# Zartash's Notes



# Second Year Physics

# Chapter No 13
# Current Electricity

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Rs 50/-

# Questions from Chapter

**Q.No.1: Define electric current**

**Ans:**

**Definition:** Flow of charges through any conductor per unit time is called electric current

**In other word**, the net charge $\Delta Q$ passes through any conductor through time $\Delta t$ is called electric current

**Formula:** It is denoted as $$I = \frac{\Delta Q}{\Delta t}$$

**Units:** The SI unit of electric current is ampere which is equal to C/s

**Q.No.2: Define the term "Ampere"**

**Ans:**

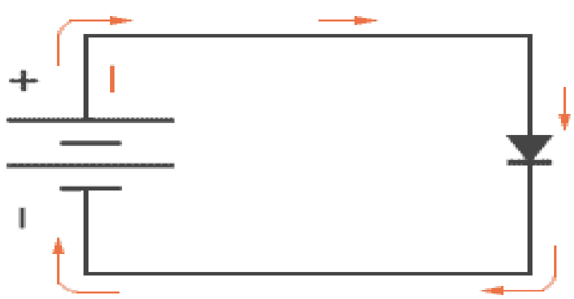
**Definition:** If 1C charge flows through any conductor in 1 second, then the current will be 1 Ampere .

**Formula:** It is denoted as $$1A = \frac{1C}{1s}$$

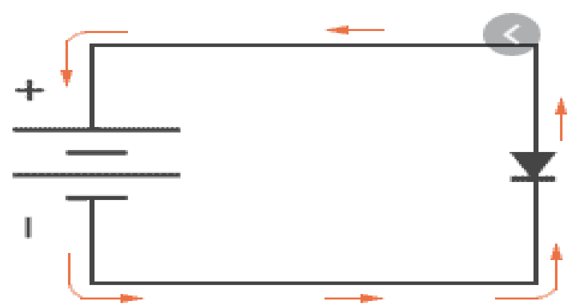
**Q.No.3: Differentiate between conventional and electronic current?**

**Ans:**

| Conventional Current | Electronic Current |
|---|---|
| The current due to the flow of positive charges or holes is called conventional current. | The current due to the flow of negative charges or electrons is called electronic current. Electronic |
| The conventional current flows from the positive terminal of battery towards the negative terminal of battery | Current flows from negative terminal of the battery towards positive terminal of the battery. |




Conventional Current




Electron Current

**Q.No.4: What is drift velocity?**

**Ans:**

**Definition:** The velocity acquired by electrons under the influence of electric field in the direction of –E is called drift velocity.

**Order:** Its order is $10^{-3}$ m/s

**Q.No.5: What is source of current? How many types of sources of current are there?**

**Ans:**

**Source of current:**

Any device which converts non-electrical energy into electrical energy is called source of current.

**Types:**

There are basically four types of sources of current.

(i) **Cells**: They convert chemical energy into electrical energy.

(ii) **Electric generators:** They convert mechanical energy into electrical energy.

(iii) **Thermo-couples:** They convert heat energy into electrical energy.

(iv) **Solar cells:** They convert solar energy into electrical energy.

**Q.No.6: How many types of effects of current? Mention their names**

**Ans:** There are basically three effects of current by which presence of current can be detected

(i) Heating effect

(ii) Magnetic effect

(iii) Chemical effect

**Q.No.7: Explain how the heat is produced in the wires due to flow of current? Also mention some uses of heating effect**

**Ans:** When current flows through a wire, electrons collide with the atoms of metal and lose some of their kinetic energy in collision. It generates heat in the wire which gives the presence of current in the wire.

**Formula:** Formula for heat is given as $H = I^2Rt$

**Uses:** The heating effect is utilized in electric heaters, kettles, toasters and electric irons etc.

**Q.No.8: Explain magnetic effect of current?**

**Ans:**

When the current passes through wire then magnetic field is produced surrounding it by which presence of electric current can be detected.

**Strength of field:**

The strength of field depends upon the value of current and distance from the current element. By this effect, current can be detected.

**Uses**: All the machines involving electric motors also use the magnetic effect of current.

**Q.No.9: Define the following terms: electrolysis, electrolyte, electrodes, voltameter**

**Ans:**

**Electrolysis:** The process in which certain liquids conduct electricity due to chemical reactions is called electrolysis.

**Electrolyte:** The liquid which conducts current is known as electrolyte.

**For example** Dilute Sulphuric Acid or Copper Sulphate Solution conduct electricity due to some chemical reaction in them

**Electrodes:** The material in the form of wire or rod which leads the current into or out of the electrolyte is known as electrode.

