# Current Electricity

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**Electric Current (I)**

- It is the rate of flow of electric charge flowing though any section of wire.

**Ohm's Law**

- Electric current flowing through a conductor is directly proportional to the potential difference across the two ends of the conductor; physical quantities such as temperature, mechanical strain, etc. remaining constant.

$V = RI$

Where, $R$ is a constant for a given conductor

**Electrical resistance:**

R=ρlAR=ρlA

Where, $r$ is the specific resistance or electrical resistivity of the material

**Conductance and Electrical conductivity:**

- Conductance G=AρlG=Aρl
- Electrical conductivity ($s$) is defined as the reciprocal of resistivity.

σ=1ρ
The other form of Ohm's law is
J= σEJ= σE
J = current density
E = electric field applied

**Motion of electrons due to thermal energy**

- Free electrons are in continuous random motion. They undergo change in direction at each collision and the thermal velocities are randomly distributed in all directions.
- Average thermal velocity,u=u1+u2+u3+........+unnu=u1+u2+u3+........+unn is zero … (1)

**Drift velocity**

- vd→vd→ is defined as the velocity with which the free electrons get drifted towards the positive terminal under the effect of the applied electric field.

- J = IA=qAt=neAtJ = IA=qAt=neat we know that I=neAvd  or  IA=nevdI=neAvd  or  IA=nevd

  Therefore, J=nevdJ=nevd

  **Limitations of Ohm's Law**

  The Ohm's law ceases to be valid in following cases:

  - *V* ceases to be proportional to *I*.
  - Sign of V affects the relation between *V* and *I*.
  - There is more than one value of *V* for the same current.

  **Factors that affect resistance**

  **I. Length of the conductor**

  Resistance is directly proportional to the length of the conductor i.e.
  R∝lR∝l Where, *l* → length of the conductor

  **II. Cross-section of the conductor**

  Resistance is inversely proportional to the area of cross-section of the conductor i.e.
  R∝1AR∝1A

  *A* → area of cross-section
  So, R∝lAR∝lA
  Or,
  R=ρlAR=ρlA

  Where, $\rho$ is the proportionality constant, called the **electrical resistivity** of the material of the conductor. It is also known as specific resistance.

- The SI unit of resistivity is Ω m (Ohm-meter).

- Resistivity is the characteristic property of a material. It only depends on the nature of the material and not its dimensions. This is one of the major differences between resistance and resistivity. But like resistance, resistivity also varies with temperature.

- Metals have low resistivities. It is in the range of $10^{-8}$ Ω m to $10^{-6}$ Ω m. Insulators have resistivities $10^{18}$ times greater than metals. Semi-conductors lie in between them. The following table shows the resistivity of some materials at 20 °C.

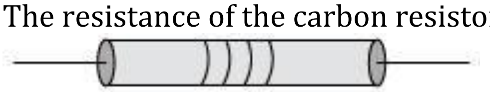
**Conductivity**

The reciprocal of resistivity is known as conductivity. Its SI unit
is ohm−1metre−1 or Ω−1m−1 or siemen metre−1ohm-1metre-1 or Ω-1m-1 or siemen metre-1.
$\sigma=1\rho=lRa\sigma=1\rho=lRa$

**Finding resistance of the carbon resistor**

| **TABLE 3.2 RESISTOR COLOUR CODES** | | | |
|---|---|---|---|
| **Colour** | **Number** | **Multiplier** | **Tolerance (%)** |
| Black | 0 | 1 | |
| Brown | 1 | $10^{1}$ | |
| Red | 2 | $10^{2}$ | |
| Orange | 3 | $10^{3}$ | |
| Yellow | 4 | $10^{4}$ | |
| Green | 5 | $10^{5}$ | |
| Blue | 6 | $10^{6}$ | |
| Violet | 7 | $10^{7}$ | |
| Gray | 8 | $10^{8}$ | |
| White | 9 | $10^{9}$ | |
| Gold | | $10^{-1}$ | 5 |
| Silver | | $10^{-2}$ | 10 |
| No colour | | | 20 |

The resistance of the carbon resistor is found by using the table



- Here, first two bands from one end indicate the first two significant figures of resistance in ohms.
- Third band indicates the decimal multiplier.
- The last band stands for tolerance. Its absence indicates a tolerance of 20%.

