According to new syllabus of all intermediate boards of Sindh.

Prof. Rawala's ……..

PHYSICS

HELPING BOOK

For
Class XI
(All science students)

UNIT -10

D.C circuits.

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Thoroughly revised and updated 2026 – 2027

- ***Detailed notes.***
- ***Multiple Choice Questions (M.C.Q's).***
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Unit. 10 .....

D.C Circuits

Ohm's law:

Q.No.1: State and explain Ohm's law?

Ans: According to Ohm's law:

"Potential difference "ΔV " across the ends of a conductor is directly proportional to Current " I" flowing through it provided temperature and other physical conditions of the conductor do not change".

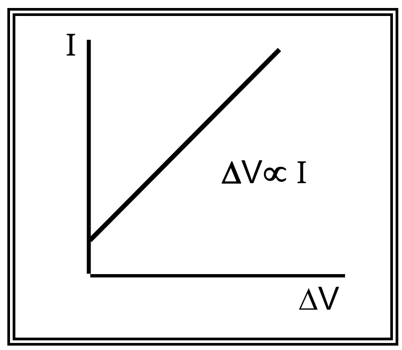
$$\Delta V \propto I$$

$$\therefore \quad \boxed{\Delta V = R\,I}$$

Where "R" is the constant of proportionality, it is known as **"Resistance of the conductor"**

Its value depends upon ***dimensions, material*** and ***temperature*** of the conductor.

Hence the product of current "I" and resistance "R" of a conductor is equal to the potential difference "ΔV" across its ends, provided ***temperature*** and other physical conditions of the conductor do not change. The graph between potential difference "ΔV" and the resulting current "I" flowing through it, is a **straight line** if Ohm's law is obeyed.



A material that obeys Ohm's law is called ***Ohmic conductor***.

Q.No.2: Give an example in which Ohm's law is not valid.

Ans: When current is passed through an electric bulb its temperature rises. It converts part of electrical energy into heat and a part into light. In this case since the temperature of filament of the bulb rises, therefore, current flowing through it will not be directly proportional to the potential difference across its ends. ***In other words,*** Ohm's law will **not be obeyed**.

Circuit representation

Q.No.3: What is resistance? How is it offered?

Ans: It is the ***opposition*** offered by a conductor to the flow of electric current through it

When current is passed through a conductor, free electrons move through the conductor in one direction. These free electrons suffer elastic collisions with the vibrating atoms of the conductor. As a result of which their motion is opposed. This opposition to the flow of current (or to the motion of free charges) is called ***resistance*** of the conductor.

Note that, with a few exceptions, resistance of materials ***increases*** with a rise in temperature and ***decreases*** with a fall of temperature.

- The change in resistance with temperature, above and below 0°C, over a wide range of temperature is uniform.

Also note that, resistance of semiconductors decreases with a rise in temperature.

***Q.No.4*: On what factors does the resistance of a conductor depend?**

Ans: Resistance offered by a conductor depends upon:

1. ***Material*** of the conductor.
2. Geometrical ***dimensions*** (length, area of cross section etc.) of the conductor.
3. ***Temperature*** of the conductor.

***Q.No.5*: What is the unit of resistance?**

Ans: The S.I unit of resistance is ***"ohm Ω"***.

Resistance of a conductor is said to be one ohm (1 Ω) if it allows one ampere (1 A) current to pass through it when a potential difference of one volt (1V) is maintained across it.

$$\boxed{1\,\Omega = \frac{1A}{1V}}$$

In electronic circuits resistors are used to control the flow of current within desired values.

***Q.No.6*: Why does the resistance of a conductor increase with a rise in its temperature? Why is Ohm's law *not obeyed* when temperature of the conductor rises?**

Ans: When temperature of a conductor is ***raised***, vibrational kinetic energy of its atoms increases. Atoms of the conductor now vibrate **more vigorously** and through **longer distances**, as a result of which the chances of collisions between these rapidly vibrating atoms and the free electrons flowing through it ***increases***. Due to the increased number of collisions, the opposition to the movement of free electrons or ***in other words***, resistance of the conductor ***increases***.

Similarly, when temperature of a conductor is ***lowered***, the atoms of the conductor vibrate slowly with decreased amplitude of vibrations, due to which chances of their collisions with free electrons or ***in other words,*** resistance of the conductor ***decreases***.

Ohm's law is valid as long as, along with the other physical properties, mainly temperature of the conductor ***must not change***, because if temperature of the conductor changes it's resistance will also change. Since resistance "R" is a constant of proportionality in Ohm's law, therefore, whenever resistance of a conductor changes while current is flowing through it, ***Ohm's law will not be obeyed***.

In other words, when temperature of the conductor changes, potential difference across the conductor ***will not be*** directly proportional to current flowing through it ($V \propto I$).

Resistor color code:

In electronic circuits carbon resistors are used for introducing high resistances for various purposes. They are ***small***, their value is indicated by a ***color code***.

Color code is in the form of usually four colored coaxial bands in a particular order. Following table having four columns shows how to use the color code.

First and **second** bands represent number or significant value, **3rd band** represents multiplier whereas the **fourth band** indicates tolerance (**in other words**, possible variation in resistance, it is expressed in %).

Color	Value (1st 2nd band)	Multiplier	Tolerance
Black	0	10^0	Gold $\pm$ 5%
Brown	1	10^1	Silver $\pm$ 10%
Red	2	10^2	No color $\pm$ 20%
Orange	3	10^3	
Yellow	4	10^4	
Green	5	10^5	
Blue	6	10^6	
Violet	7	10^7	
Grey	8	10^8	
White	9	10^9	

To understand the color code, let us assume that the first color band is **Orange**, second is **Blue**, third is **Violet** and the fourth is **Gold**. Substituting 3 (for Orange), 6 (for Blue), 10^7(for Violet) and $\pm$ 5% (for Gold) we will get the value of resistance as $R=35\times10^7 \pm 5\%$.

Resistivity:

Q.No.1*: What is resistivity** (or ***specific resistance) ***of a conductor?***

Ans: Resistivity or specific resistance of a conductor may be defined as:

"The resistance offered by a conductor of unit length and unit area of cross section".