**Types of electrodes:** There are two types of electrodes. Anode and cathode

**Anode:** The electrode connected with the positive terminal of the battery is called anode

**Cathode:** The electrode connected with the negative terminal of the battery is called cathode.

**Voltameter:** The vessel containing the two electrodes and the liquid is known as voltameter.

**Q.No.10: What is electroplating?**

**Ans:**

**Electroplating:**

A process of coating a thin layer of some expensive metal (gold, silver etc) on an article of some cheap metal to conduct electricity is called electroplating.

**Q.No.11: State Ohm's Law?**

**Ans:**

**Statement:**

Ohm's Law states that the current flowing through a conductor is directly proportional to the potential difference across the ends of the conductor at constant temperature.

**Formula:** Mathematically it can be written as $V \propto I$

This implies that $V = IR$

**Q.No.12: Define resistance. Give its formula and units?**

**Ans:**

**Definition:** Measure of the opposition offered to the motion of electrons by the wire is called resistance.

**Formula:** Its formula is represented as $R = \frac{V}{I}$

**Units:** Its units are ohm

**Q.No.14: Upon what factors resistance of conductor depends?**

**Ans:** The value of resistance depends upon the following

(i) Nature of the conductor

(ii) Dimensions of conductor

(iii) Physical state of conductor

**Q.No.15: Define the term "Ohm"**

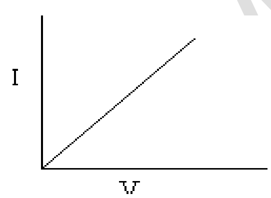
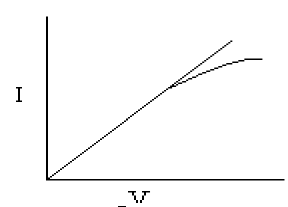
**Ans:**

**Definition:** A conductor has a resistance of 1 ohm if a current of 1 ampere flows through it when the potential difference of 1 volt is applied across it

**Formula:** Its formula is represented as $1\Omega = \frac{1V}{1A}$

**Q.No.16: Differentiate between ohmic and non-ohmic conductors?**

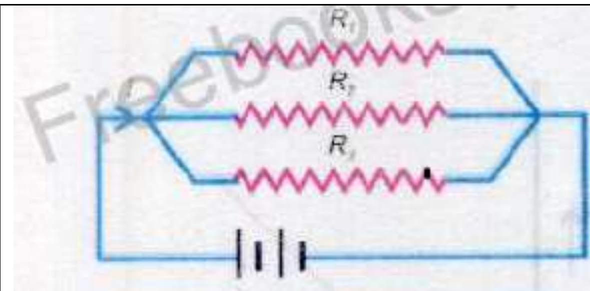
**Ans:**

| Ohmic conductors | Non-ohmic conductors |
|---|---|
| The conductors which strictly obey ohm's law are said to be ohmic. | The conductors which do not obey ohm's law are said to be non-ohmic. |
| All metals including copper, iron, silver etc are examples of ohmic conductors | Semiconductors and insulators such as semiconductor diodes and filament are examples of non-ohmic conductors. |
| The graph between I and V is a straight line as shown in fig 1. | The graph between I and V is not a straight line as shown in fig 2 |
|   fig 1 |   fig 2 |

**Q.No.17: What do you know about series and parallel combination of resistors?**

**Ans:**

| Series combination | Parallel combination |
|---|---|
| In series combination, the resistors are connected end to end such that the same current passes through them as shown in fig. | In parallel combination, the resistors are connected side by side with their ends joined together at two common points |
| The equivalent resistance $R_e$ for this arrangement is given by the given equation $R_e = R_1 + R_2 + R_3$ | The equivalent resistance $R_e$ for this arrangement is given by the given equation $\frac{1}{R_e} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ |

| | |
|---|---|
|  |  |

**Q.No.18: Differentiate between resistance and resistivity?**

**Ans:**

| **Resistance** | **Resistivity** |
|---|---|
| The opposition in the flow of current is called resistance. | The specific resistance of the material of the wire or reciprocal of conductivity is called resistivity. |
| It is denoted by R | It is denoted by ρ. |
| It is the characteristics of wire | It is the property of material by which the wire is made. |
| Its formula is given as R=V/I | Its formula is given as ρ=RA/L |
| The unit of resistance is ohm | The unit of resistivity is ohm-meter. |

**Q.No.19**

**: Define conductivity?**

**Ans:**

**Definition:** The reciprocal of resistivity is called conductivity.

**Formula:** It is denoted as σ=1/ρ.

**Units:** The SI units of conductivity are $ohm^{-1}m^{-1}$.

**Q.No.20: Define temperature co-efficient of resistance?**

**Ans:**

**Definition:** The fractional change in resistance per Kelvin is known as the temperature coefficient of resistance.

**Formula:** It is denoted as $\alpha = \frac{R_t - R_o}{R_o t}$

**Units:** Its units are k-1

**Q.No.21: Define temperature co-efficient of resistivity?**

**Ans:**

**Definition**: The fractional change in resistivity per Kelvin is known as the temperature coefficient of resistivity.

**Formula:** It is denoted as $\alpha = \frac{\rho_t - \rho_o}{\rho_o t}$

**Q.No.22: How you can interpret the color bands of resistor?**

**Ans:** There are four bands which are interpreted as follows:

1. The first band indicates the first digit in the value of resistance.
2. The second band gives the second digit.
3. The third digit gives the number of zeros.
4. The four band gives the value of tolerance. Its colour is either silver or gold.