**Temperature Dependence of Resistivity**

- On increasing temperature, the number of collisions of electrons and ions in conductors increases; this, in turn, increases their resistivity.
- Relation between resistivity and temperature:

$\rho = \rho 0 \ (1 + \qquad t)$

Here, is the temperature coefficient of resistance of the material of a conductor

- The resistivity of a metallic conductor increases with increase in temperature.
- The resistivity of an alloy has a weak temperature dependence.
- The resistivity of a semiconductor decreases rapidly with increasing temperature.

Alloys are used for preparing standard resistance coils because of their high resistance and low temperature coefficient of resistance.

**Superconductivity**

- Superconductivity is the phenomenon in which a material loses its resistivity completely.
- Superconducting cables can be used for power distribution without loss.
- Speed of a computer can be increased by superconducting wires.
- Superconductivity can help produce a very strong magnetic field without power loss.
- Superconductivity exists at subzero temperature, which hinders its use at normal temperature.

**Thermistor**

- Thermistor is a heat-sensitive semiconductor device whose resistance changes very rapidly with change in temperature.
- It is used for remote sensing, voltage stabilisation, temperature control, etc.

**Electric Energy**

- It is the work done by the source of *emf* in maintaining the electric current in the circuit for a given time.
- $W = VIt$

**Electric Power**

- It is the rate at which work is done by the source of *emf* in maintaining the electric current in a circuit.

P=V2R=I2RP=V2R=I2R

**Electric Cell**

- Primary Cell – In a primary cell, chemical energy is directly converted to electrical energy. They cannot be reused once completely discharged.
  For example, simple voltaic cell, Leclanche cell

- Secondary Cell– In a secondary cell also, chemical energy is directly converted to electrical energy. But the basic difference between primary and secondary cells is that secondary cells are reusable as they can be charged using external sources. Thus, when secondary cells are charged, electric energy gets converted into chemical energy.

  Examples of secondary cells: lead acid cell, Ni–Cd cell

**Emf**

- Potential difference between the two poles of the cell in an open circuit is called *emf* of the cell.

**Internal resistance ($r$) of cell**

Resistance offered by the electrolyte of the cell when the electric current flows through it is,
r=(EV−1)Rr=EV-1R
where,
$E$ – *emf* of cell
$r$ – Internal resistance of the cell
$R$ – External resistance
$K$ – Key
$V$ – Voltmeter

**Combination of cells**

- **Series combination of the cells**

- The equivalent emf of a series combination of n cells ($E_{eq}$)
- $E_{eq} = E_1 + E_2 + .............+ E_n$
- The equivalent internal resistance of a series combination of n cells ($r_{eq}$)
- $r_{eq} = r_1 + r_2 + ................+ r_n$

- **Parallel combination of the cells**

  - For a parallel combination of n cells with emfs $E_1$ , $E_2$........ and $E_n$ and internal resistances $r_1, r_2$.............. *and* $r_n$
  - Equivalent emf:

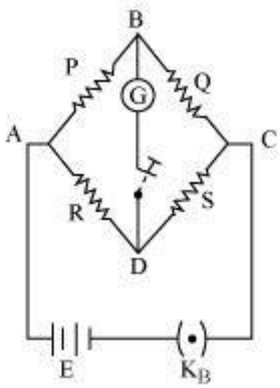
  $E_{eq}$ = E1r1+E2r2+..............EnrnE1r1+E2r2+..............Enrn
  Equivalent internal resistance($r_{eq}$) :

1req=1r1+1r1..........+1rn1req=1r1+1r1..........+1rn

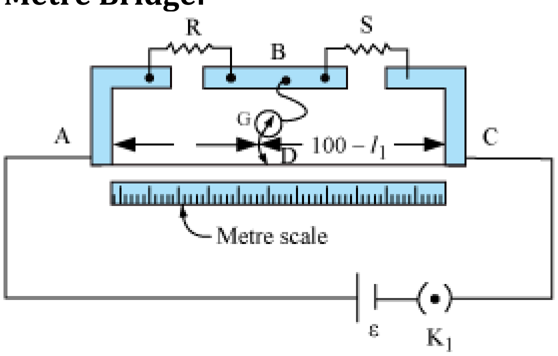
**Kirchhoff's laws:**

- First law: In any electrical network, the algebraic sum of the currents, , meeting at a junction is always zero.
- Second law: The algebraic sum of all the potential drops and emfs along any closed path in a network is zero.

