Chapter

9 Current Electricity

Quick Review

Current Electricity

Kirchhoff's Laws

- They are fundamental principles used in electrical circuit theory that dictate the response of electric circuits.
- They are widely used to analyze and solve the behaviour of complex electrical circuits.
- There are two laws under Kirchhoff's laws:

i. Kirchhoff's Current Law
ii. Kirchhoff's Voltage Law

Galvanometer

- It is an electromechanical device used to detect and measure small electric currents.
- A typical galvanometer consists of a coil of wire, an arrangement for creating a magnetic field and a needle pointer that moves in response to the flow of electric current through the coil.
- With advances in technology, electronic measuring devices like digital multimeters have largely replaced galvanometers in many practical scenarios due to their higher accuracy, versatility and ease of use.

Thermoelectricity

- It is a phenomenon where an electric current is generated in a material due to a temperature gradient across it.
- This effect was discovered by the German physicist Thomas Johann Seebeck in 1821 and is called the "Seebeck effect".
- It states that when a temperature difference exists across a thermoelectric material, charge carriers (electrons or holes) start moving from the hot side to the cold side. This movement of charge leads to the establishment of an electric potential difference, and thus electric current flows through the material.

Kirchhoff's Laws:

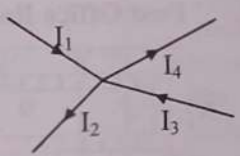
- Introduced by the German Physicist Gustav Kirchhoff in 1845.
- Utilised to analyse the behaviour of electrical circuits, calculate voltages and currents and are extensively used in electronics, power system design, networking and telecommunications.

Kirchhoff's current law (KCL)

The algebraic sum of the currents at a junction is zero in an electrical network.

i.e., $\sum_{i=1}^{n} I_i = 0$

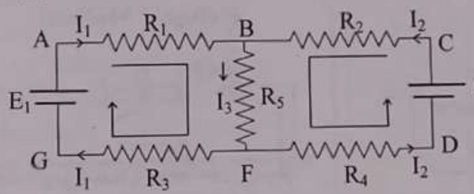
Here, $I_1 + I_3 = I_2 + I_4$



Kirchhoff's voltage law (KVL)

The algebraic sum of the potential differences (products of current and resistance) and the electromotive forces (emfs) in a closed loop is zero.

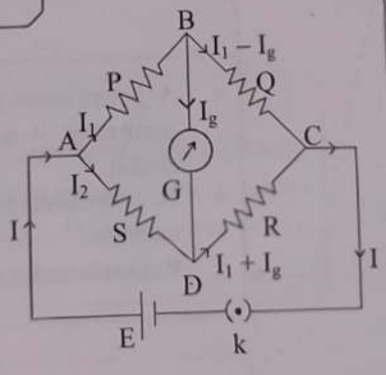
i.e., $\sum IR + \sum E = 0$ **OR** $\sum E = \sum IR$



Wheatstone bridge

i. Wheatstone bridge was invented by Samuel Hunter Christie in 1833, however, it was made famous by Sir Charles Wheatstone. It provides a method by which unknown resistances could be calculated with high accuracy.

ii. A Wheatstone bridge is used in diverse domains like strain gauge measurements, temperature and pressure sensing and humidity measurement.



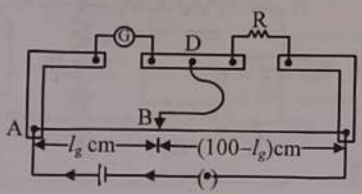
Wheatstone bridge

Metre Bridge

- A meter bridge (slide wire bridge), is a device used to measure the unknown resistance of a conductor.
- It is an effective tool for measuring resistances with good accuracy.

Principle: When a constant current flows through the wire, the potential difference (voltage) across any point on the bridge wire is directly proportional to its distance from one end of the wire.

Kelvin's Method



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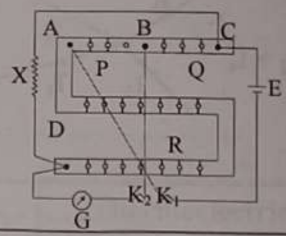
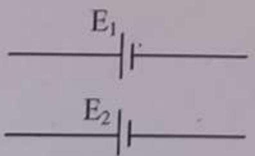


Potentiometer

- A potentiometer is a device which is used to measure potential difference accurately. It is an ideal voltmeter and does not draw any current from the circuit.
- A potentiometer has infinite resistance so that it does not draw any current.