OR

"Resistivity is the resistance offered by unit volume of a conductor".

***Q.No.2*: What is the unit of resistivity?**

Ans: The unit of resistivity is **Ω-*m*** (***ohm-meter***).

***Q.No.3*: On what factors does the resistivity of a conductor depend?**

Ans: Resistivity of a conductor depends upon its ***material*** and upon it's ***temperature***.

At a given temperature resistivity of a conductor depends only upon it's ***material***.

- Silver is the best conductor of electricity, because its resistivity is the lowest among all the conductors. ***In other words***, its unit volume offers minimum resistance to the flow of electric current among all the conductors.
- Some alloys have high resistivity, some of them find important use under suitable conditions where high resistance is required, e.g. in an electrical room heater usually nichrome is used because it's resistivity is highest.

Note that, resistivity of semiconductors is negative ***it means that*** resistance of semiconductors decreases with a rise in temperature.

Deriation:

At a given temperature resistance of a conductor is directly proportional to its length "L" and inversely proportional to its area of cross section "A":

$$R \propto L \qquad \& \qquad R \propto \frac{1}{A}$$

OR $R \propto \frac{L}{A}$ $\therefore$ $\boxed{R = \rho \frac{L}{A}}$ .... (*i*)

Where "ρ" is a constant of proportionality, it is known as **resistivity of the conductor**.

At a constant temperature the value of resistivity "ρ" depends upon ***material*** of the conductor. Usually the value of "ρ" for conductors is ***low*** and for insulators (or bad conductors) its value is ***high***.

From the above formula: $\rho = \frac{R\,A}{L}$

Resistivity "ρ" may be defined as ***the resistance offered by a conductor of unit length (L = 1) and unit area of cross section (A = 1). (Or resistance offered by its unit volume).***

S.I unit of resistivity "ρ" is ohm-m (Ωm).

Resistance, resistivity and temperature coefficient:

Resistance of a conductor of given material changes with temperature, hence if R_o is its resistance at 0°C and R_T at T°C then:

$$R_T - R_0 \propto R_0\,T$$

$$R_T - R_0 = \alpha\,R_0\,T$$

Where "α" is the constant of proportionality known as **temperature coefficient** of the given material.

Temperature coefficient of resistance "α":

Temperature coefficient "α" may be defined as the change in resistance per unit resistance per degree rise in temperature.

- **Its value depends upon material of the conductor.**
- **Its unit is (°C)$^{-1}$ or K^{-1}.**

Therefore: $R_T = R_0 + \alpha\,R_0\,T$

$$R_T = R_0\,(1 + \alpha\,T)$$

Hence resistivity of a conductor of given material increases with temperature. if "ρ_0" and "ρ_T" are resistivities of a conductor of given material at 0°C and T°C respectively, then in terms of resistivities the above equation becomes:

$$\rho_T = \rho_0\,(1 + \alpha\Delta T)$$

This equation can be used to find the resistivity of a material at any temperature provided its resistivity at 0°C and its temperature coefficient "α" are known (this equation depends purely on material).

Temperature coefficient of resistance "α" is **positive** for most of the conductors, showing that their **resistance increases** with a rise in their temperature. But in case of semiconductors value of "α" is **negative**, showing that their **resistance decreases** with a rise in their temperature.

In semiconductors number of charge carriers (conduction electrons, holes) increases with a rise in its temperature due to which its "α" is **negative**. ***In other words,*** its resistance **decreases**.

Conductance and conductivity:

Q.No.5: What are conductance and conductivity of a conductor?

Ans: Conductance of a conductor is the reciprocal of its resistance R, similarly it's conductivity "σ" is the reciprocal of its resistivity "ρ" (i.e. $\sigma = 1/\rho$).

Unit of conductance is Siemens "S".

Unit of conductivity is Siemens/meter "S m⁻".

In terms of conductivity "σ" equation (*i*) becomes:

$$\boxed{R = \frac{L}{\sigma A}} \text{ .... } (ii)$$

Conductance is a measure of how **good** or how **bad** a conductor is. If conductance of a conductor is **low,** its resistance "R" and resistivity "ρ" will be **high** and for a given potential difference it will allow **less** current to pass through it, ***in other words***, it will be a **bad conductor** of electricity. But if conductance of a conductor is **high**, its resistance "R" and resistivity "ρ" will be **low** and for a given potential difference it will allow **more** current to pass through it, ***in other words***, it will be a **good conductor** of electricity.

Electromotive force emf:

When current is passed through an electrical circuit, movement of charges (free electrons) is opposed (due to resistance of the conductor). To overcome this opposition charges will have to do work. This work done dissipates energy of the charges and appears as heat. Charges will, therefore, continuously lose energy. To maintain a constant current some source of power is needed. This source must be able to supply power equal to the power dissipated. Strength of such a source is measured by its electromotive force emf. Hence, the electromotive force "E" of a source of current (Cell, battery, electric generator etc.) may be defined as:

The potential difference across its terminals when no current is drawn from it.

Internal resistance:

Q.No.1: What is internal resistance?

Ans: Internal resistance of a source is:

"The opposition to the flow of charges through a source of emf".

Q.No.2: What causes internal resistance in a cell, a battery?

Ans: In the external electrical circuit conventional current flows from positive to negative terminal of a source of emf. To complete the circuit same amount of current also flows through the source from negative to positive terminal. While passing through the source, charges suffer collisions with the atoms of the electrolyte. This opposition to the flow of charges while passing through a source is called ***internal resistance*** of the source. Internal resistance is offered by the electrolyte of a cell or a battery but in case of a generator internal resistance is offered by wire of its coil.

Q.No.3: What is terminal potential difference V and what is its relation with emf?