**Wheatstone bridge:**




**Metre Bridge:**




- **Causes of probable errors while using a metre bridge:**
  - Uneven thickness of the wire used in the metre bridge
  - Contact resistances developed at the ends of the wire of the metre bridge
  - Ends of the wire not coinciding with the 0 and 100 cm marks of a metre scale
- We can minimise the errors in a metre bridge by using wire of uniform thickness and repeating the experiment by changing the position of the unknown resistance.
- In Kelvin's method, the resistance of galvanometer is given by

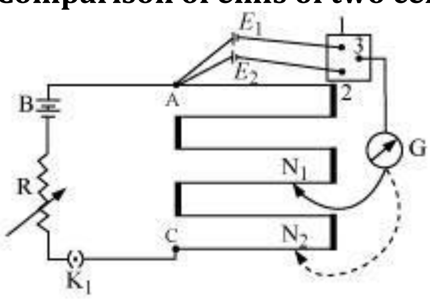
, where *R* is the resistance and $l_g$ is the point where the galvanometer shows the same deflection as shown while the jockey was not touching the wire.

- **Potentiometer**

  It works on the principle that on passing a constant current, the potential drop across any portion of the wire is directly proportional to the length of that portion.
  i.e., V α lV α l

- **Applications of a Potentiometer**

  **Comparison of emfs of two cells**

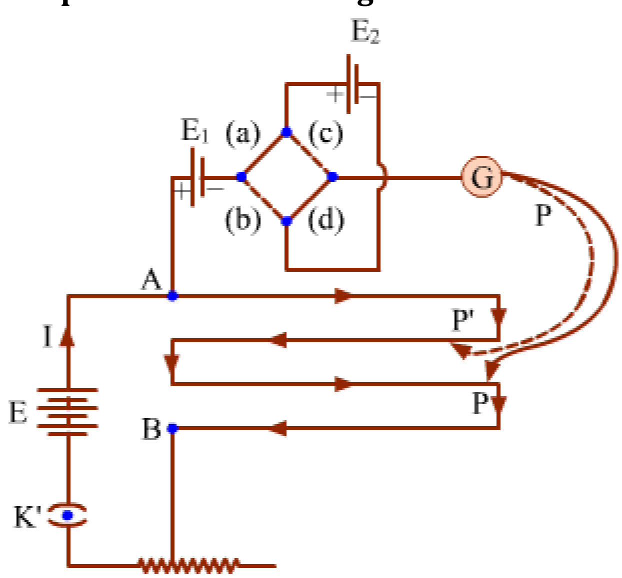



  - E1E2=l1l2E1E2=l1l2

  **Measurement of internal resistance of a cell**

  r=R(l1l2−1)r=Rl1l2-1

  **Comparison of emfs using the sum and difference method**




  - E1E2 =L1 + L2L1 − L2E1E2 =L1 + L2L1 - L2

- **Sensitivity of Potentiometer**

  The smallest ptential difference that can be measured with a potentiometer is known as its sensitivity. The sensitivity of a potentiometer can be increased by decreasing its potential gradient (E/l). The potential gradient can be decreased by following ways:

  - Increasing the length of potentiometer
  - Decreasing the current in the potentiometer wire circuit if the wire is of fixed length

- **Precautions to be taken while using a potentiometer**

  - The potentiometer wire must be uniform.
  - The resistance of potentiometer wire should be high.
  - The emf of the battery must be greater then the emfs that are to be compared.

- **Advantages of a potentiometer**

  - It can measure the terminal potential difference as well as the emf of a cell.
  - Its accuracy can also be increased by increasing the length of the wire.

- **Disadvantages of a potentiometer**

  - It cannot directly indicate the value of the potential difference.
  - It is not portable.