2nd Year Physics

Chapter # 13

Current Electricity

pakcity.org
www.pakcity.org

Written by:

Mr. Shahroze Saleem

M. Phil (Physics), B. Ed.

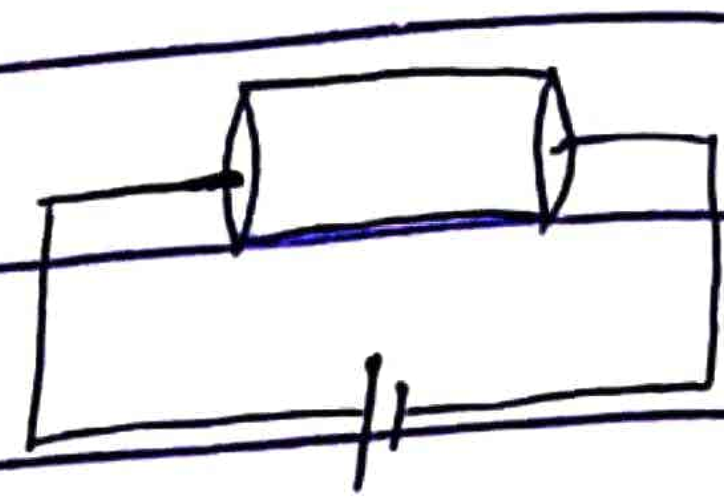
Lecturer, Chenab College Jhang.

Ch # 13

Current Electricity

Current: The rate of flow of charges is called current. It is denoted by I.

$$I = \frac{\Delta q}{\Delta t}$$



SI unit of current is ampere (A).

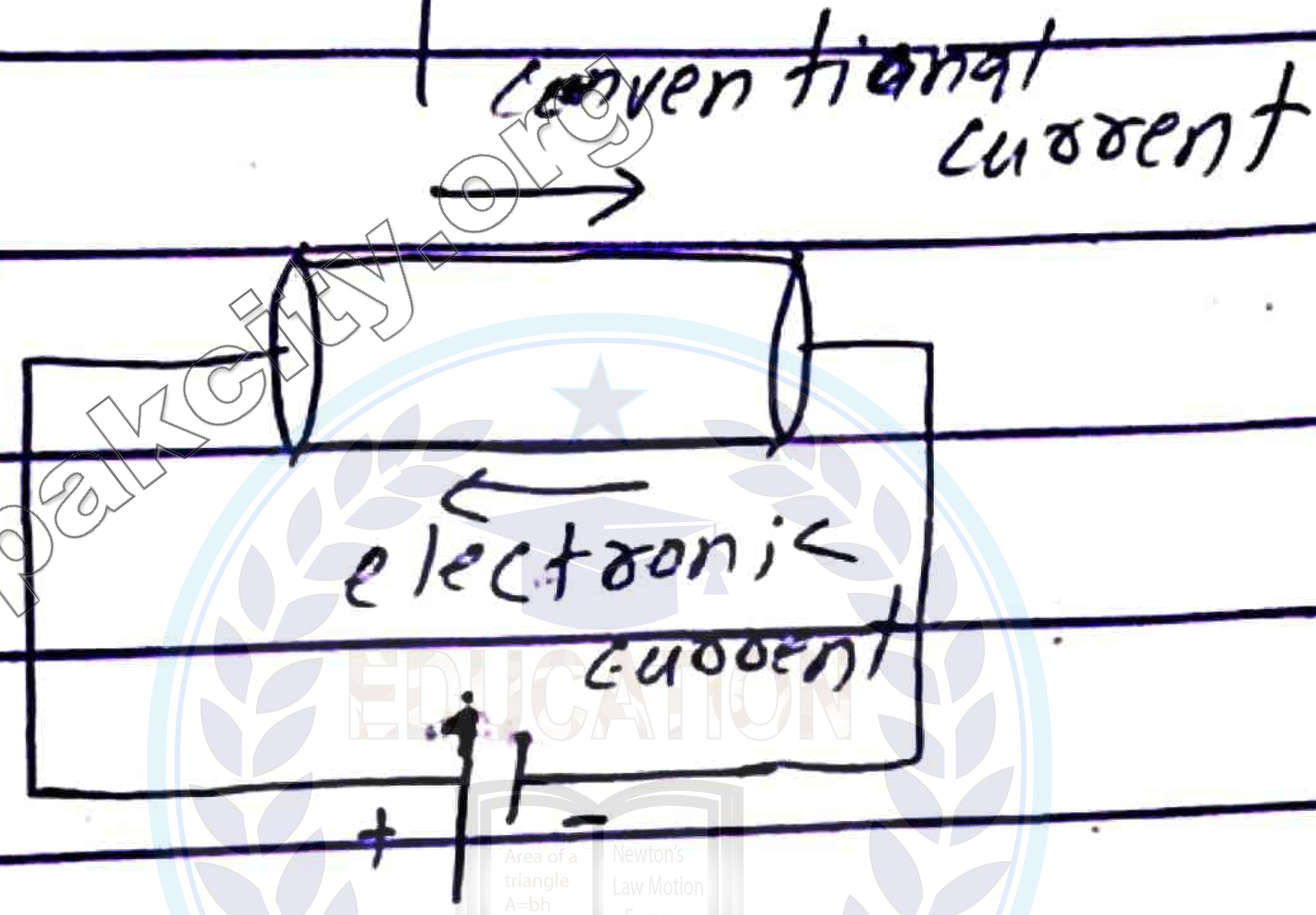
Ampere: If one coulomb charge passes through a conductor in one second, then the current will be one ampere.