Ans: Terminal potential difference is the ***potential difference available across the terminals of a source for the external circuit.***

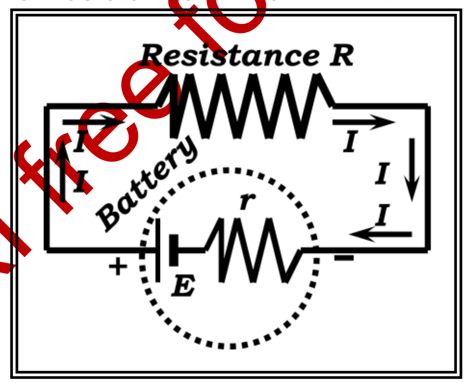
***Explanation and derivation*:**

A battery (or any source) may be considered as a source of pure emf "E" and an internal resistance "r" connected in series to it. If "R" is the total resistance of the circuit connected externally across the battery, then according to Ohm's law current "I" flowing through the circuit (having "r" and "R" connected in series to it) is given by:

$$I = \frac{E}{(R + r)}$$

$$\boxed{E = I R + I r}$$

"I r" is the ***potential drop*** within the source across its internal resistance "r". Hence the potential difference actually acting across the external resistance "R" is "I R". It is less than emf "E" of the source. Let "I R" be represented by "V", then



$$E = V + I r$$

Hence, $$\boxed{V = E - I r}$$

"V" is known as the ***terminal potential difference***. When current is delivered by a source, terminal potential difference "V" will be less than it's emf "E", but when no current is drawn there will be no potential drop across the internal resistance, therefore, terminal potential difference "V" will be equal to its emf "E". Larger the value of current drawn from a source larger will be the potential drop within the source and smaller will be the terminal potential difference "V" available for the external circuit.

***Power dissipation in resistors*:**

When current is passed through a conductor, free electrons flowing through the conductor suffer elastic collisions with the vibrating atoms. During these collisions a part of electric potential energy of these free electrons is transferred to the atoms, as a result of which kinetic energy of atoms increases, resulting in a rise in temperature of the conductor. **Electrical energy** is, therefore, converted into **heat energy**.

Hence power dissipation of any electrical device is the rate at which electrical energy is converted into heat when current passes through it.

In other words, we can say that free electrons have to do work to overcome the opposition (resistance of the conductor) to their flow. This work done by the electrons is equal to the amount of heat produced.

If current "I" is passed through the conductor for time "t" under a potential difference "V" then by definition:

Work done per unit charge = V

Work done to move charge "Q" from one end to the other = QV

But $I = \frac{Q}{t}$ $\therefore$ $Q = It$

$\therefore$ Work done to move charge "Q" from one end to the other = V I t

Since work done by free electrons to overcome resistance "R" of the conductor is equal to the amount of heat produced, hence:

$$\boxed{\text{Heat produced} = V I t}$$

But power is the rate of doing work or it is the rate at which one form of energy is converted into the other (in this case electrical energy is converted into heat energy).

$$\text{Power} = \frac{\text{Work or energy}}{\text{Time}} \qquad P = \frac{V\,I\,\cancel{t}}{\cancel{t}}$$

$$\boxed{P = V\,I}$$

But according to Ohm's law: $V = I\,R$

$$\boxed{P = I^2 R \qquad P = \frac{V^2}{R}}$$

S.I unit of power is **watt**. But watt (w) is a small unit of power, it's commonly used multiples are kw and Mw:

1 kilowatt (kw) = 10^3 w
1 megawatt (Mw) = 10^6 w

Old unit of power (which is still used in some cases) is horsepower (hp).

1 horsepower (hp) = 746 w = 0.746 kw.

***Q.No.1*: What is kilowatt-hour (kwh)?**

Ans*:** Kilowatt-hour is the ***unit of energy, it is used to measure electrical energy on commercial scale.

I kilowatt-hour (1kwh) is that amount of energy which is delivered by the electric current by constant power of 1 kilowatt (kw) in 1 hour (h).

Since: $\text{Power} = \frac{\text{work (or energy)}}{\text{time}}$

OR $P = \frac{E}{t}$ $\quad\therefore\quad E = P \times t$

Hence energy can be expressed in terms of power unit.
If power is 1 kilowatt and time taken is 1hour, then:

Energy E = 1 kw ×1 h = 1 kwh.

But 1kw = 10^3 w & 1 h = 3600 s

$\therefore$ 1 kwh = 10^3 w × 3600 s
1 kwh = 10^3 J/s × 3600 s
1 kwh = 3.6×10^6 J
1 kwh = 3.6 MJ.

This formula gives the relation between the commercial unit of energy "kwh" and the standard S.I unit of energy "J".

1kwh electrical energy is commonly known as a ***unit*** of electricity.

Kirchoff's laws:

Kirchoff's laws are useful in analyzing complex networks (a complex network is that electrical circuit which has two or more voltage sources along with different series and parallel combinations of resistances).

Kirchoff's first law:(OR Kirchoff's Current law KCL)

According to Kirchoff's first law:

Total current flowing towards a junction is equal to the total current flowing away from it.

Kirchoff's first law is also known as the ***Kirchoff's current law KCL***, it is the direct result of ***law of conservation of charge***.

Current is the rate of flow of charge (amount of charge flowing per second). Since charge can-not be created nor can it be destroyed, therefore, total amount of charge flowing per second ***towards*** must be equal to the total amount of charge per second flowing ***away*** from a junction.

Mathematically we can write:

$$\Sigma I_{towards} = \Sigma I_{away}$$

Kirchoff's second law: (***OR Kirchoff's Voltage Law KVL***)

According to Kirchoff's second law:

The sum of electromotive forces in a loop equals the sum of potential drops in the loop.

OR

The net voltage change in a closed loop is equal to zero.

Kirchoff's second law is also known as the ***Kirchoff's voltage law (KVL)***, it is the direct result of ***law of conservation of energy***.

When a charge moves from a lower potential to a higher potential it gains energy but when it moves from higher potential to lower potential it looses energy. OR we can say that it gains energy when it moves through a source of e.m.f from its negative to positive terminal but it looses energy when there is a potential drop.

Hence if charge is moved round a closed path starting and ending at the same point (either **clockwise** or **anticlockwise**) then it will have the same final potential energy as its initial potential energy.