**Q.No.23: Define tolerance?**

**Ans:**

**Definition:** The possible variation from the given or marked value is called tolerance.

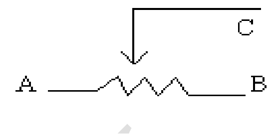
**Values:** For silver its value is ±10% and for gold its value is ±5%. If there is no fourth band then tolerance is ±20%.

**Q.No.24: Define Rheostat? Draw its symbolic diagram?**

**Ans:**

**Definition:** The wire wound variable resistance is called Rheostat. It consists of bare manganin wire wound over an insulating cylinder.

**Symbolic diagram:** Its symbolic diagram is given as




**Q.No.25: Write down the uses of Rheostat?**

**Ans:**

Rheostat have following uses:

(i) The rheostat is used as a variable resistance

(ii) The rheostat also as a potential divider.

**Q.No.26: What do you know about thermistors?**

**Ans:**

**Definition:** A thermistor is a heat sensitive resistor. The thermistors with both positive and negative coefficient of resistances are available.

**Formation:** They are made by heating under high pressure semiconductor ceramic made from mixtures of metallic oxides of manganese, nickel copper etc.

**Significance:** Thermistors with high negative temperature coefficient are very accurate for measuring low temperature upto 10 K.

**Application of thermistors:** Thermistors have wide applications as temperature sensors. i.e they convert heat energy into electrical energy.

**Q.No.27: Define electrical power?**

**Ans:**

**Definition:** The energy supplied by the battery per unit time is called electrical power

**Formula:** It is denoted as

$$eletrical\ power = \frac{Energy\ supplied}{time\ taken}$$

$$eletrical\ power = \frac{V\Delta Q}{\Delta t}$$

$$P = VI$$

**Q.No.28: Define emf of battery?**

**Ans:**

**Definition:** The energy supplied by the battery to unit charge is called emf of the battery

**Formula:** It is denoted as

$$E = \frac{\Delta W}{\Delta Q}$$

**Units:** Units of emf are J/C or volts

**Q.No.29: Differentiate between emf and potential difference?**

**Ans:**

| Emf | Potential difference |
|---|---|
| The energy supplied by the battery to unit charge is called emf of the battery | Work done in bringing a unit positive charge from A to B point in an electric field keeping the charge in equilibrium is called potential difference between these points A and B. |

| | |
|---|---|
| Emf is a cause | Potential difference is effect of emf |
| If there is no current flowing through the battery then emf will also present | If there is no current flowing through the battery then the potential difference will be zero. |
| It is denoted by E | It is denoted by ΔV |

**Q.No.30: Calculate the maximum power output?**

**Ans:** Output is denoted as

$$P_{out} = VI$$

By putting the value $V = IR$

$$P_{out} = I^2R$$

As $I = \frac{E}{R+r}$

So

$$P_{out} = \frac{E^2R}{(R+r)^2} = \frac{E^2R}{(R-r)^2 + 4Rr}$$

When R=r then denominator of the expression $P_{out}$ is least and so $P_{out}$ is then maximum as described below

$$(P_{out})_{max} = \frac{E^2R}{(R-R)^2 + 4RR} = \frac{E^2R}{4RR} = \frac{E^2}{4R}$$

**Q.No.31: State Kirchhoff's First and second rule?**

**Ans:**

**Kirchhoff's First Rule:**

**Statement:** The first rule states that sum of all currents meeting at a point in the circuit is zero.

**Formula:** Mathematically it is represented as ΣI=0.

**Kirchhoff's Second Rule:**

**Statement:** The second rule states that the algebraic sum of potential changes in a closed circuit is zero

**Formula:** Mathematically it is represented as ΣV=0.

**Q.No.32: Write down the rules for finding the potential charges before applying the Kirchhoff's second rule?**

**Ans:** The rules for finding the potential charges before applying the Kirchhoff's second rule are given as:

1- If the charge moves from negative terminal to the positive terminal of the battery then the potential change is taken as positive and is negative in opposite direction.
2- If the charge is transferred through a resistor then the change in potential is taken as negative.

**Q.No.33: Write down the procedure for the solution of circuit problems?**

**Ans:**

1- Draw the circuit diagram
2- The choice of loops should be such that each resistance is included at least once in the selected loops.
3- All the loop currents should be in the same sense. It may be either clockwise or anticlockwise.
4- Write down equations for selected loops by using Kirchhoff's rule
5- Solve these equations for the unknown quantities.