$$1A = \frac{1C}{1s}$$

pakcity.org

Conventional current	Electronic current
i- The current produced in the conductor due to the flow of	i- The current produced in the conductor due to the flow of electrons (negative

positive charges is called conventional current	charges) is called electronic current.
ii. It flows from high potential to low potential	ii- It flows from low potential to high potential



www.pakcity.org

Charge carriers:

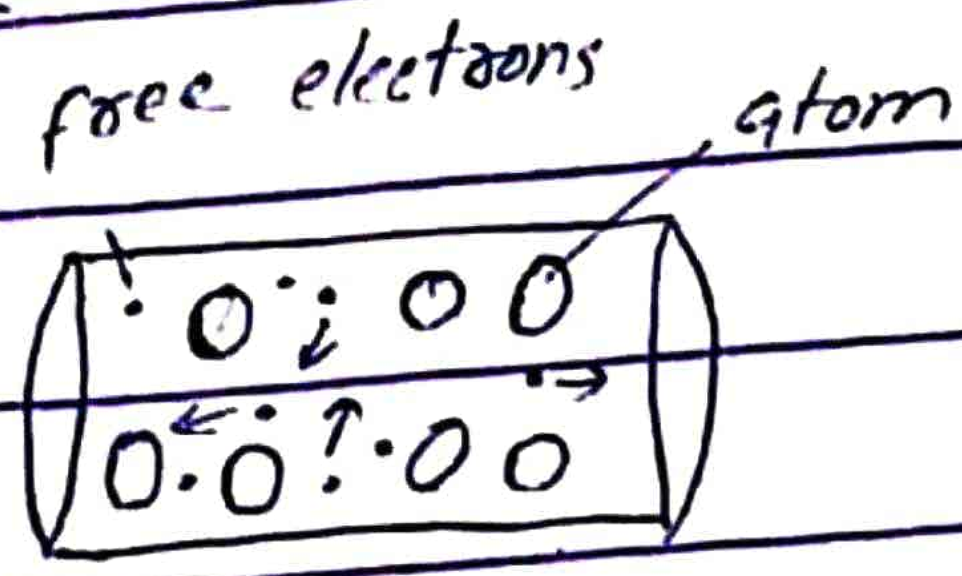
metalic conductors → electrons
electrolyte → positive and negative ions
gases → electrons and ions.

Free Electrons:

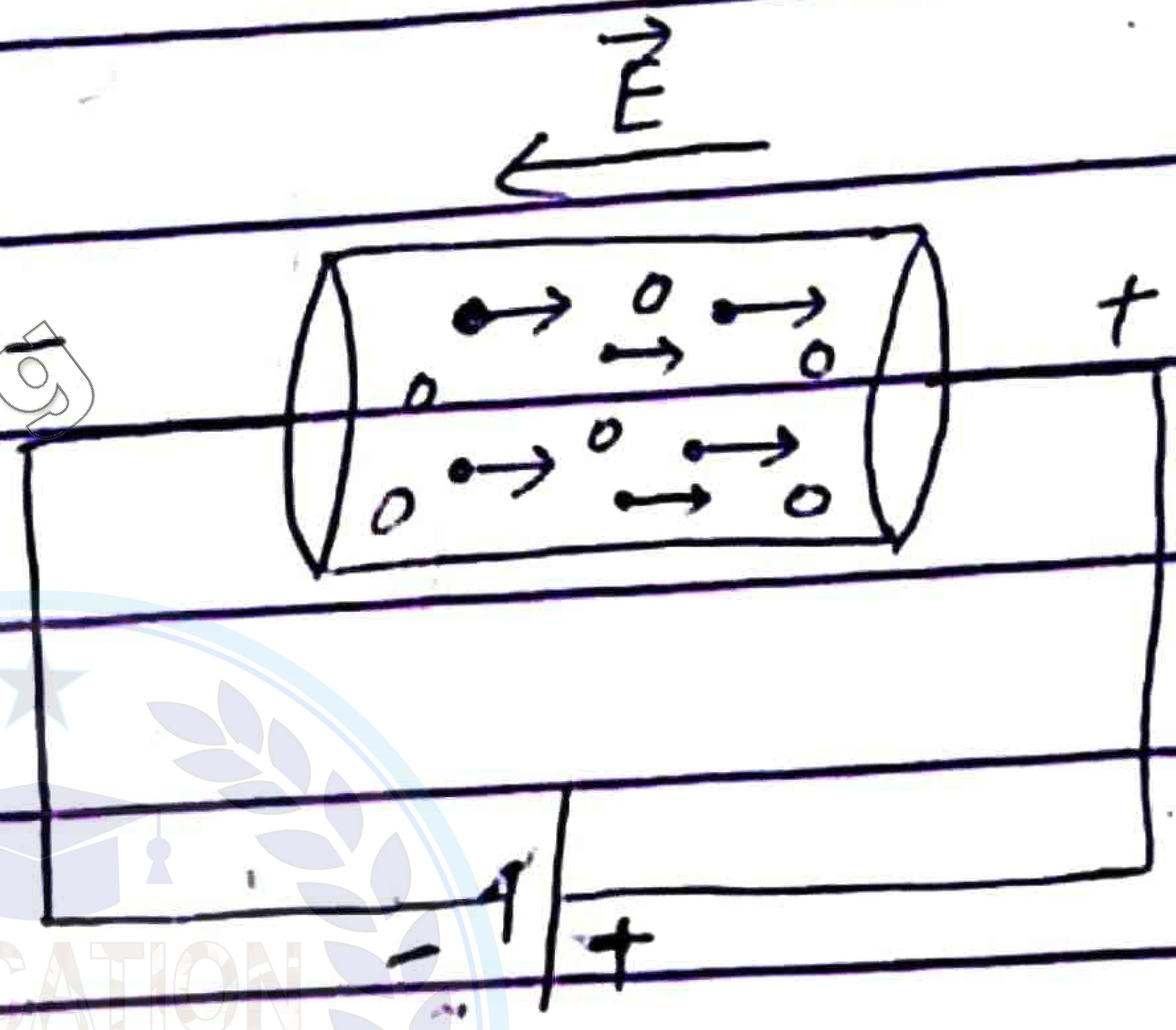
— Book —

Effect of battery:

When there is no battery attached to the conductor. the free electrons cancel the effect of each other and there is no current in the conductor.



When a battery is attached to the ends of conductor.



The electrons move from negative terminal of battery to positive terminal. In this way they move opposite to electric field. and current is established through the conductor.

www.pakcity.org
pakcity.org

Drift velocity:

The average velocity of electrons while passing through a conductor opposite to the electric field in the presence of the battery is called drift velocity.

The drift velocity is of the order of $10^{-3} ms^{-1}$. Whereas the velocity of free electrons at room temperature due to their thermal motion is several hundred kilometres per second.

www.pakcity.org

Sources of Current:

pakcity.org

Definition:

Every source of the current convert to some non electrical energy such as chemical, mechanical, heat or solar energy. in to electrical energy

Types:

There are many types of sources of current.

⟹ cells(Primary as well as Secondary). which

convert Chemical energy
in to electrical energy.
⇒ Electric generators which
convert mechanical energy
in to electrical energy.
⇒ Thermo-couples which convert
heat energy in to electrical
energy.
⇒ solar cells which convert
sunlight directly into
electrical energy.

pakcity.org

★ Effects of current:

The presence of electric current
can be detected by the
various effect which is
produces

→ Heating effect.
→ Magnetic effect
→ Chemical effect.