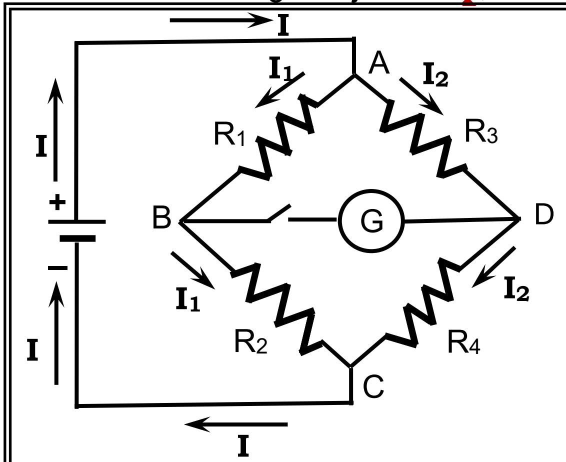
While solving a complex network (a complex network is that electrical circuit which has two or more voltage sources), by Kirchoff's voltage rule KVL,following steps must be taken:

- Direction of current flowing through all loops is assumed to be either **clockwise** or **anticlockwise**, or you can assume current in a loop in **clockwise** and in other loops **anticlockwise**.
- If the direction of that loop current is such that it flows **through a voltage source** from its **negative** to **positive** terminal, voltage change across that source of emf is taken +E (E is the emf or voltage of the source).
- Similarly, if the direction of that loop current is such that it flows **through a voltage source** from its **positive** to **negative** terminal, voltage change across that source of emf is taken **–** E (E is the emf or voltage of the source).
- Kirchoff's second rule KVL is then applied to each loop separately, finding the potential drop across each resistor in a loop by applying Ohm's law (V = I R).
- Apply Kirchoff's second rule KVL to each loop separately, assuming the current in that particular loop to be **greater** than current in its adjacent loop/s. You will get an equation for each loop. Solve these equations simultaneously. Thus, you will get the value of current in each loop.
- If current in a loop comes out to be **negative**, then its correct direction of flow will be **opposite** to its assumed direction, ***it means that*** if the direction of current assumed is **clockwise** and if it comes out to be **negative** then its correct direction of flow will be **anticlockwise**. With the help of each loop current determine the value of current in each resistor.

Wheatstone bridge:

Q.No.1: What is Wheatstone bridge?
Describe working of a Wheatstone bridge.

Ans: If four resistances R_1, R_2, R_3, and R_4 are connected end to end in such a manner that they form a closed loop. A sensitive galvanometer through a key is connected across two opposite junctions whereas, a cell is connected across the remaining two junctions, then such an electrical circuit is known as ***Wheatstone bridge***



Wheatstone bridge

When current is switched on in a Wheatstone bridge, some current "I" is delivered by the battery. It divides into two parts "I_1" and "I_2" at point "A". These parts will further divide at points "B" and "D". Some current will flow through the galvanometer, due to which it shows deflection. The magnitude and direction of current flowing through the galvanometer and the direction of deflection of its pointer depends upon the potentials at points "B" and "D". If point "B" is at a higher potential then current will flow from "B" to "D" and vice versa.

If points "B" and "D" are at the **same potential** then no current will flow through the galvanometer, hence it's deflection will be **zero** (**null point** is obtained). Under this condition Wheatstone bridge is said to be ***balanced***.

Q.No.2: Derive a condition for a balanced Wheatstone bridge.

Ans: For a balanced Wheatstone bridge potentials at points "B" and "D" must be equal i.e. $V_B = V_D$ or ***in other words***, potential difference across "R_1" must be equal to the potential difference across "R_3".

But Potential difference across $R_1 = I_1 R_1$

Potential difference across $R_3 = I_2 R_3$

$\therefore$ $I_1 R_1 = I_2 R_3$ …………… (*i*)

Similarly potential difference across R_2 and R_4 must be equal.

But Potential difference across $R_2 = I_1 R_2$

Potential difference across $R_4 = I_2 R_4$

$\therefore$ $I_1 R_2 = I_2 R_4$ ……………..(*ii*)

Dividing equation (*i*) by equation (*ii*) we get,

$$\frac{I_1 R_1}{I_1 R_2} = \frac{I_2 R_3}{I_2 R_4}$$

$$\therefore \quad \boxed{\frac{R_1}{R_2} = \frac{R_3}{R_4}}$$

This is the condition for a balanced Wheatstone bridge. If this equation is satisfied, the bridge will be balanced i.e. **no current** will flow through its galvanometer and **null point** will be obtained. ***In other words***, if R_1 are R_2 are in the same ratio as R_3 and R_4 then the bridge will be balanced i.e. no current will flow through the galvanometer.

- If three resistances are known in the above equation then the fourth one can be determined after balancing the bridge. Many electrical circuits used for measuring unknown resistance, such as meter bridge, post office box etc. are based on the principle of balanced Wheatstone bridge.

***Thermoelectric current*:**

When junctions of two wires made of different materials are maintained at different temperatures an electromotive force emf is generated across their ends. This emf is called **thermoelectric emf** and the resulting current is called **thermoelectric current**.

Thermoelectric emf finds many applications in modern day life.

Devices such fire alarms, thermostats etc. work using thermoelectric emf.

Section–A Multiple-Choice Questions MCQs:

Q.No.1: Kirchhoff's laws are useful in determining:
(A) current flowing in a circuit.
(B) emf and voltage drops in a circuit
(C) Power in a circuit.
(D) Only emf in a circuit.

Q.No.2:The resistance of a superconductor is (A) finite. (B) Infinite.
(C) Changes with every conductor.
(D) Zero.

Q.No.3: Reciprocal of resistance is called:
(A) Conductance. (B) resistivity.
(C) Resonance. (D) Capacitance.

Q.No.4: The graphical representation of Ohm's law is:
(A) Parabola. (B) Hyperbola.
(C) Ellipse. (D) Straight line.

Q.No.5: A potential difference is applied across the ends of a wire. If the potential difference is doubled, the drift velocity of free electrons will:
(A) be quadrupled. (B) be doubled.
(C) be halved. (D) remain unchanged.

Q.No.6: Internal resistance is the resistance offered by:
(A) Capacitor. (B) Resistor.
(C) Conductor. (D) Source of emf.

Q.No.7: Power dissipation in a resistor can be calculated using which formula.
(A) $P= V^2/R$ (B) $P = I^2R$
(C) $P = V I$ (D) $P= R/(V I)$

Q.No.8: What is a potentiometer used for:
(A) Measuring electric current.
(B) Measuring electric charge.
(C) Measuring potential difference.
(D) Measuring electric resistance.