**Q.No.34: Define Potentiometer?**

**Ans:** A very simple instrument which can measure and compare the potential differences accurately is called potentiometer

**Q.No.35: Give the uses of potentiometer?**

**Ans:** Potentiometer can be used

(i) as a potential divider

(ii) to find the unknown emf of the cell

(iii) to compare the emf's of two cells

# Exercise Questions

**Q.No.13.1: A potential difference is applied across the ends of a copper wire. What is the effect on the drift velocity of the free electrons by**

**(i) increasing the potential difference**

**(ii) decreasing the length and temperature of the wire**

**Ans:**

**(i) Drift velocity will be increased**

**Explanation:**

Drift velocity has the following relation

$$v_d \propto I$$

As

$$I = \frac{V}{R}$$

$$v_d \propto \frac{V}{R}$$

So from the above equations it is clear that drift velocity is directly proportional to potential difference. So by increasing the potential difference, drift velocity will also be increased.

**(ii) Drift velocity will be increased**

**Explanation:**

Drift velocity has the following relation

$$v_d \propto \frac{V}{R}$$

**As**

$$R \propto L$$

As resistance is inversely proportional to the drift velocity so by decreasing the length and temperature of the wire, resistance will decrease and hence drift velocity will increase.

**Q.No.13.2: Do bends in a wire affect its electrical resistance? Explain**

**Ans:** No, bend in wire does not affect its electrical resistance.

**Explanation:**

The resistance of the conductor is given as

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

It is clear from the formula that resistance depends upon the length and area of the wire. By bending the wire there is no affect on the length and area. So bends in the wire does not affect the resistance

**Q.No.13.4: Why does the resistance of a conductor rise with temperature?**

**Ans:** When the temperature of conductor increases then atoms vibrate with large amplitude and their number of collisions with free electrons increases. Due to which opposition offered by the conductor to the flow of the current (Resistance) increases.

**Q.No.13.5: What are the difficulties in testing whether the filament of a lighted bulb obeys Ohm's law?**

**Ans:** *Temperature* is the main difficulty in testing whether the filament of lighted bulb obeys ohm law.

**Explanation:** Ohm's law states that "Current flowing the through the conductor is directly proportional to the applied potential difference at constant temperature". In case of lighted bulb, temperature increases with the passage of current through it that's why resistance of filament increases and hence filament does not obey ohm's law.

**Q.No.13.6: Is the filament resistance lower or higher in a 500 W, 220 V light bulb than in 100 W, 220 V bulb?**

**Ans:**

Filament resistance will be lower in a 500 W, 220 V light bulb than 100 W, 220 V bulb.

**Proof:**

We know that $P = \frac{V^2}{R}$ or $R = \frac{V^2}{P}$

**Resistance of 500 W, 220 V bulb:**

$$R = \frac{(220)^2}{500}\,\Omega = 96.8\,\Omega$$

**Resistance of 100 W, 220 V bulb:**

$$R = \frac{(220)^2}{100}\,\Omega = 484\,\Omega$$

Hence it is clear that filament resistance will be lower in a 500 W, 220 V light bulb than 100 W, 220 V bulb.

**Q.No.13.7: Describe a circuit which will give a continuously varying potential**

**Ans:** Write a short note on potentiometer with help of diagram

**Q.No.13.8: Explain why the terminal potential difference of a battery decreases when the current drawn from it is increased?**

**Ans:** The formula of terminal potential difference is given as

$$V_t = E - Ir$$

It is clear from the above formula that if current I is large then factor Ir becomes large and terminal potential becomes small.

**Q.No.13.9: What is Wheatstone bridge? How can it be used to determine an unknown resistance?**

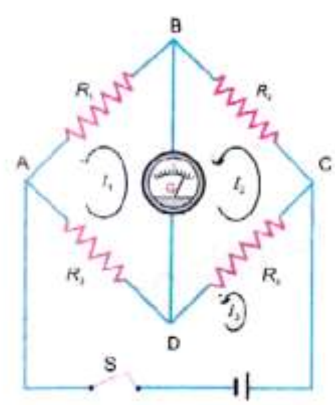
**Ans:**

**Definition:** An electronic circuit which consists of four resistances and used to find the unknown resistance is called Wheatstone bridge.

**Measurement of unknown resistance:**

Unknown resistance can be calculated by the given formula. By knowing the values of $R_2$, $R_3$, $R_4$, we can find the value of unknown resistance $R_1$

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



# Long Questions

## 13.4 OHM'S LAW:

**SATEMENT:**

This law states that "The current flowing the circuit is directly proportional to the potential difference across its ends provided the physical state such as temperature of the conductor remains constant"

**FORMULA:**

It is mathematically expressed as

$$V \propto I$$

or

$$V = IR$$

**EXPLANATION:**

**Introduction:**

It is already observed that when a battery is connected across the conductor, an electric current begins to flow it. How much current flows through the conductor when a certain potential difference is applied through it? Answer of this question was given by George Simon Ohm in 1827 who was German Physicist. He explained with experiments that current through metal conductor is directly proportional to potential difference across its ends.