Heating effect:

Current flows through a metalic wire due to motion of free electrons. During the course of their motion, they collide frequently with the atoms of the metal. At each collision they lose some of their kinetic energy and give it to atoms with which they collide. Thus as the current flows through the wire it increases the kinetic energy of the vibrations of the metals atoms i.e. generate heat in the wire

$$H = I^2RT.$$

The heating effect of the current is utilized in electric heaters, kettles, toaster and electric iron

Magnetic Effect:

The passage of current is always accompained by the magnatic field in the surrounding space. The strength of the feild depends upon the value of current and the

www.pakcity.org
EDUCATION
pakcity.org

the distance from the current element.
Megnatic effect is utilized in the detection and measurnment of current.
All the machines involving electric motors also use the magnetic effect of current.

Chemical effect:

⇒ **electrolysis:**

Certain liquid such as dilute sulphuric acid or copper sulphate solution conduct electricity due to some chemical reaction that take place with in them. This process is called electrolysis

⇒ **electrolyte:**

The liquid ~~such as di~~ which conducts current is known as electrolyte.

www.pakcity.org
pakcity.org

electrode:

The material in the form of wire or rod or plate which lead the current into and out of the electrolyte is called electrode.

Types of electrode:

pakcity.org

There are two types of electrodes.

→ anode

→ cathode

www.pakcity.org

Anode:

The electrode connected to the positive terminal of the battery (current source) called anode.

Cathode:

The electrode connected to the negative terminal of the battery (current source) called cathod.

Voltameter:

The Vessele containing the two electrodes and the liquid is known as voltameter.

Electroplating:

A process of ~~containing~~ coating a thin layer of some expensive metal (gold, silver etc) on an article of some cheap metal.

Ohm's Law:

pakcity.org

Statement:

The current flowing through a conductor is directly proportional to the P.D across its ends provided the physical state such as temperature of the conductor remains constant.

Explanation:

Consider a conductor connected with the battery having potential difference V and current I is produced in the conductor. According to Ohm's law

$$V \propto I$$

$$V = (\text{constant}) I$$

$$V = IR$$

www.pakcity.org

Here R is the proportionality constant called the resistance of the conductor.

pakcity.org

Resistance: The opposition to the flow of electrons through a conductor is called resistance. It is due to the atoms of the conductor.

Dependence: Resistance of a conductor depends upon the nature of conductor, dimensions and physical state of the conductor.

www.pakcity.org
EDUCATION
pakcity.org

Unit of resistance:

The SI unit of resistance is ohm denoted by Ω

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

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

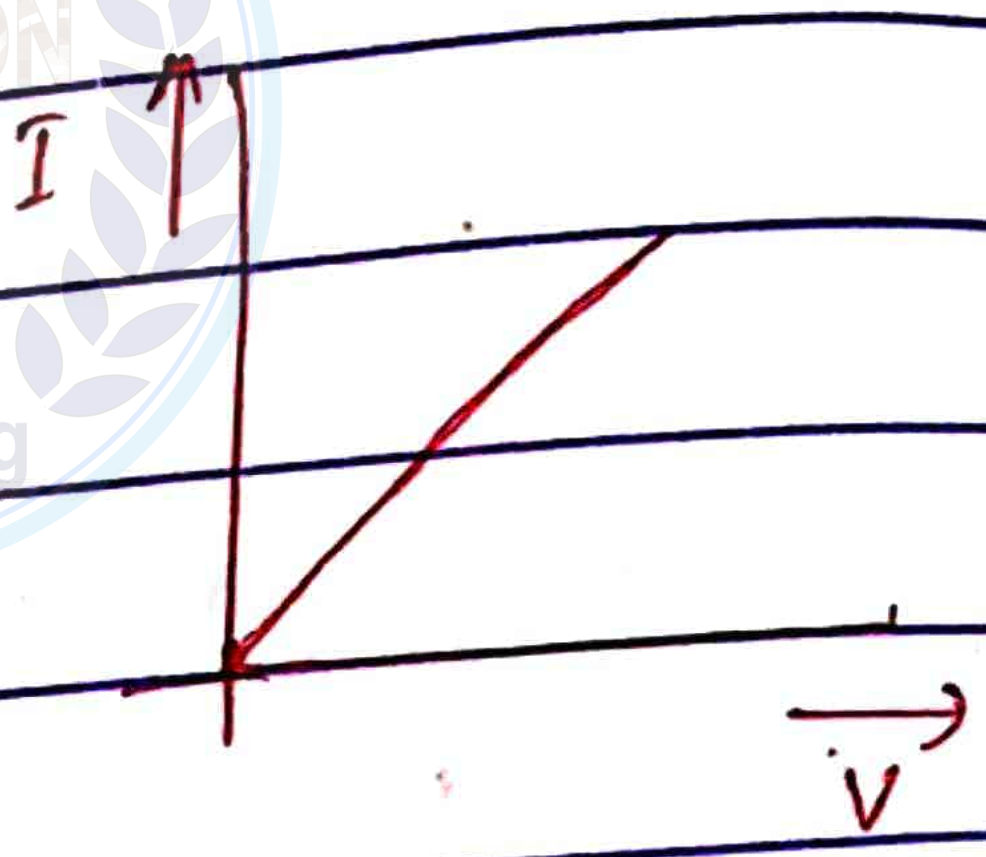
The resistance of the conductor will be 1Ω if