Q.No.9: A heat sensitive device whose resistivity changes with the change in temperature is called:
(A) Conductor. (B) Resistor.
(C) Thermistor. (D) Thermometer.

Q.No.10: A wire of uniform area of cross-section A length L and resistance R is cut into two parts. The resistivity of each part is:
(A) becomes zero. (B) is halved.
(C) is doubled. (D) remains same.

Q.No.11: Temperature coefficient of resistance is of a semiconductor is:
(A) Positive. (B) Negative. (C) Zero.
(D) Can be positive or negative.

Q.No.12: The commercial unit of electrical energy is: ***(2005,10 Karachi Board)***
(A) ohm. (B) watt. (C) kwh (D) ampere

Q.No.13: The rate of transfer of charges through a circuit is called:
(2006 Karachi Board)
(A) resistance. (B) current.
(C) potential difference.(D) all of them

Q.No.14: When a resistor carries a current "I", the power dissipation by it is "P". If the same resistor carries the current of '3 I', the power dissipation will be:
(2007 Karachi Board)
(A)P (B) P/3 (C) 3P (D) None of the above

Q.No.15: If a wire of uniform area of cross section is cut into two equal parts, the resistivity of each will be:
(2007 Karachi Board)
(A) Halved. (B) Doubled.
(C) Remains the same. (D) none of the above

Q.No.16: A piece of wire of length 'L' and an area of cross section 'A' has a resistance 'R'. Another piece of wire of the same material and the same length but twice the area of cross section is connected end-to-end with the previous wire. The effective resistance is: ***(2008 Karachi Board)***
(A) R (B) 2 (C) $\frac{1}{3}$ R (D) $\frac{1}{2}$ R

Q.No.17: In a house circuit all the electrical appliances are connected in parallel with the phase and the neutral to get:
(2008 KARACHI Board)
(A) Same current and potential difference.
(B)Different currents but same potential difference
(C) Different currents and different potential difference
(D) Same currents and same potential difference

Q.No.18: The electrical energy dissipated as heat in a resistor is:
(2016,10,9,6,5 Karachi Board)
(A) V^2 R. (B) V^2 R t. (C) I^2 R t. (D) I^2 R.

Q.No.19*: Resistances of 10Ω, 30Ω and 40Ω are connected in series, if the current in 10 Ω is 0.1 A then the current through 40 Ω will be: (2019, 10 Karachi Board***)

(A) 0.4A (B) 0.3A (C) 0.1A (D) 0.08A

***Q.No.20*: Resistivity of a material is ρ, If area of cross section of the material is doubled and length is halved then the resistivity of the conductor will:

(***2022, 18 Karachi Board***)

(A)Remains constant (B)Increase 4 times
(C) Decrease 2 times (D) is one fourth

Q.No.21: Four bulbs of 10Ω, 20Ω, 30Ω and 40Ω are connected in series, the bulb that will shine the most is:

(***2022 Karachi Board***)

(A) 10 Ω (B) 20 Ω (C) 30 Ω (D) 40 Ω

Q.No.22: A current of 9 amp. flows in a circuit of three resistors connected in parallel. If each resistor has magnitude 5 Ω, then current in the 3rd resistor is:

(***2022 Karachi Board***)

(A)9 amp (B) 3 amp (C)1.5 amp. (D)0.5 amp.

Q.No.23: A 12 volt battery with internal resistance 0.1Ω is to be charged at 10 ampere. the charger must be of:

(***2022 Karachi Board***)

(A)11 volts (B)9 volts (C)13 volts (D)12 volts

Q.No.24: A 2.2 kW electric iron operates at 220 volt, current it draws:

(***2022 Karachi Board***)

(A)20 amp (B)22 amp (C)10 amp (D)5 amp.

Q.No.25: Total potential difference across the combination of three cells becomes maximum when: (***2003 Karachi Board***)

(A) All the three cells are combined in series.
(B) All the three cells are combined in parallel.
(C) Two cells are connected is parallel and the third cell in series with the combination.
(D) Two cells are connected in series and the third cell in parallel with the combination.

Q.No.26: If 1A current flows through 2 m long wire, the charge flows through it in 2 hours will be: (***2023 Karachi Board***)

(A) 3600 C (B) 7200 C (C) 1 C (D) 600 C

Q.No.27: Reciprocal of resistance is called:

(***2025, 26 Karachi Board***)

(A) Resistivity. (B) Conductance.
(C) Resonance. (D) Capacitance.

Answers:

(1) (A) current flowing in a circuit.
(2) (D) Zero.
(3) (A) Conductance.
(4) (D) Straight line.
(5) (C) be halved.
(6) (D) Source of emf.
(7) (A),(B)If "V" is constant then $P = V^2/R$, If "I" is constant then $P = I^2R$.
(8) (C) Measuring potential difference.
(9) (C) Thermistor.
(10) (D) remains same.
(11) (B) Negative.
(12) (C) kwh.
(13) (B) current.
(14) (C) 3P
(15) (C) Remains the same.
(16) (C) $\frac{1}{3}$ R
(17) (B)Different currents but same potential difference.
(18) (C) $I^2 R t$.
(19) (C) 0.1A.
(20) (A) Remains constant.
(21) (A) 10 Ω.
(22) (B) 3 amp.
(23) (C) 13 volts.
(24) (C)10 amp.
(25) (A) All the three cells are combined in series.
(26) (B) 7200 C
(27) (D) Capacitance.

Numericals:

Q.No.1: **The storage battery of a car has an emf of 12 V. If the internal resistance of the battery is 0.5 Ω, What is the maximum current that can be drawn from the battery?**

Data:

EMF E = 12 V Internal resistance r = 0.5 Ω

Max. current =?

Solution:

Current drown from a battery is given by:

$$I = \frac{E}{(R + r)}$$

Where R is the load resistance.

Maximum current can be drawn from a battery when load resistance is negligible.

$$I = \frac{12}{(0+ 0.5)} \qquad \boxed{I = 24 \text{ amperes.}}$$

Q.No.2: **A negligibly small current is passed through a wire of length 12 m and uniform cross section 4.0×10^{-7} m² and its resistance is measured to be 6.0 Ω.**

What is resistivity of the material at temperature of the experiment?

