Applications:

- Cars
- Motorcycles
- Trucks

2. Industrial Batteries

- **Use:** Backup power and heavy-duty applications in Power plants,Telephone exchanges etc

Common Types:

- Lead–acid batteries
- Nickel–cadmium (Ni–Cd) batteries

3. Stationary Batteries

Use: Fixed installations for emergency or continuous power

Common Types:

- Lead–acid
- Nickel–cadmium

Applications:

- Emergency lighting
- Backup for computers and servers
- Solar power systems

4. Traction Batteries

Use: To supply power for movement (traction)

Common Types:

- Lead–acid
- Lithium-ion

Applications:

- Electric vehicles (EVs)
- Forklifts
- Electric trains

5. Portable Batteries

Use: Small, handheld electronic devices

Common Types:

- Lithium-ion (Li-ion)
- Nickel–metal hydride (Ni–MH)

- **Applications:**
- Mobile phones
- Laptops
- Cameras
- Power banks

6. Marine Batteries

Use: Used in boats and ships

Common Types:

- Lead–acid
- Lithium-ion

Applications:

- Navigation systems
- Ship lighting
- Marine engines

7. Renewable Energy Storage Batteries

Use: Energy storage from renewable sources

Common Types:

- Lead–acid
- Lithium-ion

Applications:

- Solar power plants
- Wind energy systems

Ampere-hour (Ah) Efficiency of a Battery:

The ampere-hour efficiency of a battery is the ratio of ampere-hours obtained during discharge to the ampere-hours supplied during charging.

.Ampere-hour (Ah) efficiency, measures how well a battery stores and releases charge,

Formula: Ah Efficiency = $\frac{Discharge\ Ah}{Charge\ Ah} \times 100\%$

Note: Ah efficiency is always **less than 100%** due to losses during charging.

Watt-hour Efficiency of a Battery

Definition :
Watt-hour efficiency of a battery is the ratio of the energy delivered during discharge to the energy supplied to the battery during charging, expressed as a percentage.

Formula

$$\text{Watt-hour efficiency } (\eta_{Wh}) = \frac{\text{Watt-hours during discharge}}{\text{Watt-hours during charge}} \times 100$$

or

$$\eta_{Wh} = \frac{V_d \times I_d \times t_d}{V_c \times I_c \times t_c} \times 100$$

Where:

- V_d= discharge voltage
- I_d= discharge current
- t_d= discharge time
- V_c= charging voltage
- I_c= charging current
- t_c= charging time

*Difference between Ah and Wh:

Amp-Hour (Ah) Efficiency

- What it is: The ratio of the charge (in Ampere-hours) you get out of a battery to the charge (in Ampere-hours) you put in.

Focus: Electrical *charge* capacity.

Watt-Hour (Wh) Efficiency:

- **What it is**: The ratio of the actual energy (in Watt-hours) you get out to the energy (in Watt-hours) you put in.

Focus: Total stored *energy*, accounting for voltage.

Types of batteries and their applications:

- Lead-acid: Cost-effective, used in vehicles, UPS systems, and backup power.

● Ni-Cd (Nickel-Cadmium): Rechargeable, durable, used in portable devices, power tools, and some medical equipment.

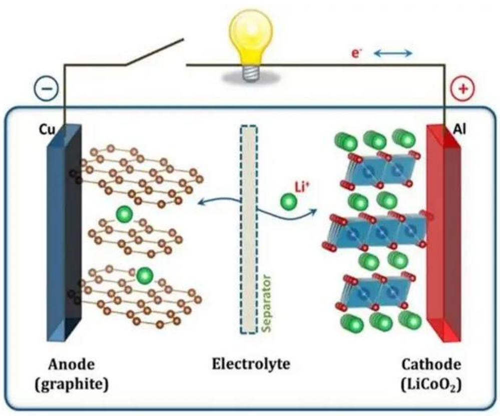
● Li-ion (Lithium-ion): High energy density, lightweight, used in smartphones, laptops, electric vehicles, and power tools.

● Ni-MH (Nickel-Metal Hydride): Used in hybrid vehicles and portable electronics.

● Ni-Polymer: Lightweight, flexible, used in portable devices.

Lithium-ion Battery Construction and Working:

Construction:



Typically consists of a positive electrode (cathode), a negative electrode (anode), a separator, and an electrolyte.

1. **Anode (Negative Electrode):**

● Material: Graphite

● Coated on Copper (Cu) foil.

● Function: Stores lithium ions when the battery is charged.

2. **Cathode (Positive Electrode):**

● Material: Lithium Cobalt Oxide ($LiCoO_2$)

● Coated on Aluminum (Al) foil.

● Function: Releases lithium ions during discharge.

3. **Electrolyte:**

● A lithium salt (like $LiPF_6$) dissolved in an organic solvent.

● Allows Li^+ ions to move between the anode and the cathode.

4. **Separator:**

● A porous membrane is placed between the anode and cathode.

● Function: Prevents short-circuit but allows the movement of Li^+ ions.

Working:

○ During discharge, lithium ions move from the anode to the cathode through the electrolyte and an external circuit, generating an electrical current.

○ The process reverses during charging.

○ The high energy density is due to the energy stored in the atomic bonds of lithium.

○ A Battery Management System (BMS) is crucial for monitoring and managing the battery's performance, ensuring safety, and preventing damage.

TYPES OF CHARGING SYSTEM:

1)CONSTANT -CURRENT SYSTEM: (CC)

- A constant-current charging system is a battery-charging method in which the charging current is kept constant, while the charging voltage varies according to the battery’s state of charge.

- which is typically used in the initial stages of charging to quickly replenish the battery.

- Simple charging method, Commonly used for Ni-Cd and Ni-MH batteries

A constant-current charging system maintains a fixed charging current while the battery voltage changes.

2) Constant-Voltage (CV) Charging System:

- A constant-voltage charging system is a battery-charging method in which the charging voltage is kept constant, while the charging current varies according to the battery's state of charge.

- Once the battery reaches the set voltage, the charger switches to constant voltage mode,

- This method is crucial for preventing overcharging.

***A constant-voltage charging system maintains a fixed charging voltage while the charging current varies.**

TRICKLE CHARGING :

This is a very slow charging method that applies a small current to a deeply discharged battery to bring it back to a usable level. It's often used to maintain batteries in storage or when a battery is very old.

1. Keeps battery always ready for use
2. Prevents deep discharge

Indications of a Fully Charged and Discharged Cell:

Indication of a Fully Charged Cell

1. Terminal voltage reaches maximum value
   - Lead–acid: ≈ 2.1–2.2 V per cell
2. Specific gravity of electrolyte becomes constant *(lead–acid only)*
   - About 1.26–1.28 at 27°C
3. Charging current falls to a very small value
   - Especially in constant-voltage charging
4. Gassing starts *(lead–acid)*
   - Hydrogen and oxygen bubbles appear
5. Battery temperature slightly increases

Indication of a Fully Discharged Cell

1. Terminal voltage drops to minimum value
    - Lead–acid: ≈ 1.8 V per cell
2. Specific gravity of electrolyte decreases *(lead–acid)*
    - About 1.18–1.20
3. Battery fails to supply rated current
4. Dimming of lights / device stops working
5. Electrolyte becomes weak *(lead–acid)*