1A current flows through it in the presence of 1V. potential difference.

Ohmic Materials:

The conductors which obey ohm's law are called Ohmic conductors/ materials. In these conductors resistance remains constant.

For example, all the metals obey Ohm's law. A straight line shown in the V-I graph shows the Ohmic behaviour of the metals.



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

Non-Ohmic Materials:

The conductors which do not obey Ohm's law are called non-Ohmic conductors / materials.

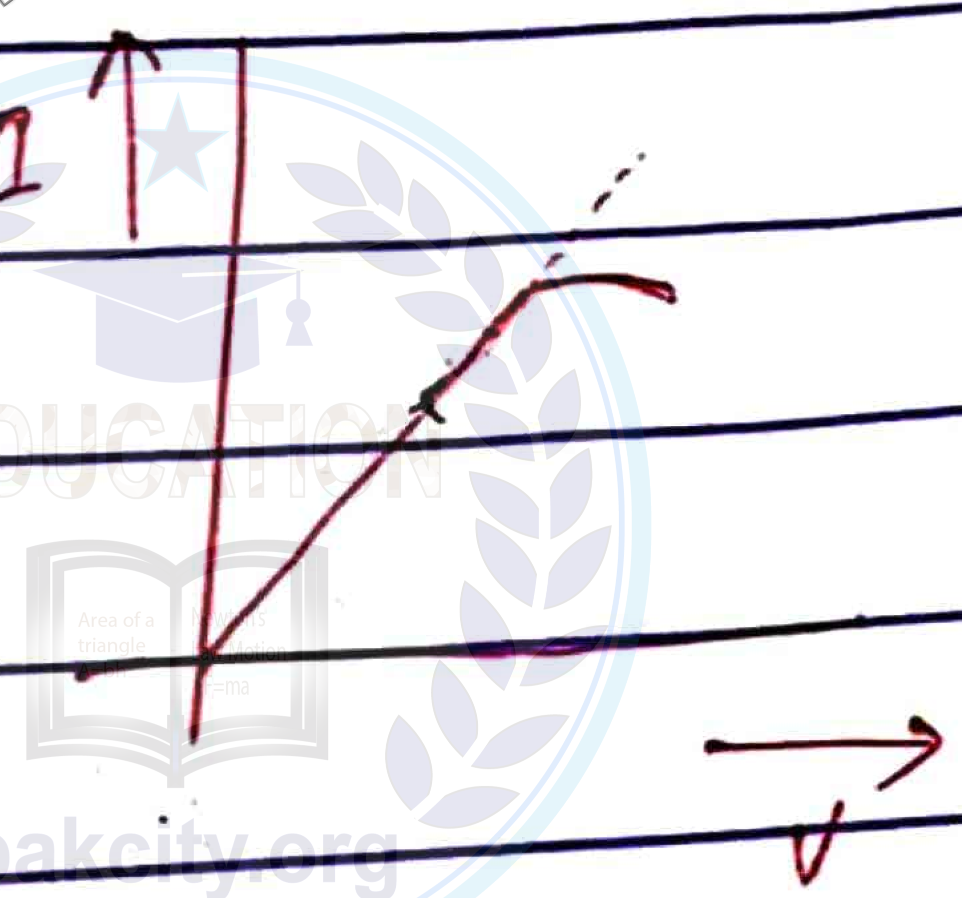
www.pakcity.org

In these conductors the resistance does not remain constant.