Potentiometer Rule: $V \propto L \quad \Rightarrow \quad V = xL$

Individual Cell Method

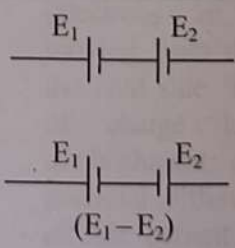


$$\frac{E_1}{E_2} = \frac{l_1}{l_2}$$

To find internal resistance of Cell

$$r = \left[\frac{l_1 - l_2}{l_2}\right]R$$

Sum and difference Method

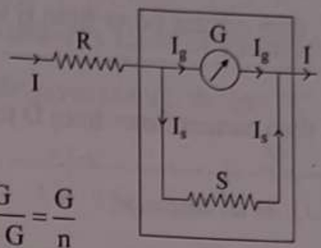


$$\frac{E_1}{E_2} = \frac{l_1 + l_2}{l_1 - l_2}$$

Galvanometer

Ammeter

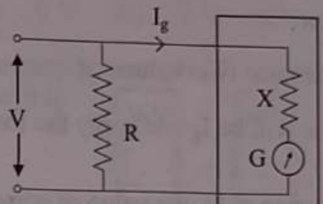
- An ammeter is a current measuring instrument. It is always connected in series with a resistance R through which the current is to be measured.



- Resistance of ammeter, $R_A = \frac{SG}{S+G} = \frac{G}{n}$

Voltmeter

- Voltmeter is used to measure potential difference between two points in an electrical circuit. It is always connected in parallel with the component across which voltage drop is to be measured.



- Resistance of voltmeter, $R_v = G + X = Gn_v$

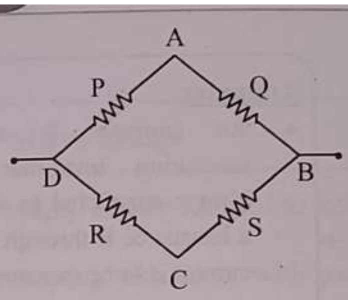
Thermoelectricity

- Seebeck Effect
- A thermocouple is a temperature sensor that converts temperature directly into an electrical voltage. It consists of two different metals or metal alloys joined together at one end, forming a junction. This junction is the measurement point where the temperature is being sensed.

Shortcuts

1. If four identical resistors, each of resistance R, are connected in the form of a square, the effective resistance between the ends of the diagonal is R.
2. When the length of a wire having resistance R is made m times and its radius n times, the resistance (R′) of the wire becomes $R' = \frac{m}{n^2} R$
3. When a wire having resistance R is stretched so as to make its length n R′ then $R' = n^2 R$
4. Current through any resistor (branch current) I′ is given by,
   $I' = \text{Main current (I)} \times \left(\frac{\text{Resistance of opposite branch}}{\text{Total resistance}}\right)$
5. To determine original length of wire when two balancing lengths for same internal resistance are given, then apply the formula, $L = \frac{l_1 l_2}{2l_2 - l_1}$ $(l_1 > l_2)$
6. Potential gradient of a potentiometer governs its sensitivity. The sensitivity and potential gradient are inversely proportional to each other.
7. The balancing length in a metre bridge experiment is independent of the area of cross-section of the wire used.

8. In a Wheatstone Bridge,



i. If $R > \frac{QS}{P}$, then current flows from B to D.

ii. If $R < \frac{QS}{P}$, then current flows from D to B.

9. Use of M.C.G. as an ammeter:

i. If there is a question involving ammeter or shunt, just look for two values in the given question and always apply the formula, $\frac{\text{smaller value}}{\text{bigger value}} = \frac{S}{S+G}$ where S is shunt which is very small and G is resistance of galvanometer.

ii. If in the question two values of current are given, always remember, the bigger value will be I and the smaller value will be I_g and apply the formula, $\frac{I_g}{I} = \frac{S}{S+G}$.

iii. If in the question only one value of current is given, remember it will always be I_g.

iv. If in the question, it is given that x% of main current passes through galvanometer, then simply apply the formula, $\frac{I_g}{I} = \frac{X}{100}$.

10. Use of M.C.G. as a voltmeter:

i. In a voltmeter, a very high resistance R is connected in series given by, $R = \frac{V}{I_g} - G$ where V is new range (for example, if galvanometer was able to read upto 10 volts and it is to be converted into voltmeter to read upto 100 volts, then V will be 100 volts) and to calculate I_g, always apply the formula, $I_g = \frac{\text{old range}}{G}$

ii. Value of R should always be very high and value of S should be very small.