Data:

Length L = 12 m Resistance R = 6.0 Ω

Area of cross section $A = 4.0\times10^{-7}$ m²

Resistivity ρ =?

Solution:

Resistance of a conductor of given material is given by:

$$R = \rho \frac{L}{A} \qquad \rho = \frac{R\,A}{L}$$

$$\rho = \frac{6 \times 4.0\times10^{-7}}{12} \qquad \boxed{\rho = 2.0\times10^{-7}\ \Omega\text{ - m}}$$

Q.No.3: **In a potentiometer arrangement, a cell of emf 1.20 V gives a balance point at 40.0 cm length of the wire. If the cell is replaced by another cell and the balance point shifts to 74.0 cm, what is the emf of the second cell?**

Data:

E_1 = 1.2 V L_1 = 40.0 cm.
E_2 =? L_2 = 74.0 cm.

Solution:

$$\frac{E_1}{E_2} = \frac{L_1}{L_2}$$

$$E_2 = \frac{E_1 L_2}{L_1} = \frac{1.2 \times 74}{40}$$

$$\boxed{E_2 = 2.22 \text{ volt.}}$$

EMF of the second cell is <u>2.22 volt.</u>

***<u>Q.No.4</u>*: (a) Three resistors 1Ω, 2Ω and 3Ω are combined in series. What is the total resistance of the combination?**
(b) If the combination is connected to a battery of emf 24 V and negligible internal resistance, obtain the potential drop across each resistor.

***<u>Data</u>*:**

$R_1 = 1\ \Omega$ $R_2 = 2\ \Omega$ $R_3 = 3\ \Omega$ $R = ?$
(a) $V = 24$ volt $V_1 = ?$ $V_2 = ?$ $V_3 = ?$

***<u>Solution</u>*:**

$R = R_1 + R_2 + R_3$ (For series combination)

$R = 1 + 2 + 3 = \mathbf{6\ \Omega}$

Total resistance of the combination is **<u>6 Ω</u>**

$V = I R$ (Ohm's law)

$I = \frac{V}{R} = \frac{24}{6} = 4$ amp.

Hence 4 ampere current flows through the combination. Since in series combination **<u>same current</u>** flows through each resistance, therefore

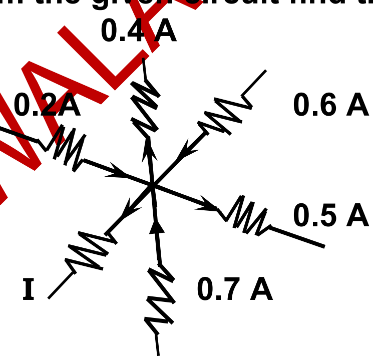
$V_1 = I R_1 = 4 \times 1$ $\boxed{V_1 = 4 \text{ volt.}}$

$V_2 = I R_2 = 4 \times 2$ $\boxed{V_2 = 8 \text{ volts.}}$

$V_3 = I R_3 = 4 \times 3$ $\boxed{V_3 = 12 \text{ volts.}}$

(To check the result, In series combination total voltage $V = V_1 + V_2 + V_3$)

***<u>Q.No.5</u>*: From the given circuit find the value of "I".**



***<u>Solution</u>*:**

According to **Kirchoff's first law (KCL)**
Total current flowing **<u>towards</u>** a junction = Total current flowing **<u>away</u>** from the junction.

Since 0.2 amp., 0.7 amp. and 0.6 amp. currents are flowing **<u>towards</u>** the junction; therefore, their sum must be equal to the sum of currents "**I**", 0.5 amp. and 0.4 amp. Which are flowing **<u>away</u>** from the junction. Hence,

$$\Sigma I_{towards} = \Sigma I_{away}$$

$$0.2 + 0.7 + 0.6 = \mathbf{I} + 0.5 + 0.4$$

$$1.5 = \mathbf{I} + 0.9 \qquad \boxed{\mathbf{I = 0.6\ ampere.}}$$

***<u>Q.No.6</u>*: In a meter bridge with a standard resistance of 15 Ω in the right gap, the ratio of balancing length is 5:3, Find the value of other resistance.**

***<u>Solution</u>*:**

Working of a meter bridge is based on the principle of balanced Wheatstone bridge.

For a balanced meter bridge
Ratio of resistances = ratio of balancing length Since the balancing lengths are in the ratio of 5:3, therefore, resistances will also be in the ratio of 5:3.

The other resistance will be 5 times the standard resistance.

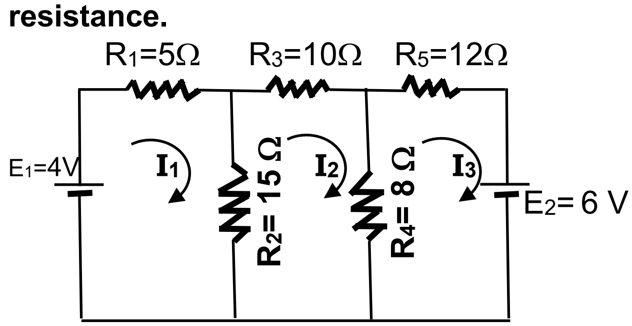
Other resistance = 5 × standard resistance

Standard resistance = 15 Ω

∴ Other resistance = 5 × 15

Other resistance = <u>75 Ω</u>

***<u>Q.No.7</u>*: By KVL (Kirchoff's Voltage Law), find current flowing through 10 Ω resistance.**



***<u>Data</u>*:**

$R_1 = 5\Omega$ $R_2 = 15\Omega$ $R_3 = 10\Omega$ $R_4 = 8\Omega$
$R_5 = 12\Omega$ $E_1 = 4$ V $E_2 = 6$ V

Current flowing through 10Ω $\mathbf{I_2} = ?$

***<u>Solution</u>*:**

In this problem direction of currents $\mathbf{I_1}$, $\mathbf{I_2}$ and $\mathbf{I_3}$ in first, second and third loops is given as **<u>clockwise</u>**.