**Resistance:**

In the formula of Ohm's law, R is constant of proportionality which is called resistance of the conductor. Resistance is defined as "Measure of opposition to the motion of electrons due to their continuous collisions with the atoms. The unit of resistance is Ohm.

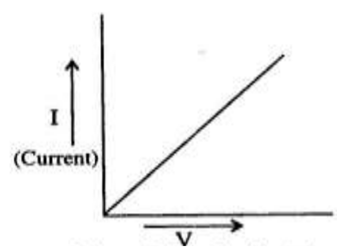
The value of resistance depends upon the following

i. Nature of the conductor
ii. Dimensions of conductor
iii. Physical state of conductor

**Definition of 1 Ohm:**

If 1 A current is measured by applying 1 volt potential difference then resistance of the wire is 1 Ohm. Which is given as

$$1\ Ohm = \frac{1\ V}{1\ A}$$




**Ohmic Conductors:**

A type of conductor which strictly obeys ohm's law is called Ohmic conductor. If resistance of the conductor remains constant then graph between V and I will be exactly a straight line as shown in figure (a).

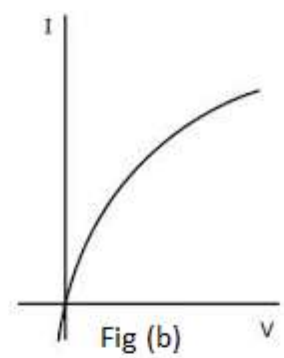


Fig (b)

**Non Ohmic Conductors:**

A type of conductor which do not strictly obeys ohm's law is called non ohmic conductor. Examples of non ohmic devices are filament bulbs and semiconductor diodes. If the resistance of the conductor will not remain constant then graph between V and I will not a straight line as shown in figure (b) & (c).

**Example of filament:**

Let us apply a certain potential difference across the terminals of filament lamp and measure the current through it. If we repeat the measurement for different values of potential differences as shown in figure (b). It means that filament is non ohmic device.

The deviation of I-V graph from straight line is due to increase in temperature. As the current passing through the filament is increased from zero, graph will be a straight line in the initial stage because there is no prominent change in temperature and resistance. So graph is a straight line in initial stage. As the current further is increased, the resistance of the filament continues to increases due to rise in temperature and graph will deviate.

**Example of semiconductor diode:**

Another example of non ohmic device is a semiconductor diode. The current-voltage plot of such a diode is shown in figure (c). The graph is not a straight line so semi conductor is also a non ohmic device.

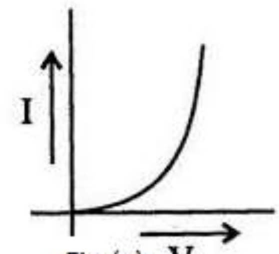


Fig (c)

**CONCLUSION:**

Ohm's law is basic and fundamental law of electrical engineering. This law gives the relation between V, I and R. It can be used to find the resistance in the circuit. It can also be used to compute the total current flowing through the circuit.

## 13.4 RESISTIVITY AND ITS DEPENDENCE UPON THE TEMPERATURE:

**RESISTIVITY:**

Resistance of a meter cube of a material is known as resistivity. In other words reciprocal of conductivity is called resistivity.

**FORMULA:**

It is mathematically expressed as

$$\rho = \frac{RA}{L}$$

**UNITS:**

The SI units of resistivity is ohm-meter (Ω-m)

**DEPENDENCE OF RESISTIVITY:**

It has been experimentally seen that the resistance R of a wire is directly proportional to its length L and inversely proportional to its cross sectional area A.

Expressing mathematically

$$R \propto \frac{L}{A}$$

Or

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

Where $\rho$ is constant of proportionality known as resistivity or specific resistance of the material of the wire.

**Resistance:**

Resistance is the characteristic of a particular wire whereas the resistivity is the property of the material of which the wire is made. It can be defined as the opposition offered by the atoms of conductor to the flow of current is called resistance.

**Units:**

Units of resistance are ohm (Ω)

**Conductance:**

Conductance is another quantity used to describe the electrical properties of materials. In fact conductance is reciprocal of resistance.

**Formula:**

It is mathematically described as

$$conductance = \frac{1}{Resistance}$$

**Units:**

Units of conductance is mho or siemen

**Conductivity:**

Reciprocal of resistivity is called conductivity

**Formula:**

It is mathematically described as

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

**Units:**

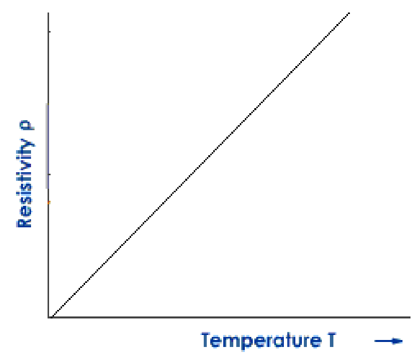
Units of conductance is $ohm^{-1}\ m^{-1}$ or $mho\ m^{-1}$

**Resistivity and temperature:**

The resistivity of a substance depends upon the temperature also. As the resistance offered by the conductor to the flow of current is due to collisions between atoms of conductor and free electrons. As the temperature of conductor rises, the amplitude of vibration of the atoms also increases and chances of collisions also increases. So by increase in the temperature of the conductor, the resistance will increase.

**Temperature coefficient of resistance:**

Experimentally change in resistance of a metallic conductor with temperature is found to be nearly linear as shown in the figure.




Fractional change in resistance per Kelvin is known as the temperature coefficient of resistance

**Formula:**

Its formula is given as

$$\alpha = \frac{R_t - R_o}{R_o t} ----(i)$$

**Units:**

SI units of temperature coefficient of resistance is $K^{-1}$

**Temperature coefficient of resistivity:**

As resistivity depends upon the temperature so

At temperature $t^oC$

$$R_t = \frac{\rho_t L}{A}$$

And at temperature $0^oC$

$$R_o = \frac{\rho_o L}{A}$$

So by putting these values in above mentioned equation (i), we get

$$\alpha = \frac{\frac{\rho_t L}{A} - \frac{\rho_o L}{A}}{R_o t}$$

Fractional change in resistivity per Kelvin is known as the temperature coefficient of resistivity

**Formula:**

Its formula is given as

$$\alpha = \frac{\rho_t - \rho_o}{\rho_o t}$$

**Units:**

SI units of temperature coefficient of resistivity is $K^{-1}$

**CONCLUSION:**

Hence it is concluded that resistance of a conductor depends upon length of conductor, area of conductor and temperature of the conductor. But resistivity depends upon only temperature and material by which wire is made.

It is also concluded that resistance and resistivity of all conductors increases with increase in temperature. Means conductors have positive temperature coefficients of resistance and resistivity.

There are some substances like germanium, silicon whose resistance decreases with increase in temperature. These have negative temperature coefficients. These substances are semiconductors.

## 13.9 WHEAT STONE BRIDGE:

**INTRODUCTION:**

An electrical circuit which is used to find out the unknown resistance is called Wheatstone bridge. Its experimental name is slide Wire Bridge.

**FORMULA FOR RESISTANCE:**

If $R_1$, $R_2$ and $R_3$ are known resistances then formula for unknown resistance $R_4$ is given as:

$$R_4 = \frac{R_2}{R_!} \times R_3$$

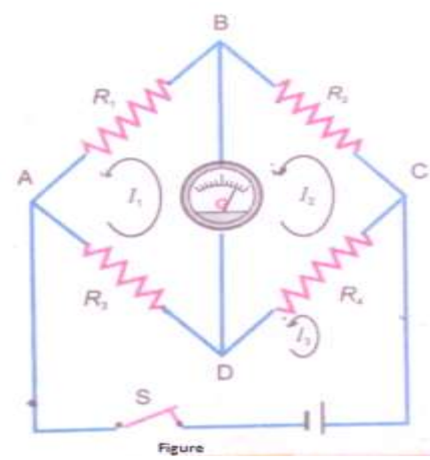
**APPARATUS:**

Circuit of wheat stone bridge consists of following apparatus

- Four resistances
- Galvanometer
- Switch
- Battery
- Connecting wires

**CONSTRUCTION:**

The Wheatstone bridge consists of four resistances $R_1$, $R_2$, $R_3$ and $R_4$ connected in such a way so as to form a mesh ABCDA as shown in the figure given below. A battery is connected between points A and C. A galvanometer of resistance $R_g$ is connected between point B and D.




**ANALYSIS USING KIRCHOFF'S SECOND RULE:**

Actually for finding the unknown resistance, we have to determine the condition under which no current flows through the galvanometer even after the switch is closed. For this purpose, we analyze this circuit using Kirchhoff's second rule.

We consider the loops ADBA, DCBD and ADCA and assume anticlockwise loop currents $I_1$, $I_2$ and $I_3$ through the loops respectively.