- Applying Kirchoff's voltage law (KVL) to <u>first loop</u> (assuming $\mathbf{I_1} > \mathbf{I_2}$) we get:

$E_1 - \mathbf{I_1} R_1 - (\mathbf{I_1} - \mathbf{I_2}) R_2 = 0$

$4 - 5\,\mathbf{I_1} - (\mathbf{I_1} - \mathbf{I_2})15 = 0$

$4 - 5\,\mathbf{I_1} - 15\,\mathbf{I_1} + 15\,\mathbf{I_2} = 0$

$4 - 20\,\mathbf{I_1} + 15\,\mathbf{I_2} = 0$ .... (1)

- Applying Kirchoff's voltage law (KVL) to <u>second loop</u> (assuming $\mathbf{I_2} > \mathbf{I_3}$) we get:

$-(\mathbf{I_2} - \mathbf{I_1})R_2 - \mathbf{I_2} R_3 - (\mathbf{I_2} - \mathbf{I_3})R_4 = 0$

$-(\mathbf{I_2} - \mathbf{I_1})15 - 10\,\mathbf{I_2} - (\mathbf{I_2} - \mathbf{I_3})8 = 0$

$-15\,\mathbf{I_2} + 15\,\mathbf{I_1} - 10\,\mathbf{I_2} - 8\,\mathbf{I_2} + 8\,\mathbf{I_3} = 0$

$-33\,\mathbf{I_2} + 15\,\mathbf{I_1} + 8\,\mathbf{I_3} = 0$ .... (2)

- Applying Kirchoff's voltage law (KVL) to <u>third loop</u> (assuming $\mathbf{I_3} > \mathbf{I_2}$) we get:

$-(\mathbf{I_3} - \mathbf{I_2}) R_4 - \mathbf{I_3} R_5 - E_2 = 0$

$-(\mathbf{I_3} - \mathbf{I_2})\, 8 - 12\,\mathbf{I_3} - 6 = 0$

$-8\,\mathbf{I_3} + 8\,\mathbf{I_2} - 12\,\mathbf{I_3} - 6 = 0$

$-20\,\mathbf{I_3} + 8\,\mathbf{I_2} - 6 = 0$

$-10\,\mathbf{I_3} + 4\,\mathbf{I_2} - 3 = 0$ .... (3)

To solve these equations simultaneously from eq. (1) we have:

$4 - 20\,\mathbf{I_1} + 15\,\mathbf{I_2} = 0$ .... (1)

$\mathbf{I_1} = \dfrac{-15\,\mathbf{I_2} - 4}{-20} = \dfrac{15\,\mathbf{I_2} + 4}{20}$

Put this value of $\mathbf{I_1}$ in eq. (2),

$-33\,\mathbf{I_2} + 3\,\cancel{15}\,\dfrac{(15\,\mathbf{I_2} + 4)}{\cancel{20}\ 4} + 8\,\mathbf{I_3} = 0$

$-132\,\mathbf{I_2} + 45\,\mathbf{I_2} + 12 + 32\,\mathbf{I_3} = 0$

$-87\,\mathbf{I_2} + 32\,\mathbf{I_3} + 12 = 0$ .... (A)

Now multiply eq. (3) by 32 and eq. (A) by 10 and then add them.

$(\cancel{-10\,\mathbf{I_3}} + 4\,\mathbf{I_2} - 3 = 0)\ 32$

$\underline{(-87\,\mathbf{I_2} + \cancel{32\,\mathbf{I_3}} + 12 = 0)\ 10}$

$128\,\mathbf{I_2} - 96 - 870\,\mathbf{I_2} + 120 = 0$

$-742\,\mathbf{I_2} - 24 = 0$

$\mathbf{I_2} = \dfrac{24}{-742} =$ $\boxed{\mathbf{I_2 = -0.03235\ Amp.}}$

<u>Negative</u> sign shows that $\mathbf{I_2}$ is flowing in **<u>anticlockwise</u>** direction.

- Current flowing through 10 Ω (represented by R_3) is **<u>0.03235 Amp.</u>** In **<u>anticlockwise</u>** direction.

<u>To check tour answer</u>:

Find the value of current in each resistor, put the value of $\mathbf{I_2}$ in eq. (1) :

$4 - 20\,\mathbf{I_1} + 15\,\mathbf{I_2} = 0$ .... (1)

$\mathbf{I_1} = \dfrac{-15\,\mathbf{I_2} - 4}{-20} = \dfrac{15\,\mathbf{I_2} + 4}{20}$

$\mathbf{I_1} = \dfrac{15\,(-0.03235) + 4}{20} = \dfrac{3.51475}{20}$

$\boxed{\mathbf{I_1 = 0.1757\ amp.}}$

Put the value of $\mathbf{I_2}$ in eq. (3) :

$-10\,\mathbf{I_3} + 4\,\mathbf{I_2} - 3 = 0$ .... (3)

$-10\,\mathbf{I_3} + 4\,(-0.03235) - 3 = 0$

$-10\,\mathbf{I_3} - 0.1294 - 3 = 0$

$\mathbf{I_3} = \dfrac{3.1294}{-10}$ $\boxed{\mathbf{I_3 = -0.31294\ amp.}}$

Negative sign shows that $\mathbf{I_3}$ is **<u>anticlockwise</u>**.

∴ <u>Current through R_2</u>:

$(\mathbf{I_1} - \mathbf{I_2}) = 0.1757 - -0.03235 = \mathbf{0.20805\ amp}$

∴ <u>Current through R_4</u>:

$(\mathbf{I_2} - \mathbf{I_3}) = -0.03235 - -0.31294 = \mathbf{0.28059\ amp}$

<u>To verify your results</u>:

Apply Kirchoff's current law to **<u>junction C</u>**:

$0.1757 + 0.03235 = 0.20805$

$0.20805 = 0.20805$

<u>Current flowing towards C</u>= <u>Current flowing away from C</u>

Apply Kirchoff's current law to **<u>junction D</u>**:

$0.31294 = 0.03235 + 0.28059$

$0.31294 = 0.31294$

<u>Current flowing towards D</u>= <u>Current flowing away from D</u>

Since current flowing in each branch satisfies Kirchoff's laws, hence verified.

***<u>Q.No.8</u>*: A silver wire 2 m long is to have a resistance of 0.5 Ω. What should its diameter be?**

***<u>Data</u>*:**

Length of the wire	$L = 2$ m.
Resistance of the wire	$R = 0.5\ \Omega$.
Resistivity of silver	$\rho = 1.52 \times 10^{-8}\ \Omega$-m
Diameter of the wire	$d = ?$

***<u>Solution</u>*:**

$R = \rho\,\dfrac{L}{A}$

$0.5 = 1.52 \times 10^{-8}\,\dfrac{2}{A}$

$A = 1.52 \times 10^{-8}\,\dfrac{2}{0.5}$ $\boxed{\boldsymbol{A = 6.08 \times 10^{-8}\ m^2}}$

But $\quad A = \pi r^2 \quad$ (For circular wire)

$6.08 \times 10^{-8} = \dfrac{22}{7} \times r^2$

$\therefore \quad r^2 = \dfrac{6.08\times10^{-8}}{3.142}$

$r^2 = 1.935\times10^{-8}$

$\therefore \quad r = \sqrt{1.935\times10^{-8}}$

$\therefore \quad r = 1.39\times10^{-4}$ m

But diameter of the wire is given by:

$\therefore \quad d = 2r = 2\times1.39\times10^{-4}$

$\boxed{\boldsymbol{d = 2.78\times10^{-4}\ m}}$

Diameter of the wire will be ***2.78 ×10⁻⁴ m***.

***Q.No.9*: A 40 Ω resistor is to be wound from platinum wire 0.1 mm in diameter.**
How much wire is needed?

***Data*:**

Resistance of the wire $R = 40\Omega$

Diameter of the wire $d = 0.1$ mm

$= \dfrac{0.1}{1000}$ m $= 1\times10^{-4}$ m

Resistivity of platinum $\rho = 11\times10^{-8}\ \Omega$-m

Length of wire $L = ?$

***Solution*:**

Diameter of the wire $d = 2r$

$\therefore \quad r = \dfrac{d}{2} = \dfrac{1\times10^{-4}}{2}$ m $= 5\times10^{-5}$ m

Area of cross section of the wire:

$A = \pi r^2 = \dfrac{22}{7}(5\times10^{-5})^2$

$\boldsymbol{A = 7.854\times10^{-9} m^2}$

Resistance of a wire is given by:

$R = \rho \dfrac{L}{A}$

$40 = 11\times10^{-8} \dfrac{L}{7.854\times10^{-9}}$

$\therefore \quad L = \dfrac{40\times7.854\times10^{-9}}{11\times10^{-8}}$ $\boxed{\boldsymbol{L = 2.86\ m}}$

2.86 m long wire will be needed.

***Q.No.10*: A resistor is made by using a 50 meter nichrome wire of diameter 0.8 mm at 0°C. Calculate its resistance at 50°C.**
(Given: resistivity $\rho = 1.1\times10^{-6}\ \Omega$-m and $\alpha = 0.0002\ °C^{-1}$ at 0°C.)
(*2009 Karachi Board*)

***Data*:**

Length of the wire $L = 50$ m

Diameter of wire $d = 0.8$mm $= 0.810^{-3}$ m

$\therefore \quad r = \dfrac{d}{2} = \dfrac{0.8\times10^{-3}}{2}$ m $= 0.4\times10^{-3}$ m

Resistivity of nichrome $\rho = 1.1\times10^{-6}\ \Omega$-m

Temperature coefficient

$\alpha = 0.0002\ °C^{-1}$ at 0°C

Resistance at 50°C, $R_{50} = ?$

***Solution*:**

Resistance of the wire at 0°C is given by:

$R_0 = \rho \dfrac{L}{A}$

$\therefore \quad R_0 = \dfrac{1.1\times10^{-6}\times 50}{\pi r^2}$

$\therefore \quad R_0 = \dfrac{1.1\times10^{-6}\times 50}{\pi(0.4\times10^{-3})^2} = \boldsymbol{109.42\ \Omega}$

$\therefore$ Resistance at 50°C is given by:

$R_{50} = R_0(1+\alpha t)$

$R_{50} = 109.42(1+0.0002\times50)$

$\therefore \quad \boxed{R_{50} = \boldsymbol{110.52\ \Omega}}$

***Q.No.11*: A 50 ohm resistor is to be wound from a platinum wire 0.1 mm in diameter.**
How much wire is needed?
(Resistivity of the wire $\rho = 11\times10^{-8}\Omega$.m)
(*2015,06,03,1999,85 Karachi Board*)

***Data*:**

Resistance $R = 50\ \Omega$

Diameter $d = 0.1$ mm $= 0.1\times10^{-3}$ m

Resistivity $\rho = 11\times10^{-8}\ \Omega$.m

Length of wire needed $L = ?$

***Solution*:**

Radius of the wire:

$r = \dfrac{d}{2} = \dfrac{0.1\times10^{-3}}{2} = 0.05\times10^{-3}$ m

Area of cross section of the wire will be:

$A = \pi r^2 = 3.143\times(0.05\times10^{-3})^2$

$= 7.854\times10^{-9}$ m^2

$\therefore \quad R = \rho \dfrac{L}{A} \qquad \therefore \quad L = \dfrac{RA}{\rho}$

$\therefore \quad L = \dfrac{50\times7.854\times10^{-9}}{11\times10^{-8}}$ $\boxed{\boldsymbol{L = 3.57\ m}}$

3.57 m long wire will be needed.

***Q.No.12*: A 20 m length of cable has a cross-sectional area of 1 mm². and a resistance of 5 ohm. Calculate the resistivity of the cable.**
(*2025 Karachi Board*)

***Data*:**

Length of cable $L = 20$ m

Area of cross-section $A = 1$ mm$^2 = 1\times10^{-6}$ m^2.

Resistance $R = 5\ \Omega$

Resistivity $\rho = ?$

***Solution*:**

Resistance of a conductor is given by:

$$R = \rho \frac{L}{A}$$

$$\therefore \quad \rho = \frac{R\,A}{L} = \frac{5 \times 1\times10^{-6}}{20} = \underline{\mathbf{2.5\times10^{-7}\ \Omega\text{–}m}}$$

Resistivity of the cable is **2.5×10^{-7} Ω–m**.