**Kirchhoff's rule on loop ADBA:**

By applying Kirchhoff's second rule on ADBA we get equation

$$-I_1R_1 - (I_1 - I_2)R_g - (I_1 - I_3)R_3 = 0 -------(i)$$

**Kirchhoff's rule on loop DCBD:**

Similarly by applying Kirchhoff's second rule on DCBD we get equation

$$-I_2R_2-(I_2-I_3)R_4-(I_2-I_1)R_g=0--------(ii)$$

**Balance point:**

It is a point at which galvanometer shows zero deflection if though the switch is closed. The current flowing through the circuit will be zero, if $I_1=I_2$

By putting this condition $I_1=I_2$ in above equations (i) and (ii) we get

$$-I_1R_1-(I_1-I_1)R_g-(I_1-I_3)R_3=0$$
$$-I_1R_1-(I_1-I_3)R_3=0$$

Or

$$-I_1R_1=(I_1-I_3)R_3----(iii)$$
$$-I_1R_2-(I_1-I_3)R_4-(I_1-I_1)R_g=0$$
$$-I_1R_2-(I_1-I_3)R_4=0$$

Or

$$-I_1R_2=(I_1-I_3)R_4---(iv)$$

By dividing equations (iii) and (iv) we get

$$\frac{-I_1R_1}{-I_1R_2}=\frac{(I_1-I_3)R_3}{(I_1-I_3)R_4}$$

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

Thus whenever the galvanometer in the Wheatstone bridge shows no deflection then above mentioned equation will be satisfied.

If we connect three resistances $R_1$, $R_2$ and $R_3$ of known values and fourth resistance of unknown value then three resistances $R_1$, $R_2$ and $R_3$ are so adjusted that galvanometer shows no deflection then $R_4$ can be determined by using the below mentioned formula

$$R_4=\frac{R_2}{R_!}\times R_3$$

**CONCLUSION:**

A Wheatstone bridge, shown in above mentioned figure, is used to measure an unknown electrical resistance by balancing the resistances in the two branches of a bridge circuit, one branch of which includes the unknown resistance

## 13.10 POTENTIOMETER:

**INTRODUCTION:**

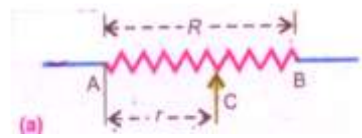
A very simple instrument which can measure and compare potential differences accurately is called potentiometer.

**PRINCIPLE:**

The principle of potentiometer is stated as "the potential difference across any length of wire of uniform area of cross-section is proportional to its length when constant current flows through it".

**POTENTILA MEASURING INSTRUMENTS:**

Potential difference is usually measured by an instrument called a voltmeter. The voltmeter is connected across the two points in the circuit between which potential difference is to be measured. Resistance of voltmeter should be very high so that minimum current should flow through voltmeter and circuit current will not disturb and potential difference can be measured accurately. So an ideal voltmeter would have an infinite resistance




However, there are some potential measuring instruments such as digital voltmeter and cathode rays oscilloscope which practically do not draw any current from them due to their large resistances. They are very accurate devices to measure potential difference but these instruments are very expensive and difficult to operate.

**CONSTRUCTION AND WORKING:**

A potentiometer consists of a resistor R in the form of a wire on which a terminal C can slide as shown in fig. (a)

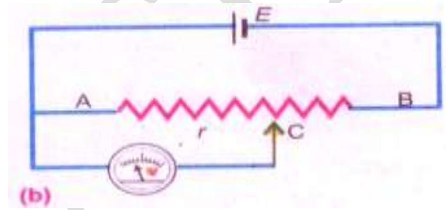
**Potentiometer as a potential divider:**

The resistance between A and C can be varied from 0 to R as the sliding contact as moved from A to B.If a battery of emf E is connected across R shown in fig. (b), the current flowing through it is given by

$$I = \frac{E}{R} - - - - - - - - (i)$$

If we represent the resistance between A and C by r, the potential drop between these points will be

$$V_{AC} = Ir - - - - - - - - (ii)$$




Putting the value of $I$ from (ii) we get

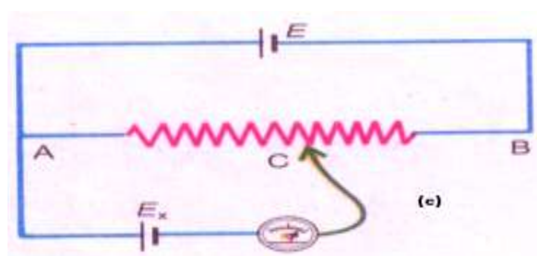
$$V_{AC} = \frac{E}{R} r$$

As C is moved from A to B, r varies from 0 to R and the potential drop between A and C changes from 0 to E such an arrangement also known as potential divider.

**Measurement of unknown emf:**

It can be used to measure the unknown emf of a source by using the circuit shown in fig (c) A source of potential say a cell whose emf $E_x$ is to be measured, is connected between A and the sliding contact C through a galvanometer G. The positive terminal of $E_x$ and that of the potential divider are connected to the same point A. if in the loop AGCA, the point C and the negative terminal of $E_x$ are at the same potential, then two terminals of the galvanometer will be at the same potential and no current will flow through the galvanometer. Therefore, to measure the potential $E_x$, the position of C is so adjusted that the galvanometer shows no deflection. Under this condition, the emf $E_x$ of the cell is equal to the potential difference between A and C whose value $\frac{E}{R} r$ is known.

In case of wire of uniform area of cross-section, the resistance is proportional to the length of the wire therefore, the unknown emf $E_x$ is also given by




$$E_X = \frac{E}{R} r = \frac{E}{L} l$$

where $L$ is the length of the wire AB and $l$ is its length from A to C, after C has been adjusted for no deflection of the galvanometer

**Comparison of two emfs:**

The method for measuring the emf of a cell as described above can be used to compare the emfs $E_1$ and $E_2$ of two cells. The balance lengths $l_1$ and $l_2$ are found separately for the two cells

Then

$$E_1 = E\frac{l_1}{L}$$

$$E_2 = E\frac{l_2}{L}$$

By dividing these two above equations we get

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

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

So the ratio of emfs is equal to ratio of balancing lengths.

**APPLICATIONS:**

Potentiometer is chosen over voltmeter to measure potential difference because voltmeter measures terminal potential of cell but it measures actual potential of cell.

The Potentiometer is an electric instrument that used to

- measure the EMF (electro motive force) of a given cell,
- measure the internal resistance of a cell.
- to compare EMFs of different cells.
- as a variable resistor in most of the applications.

These potentiometers are used in huge quantities in the manufacture of electronics equipment that provides a way of adjusting electronic circuits so that the correct outputs are obtained. Although their important use is for volume controls on radios and other electronic equipment used for audio.

# Numerical

**Numerical 13.1**: How many electrons pass through an electric bulb in one minute if the 300 mA current is passing through it?

**Solution:**

$n = ?$ $I = 300\ mA = 0.3\ A$

$t = 1\ mint = 60\ s$ $e = 1.6 \times 10^{-19} C$

As current is given as

$$I = \frac{Q}{t}$$

$$Q = It \text{------(i)}$$

Charge is also given as $Q = ne$------(ii)

By comparing these two equations, we get

$$ne = It$$

$$n = \frac{It}{e}$$

$$n = \frac{(0.3)(60)}{1.6 \times 10^{-19}}$$

$$n = \frac{18}{1.6 \times 10^{-19}}$$

$$\boxed{n = 1.12 \times 10^{20}}$$

**Numerical 13.2**: A charge of 90 C passes through a wire in 1 hour and 15 minutes. What is the current in wire?

**Solution:**

$Q = 90\ C$ $I = ?$

$t = 1\ hour + 15\ mints$

$t = 3600\ s + 900\ s = 4500\ s$

As current is given as

$$I = \frac{Q}{t}$$

$$I = \frac{90}{4500} A$$

$$I = 0.02 A$$

$$I = 0.02 \times 1000\ mA$$

$$\boxed{I = 20\ mA}$$

**Numerical 13.4**: A rectangular bar of iron is 2.0 cm by 2.0 cm in cross section and 40 cm long. Calculate its resistance if the resistivity of iron is $11\times10^{-8}$ Ωm

**Solution:**

$$A = 2.0\ cm \times 2.0\ cm$$

$$A = 2.0 \times 10^{-2} m \times 2.0 \times 10^{-2} m$$

$$A = 4.0 \times 10^{-4} m^2$$

$$L = 40\ cm = 40 \times 10^{-2} m$$

$$\rho = 11 \times 10^{-8}\ \Omega\text{m}$$

$$R = ?$$

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

$$R = (11 \times 10^{-8}) \frac{(40 \times 10^{-2})}{(4.0 \times 10^{-4})} \Omega$$

$$\boxed{R = 1.1 \times 10^{-4}\ \Omega}$$

**Numerical 13.5**: The resistance of an iron wire at 0°C is $1\times10^4$ Ω. What is the resistance at 500°C if the temperature coefficient of resistance of iron is $5.2\times10^{-3}$ $K^{-1}$

**Solution:**

$R_o = 1 \times 10^{-4} \Omega$ $R_t = ?$

$t_1 = 0C^o = 0 + 273\ K = 273\ K$

$t_2 = 500C^o = 500 + 273\ K = 773\ K$

$t = t_2 - t_1 = 773K - 273K = 500K$

$\alpha = 5.2 \times 10^{-3} K^{-1}$

$$\alpha = \frac{R_t - R_0}{R_o t}$$

$$5.2 \times 10^{-3} = \frac{R_t - 1 \times 10^4}{(1 \times 10^4)(500)}$$

$$5.2 \times 10^{-3} \times (1 \times 10^4)(500)\Omega = R_t - 1 \times 10^4$$

$$5.2 \times 10^{-3} \times (1 \times 10^4)(500) + 1 \times 10^4 \Omega = R_t$$

$$\boxed{R_t = 3.6 \times 10^4\ \Omega}$$