For example, filament bulb and semi-conductor diodes are non-ohmic.

Behaviour of filament bulb:

When the current flowing through the bulb the current increases due to increase in potential difference. after some time the filament heats up. As a result the resistance increases and current decreases. So, the proportionality is no longer obeyed. Therefore filament bulb does not obey Ohm's law.

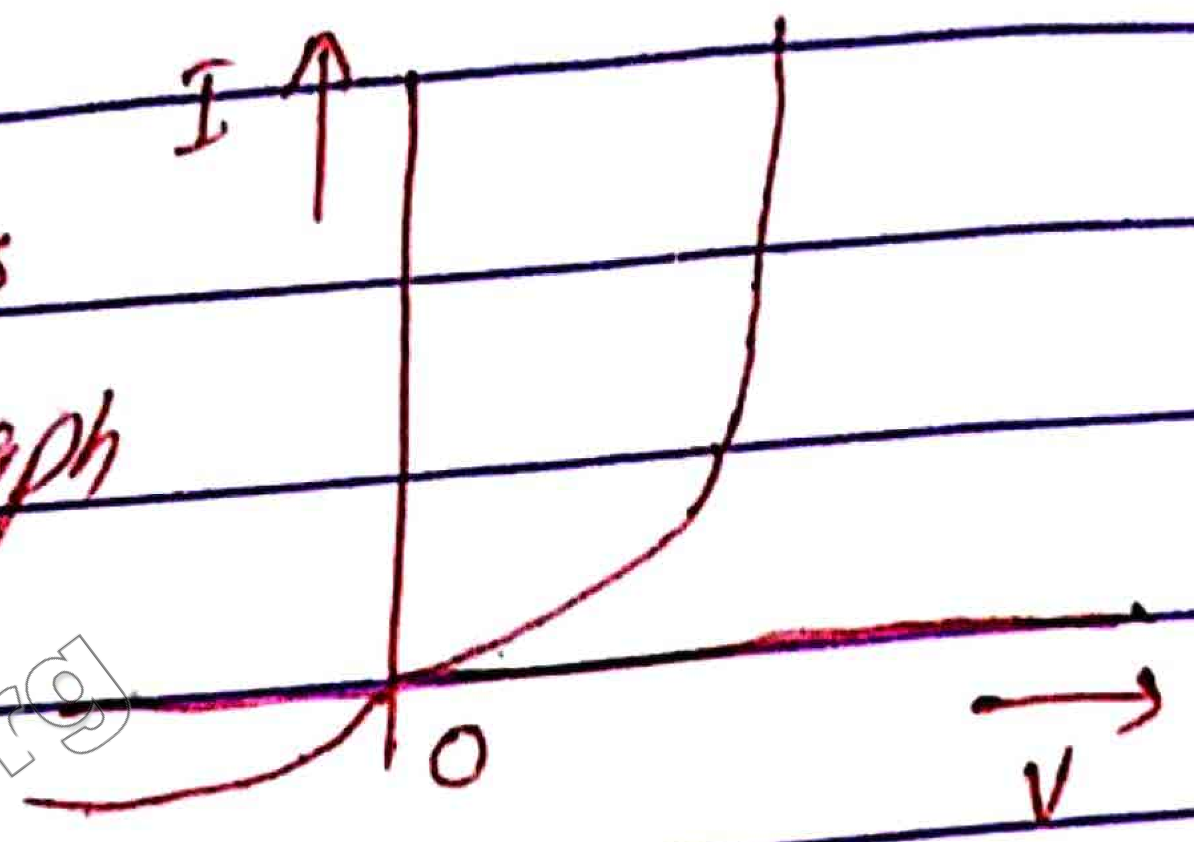


pakcity.org

Behaviour of semi-conductor diodes:

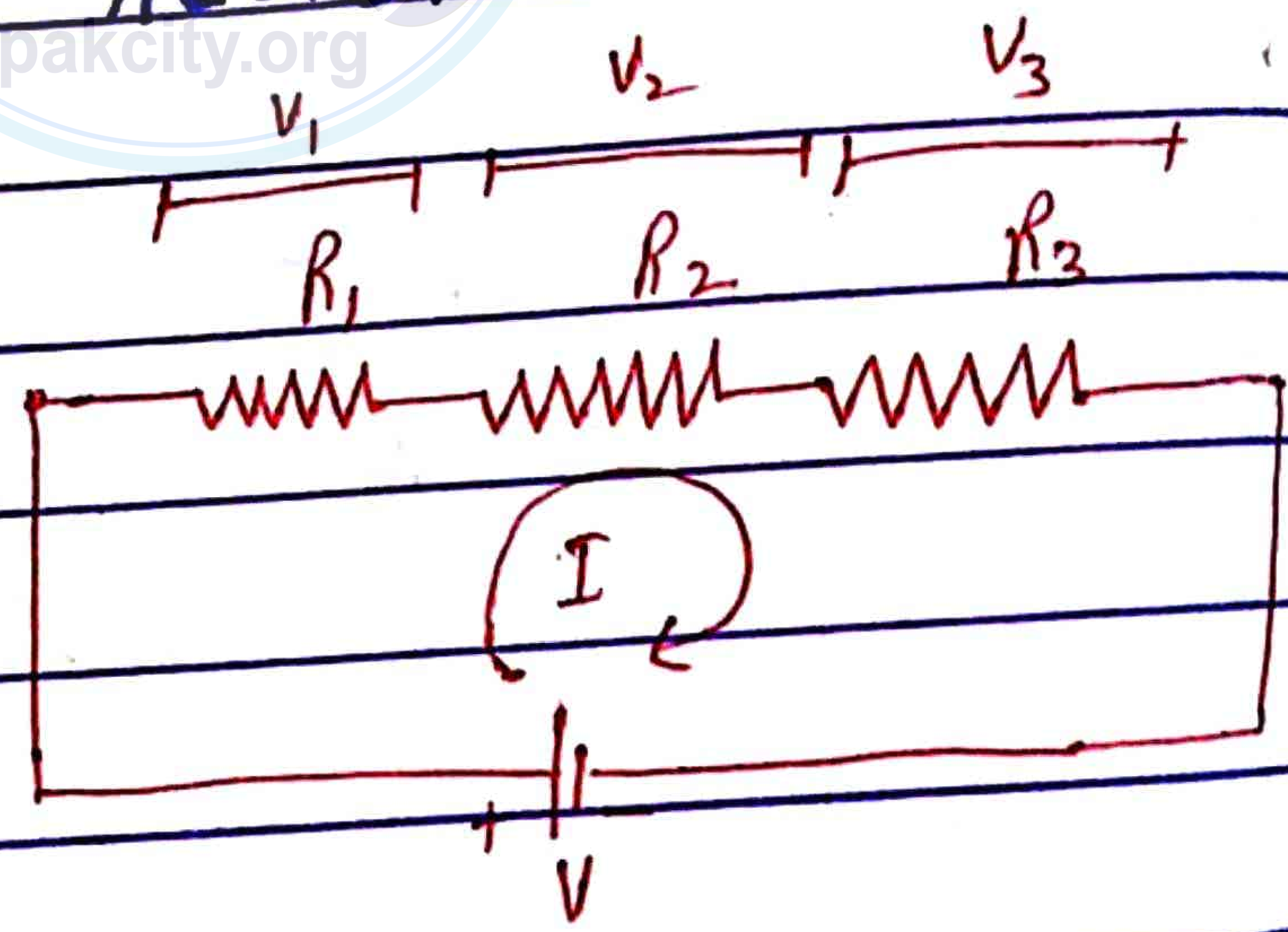
The semi-conductor diodes are non-ohmic. Because their resistance does not remain constant.

For semi-conductors the V-I graph is a non-straight line.



www.pakcity.org
EDUCATION
pakcity.org

Series Combination of Resistors



1- The end to end combination of resistors is called series combination.

2- The current will be same.

$$I_1 = I_2 = I_3 = I$$

3- Voltage drops across the resistor according to their value.

$$V = V_1 + V_2 + V_3$$

$$IR_e = I_1R_1 + I_2R_2 + I_3R_3$$
$$= IR_1 + IR_2 + IR_3$$
$$IR_e = I(R_1 + R_2 + R_3)$$

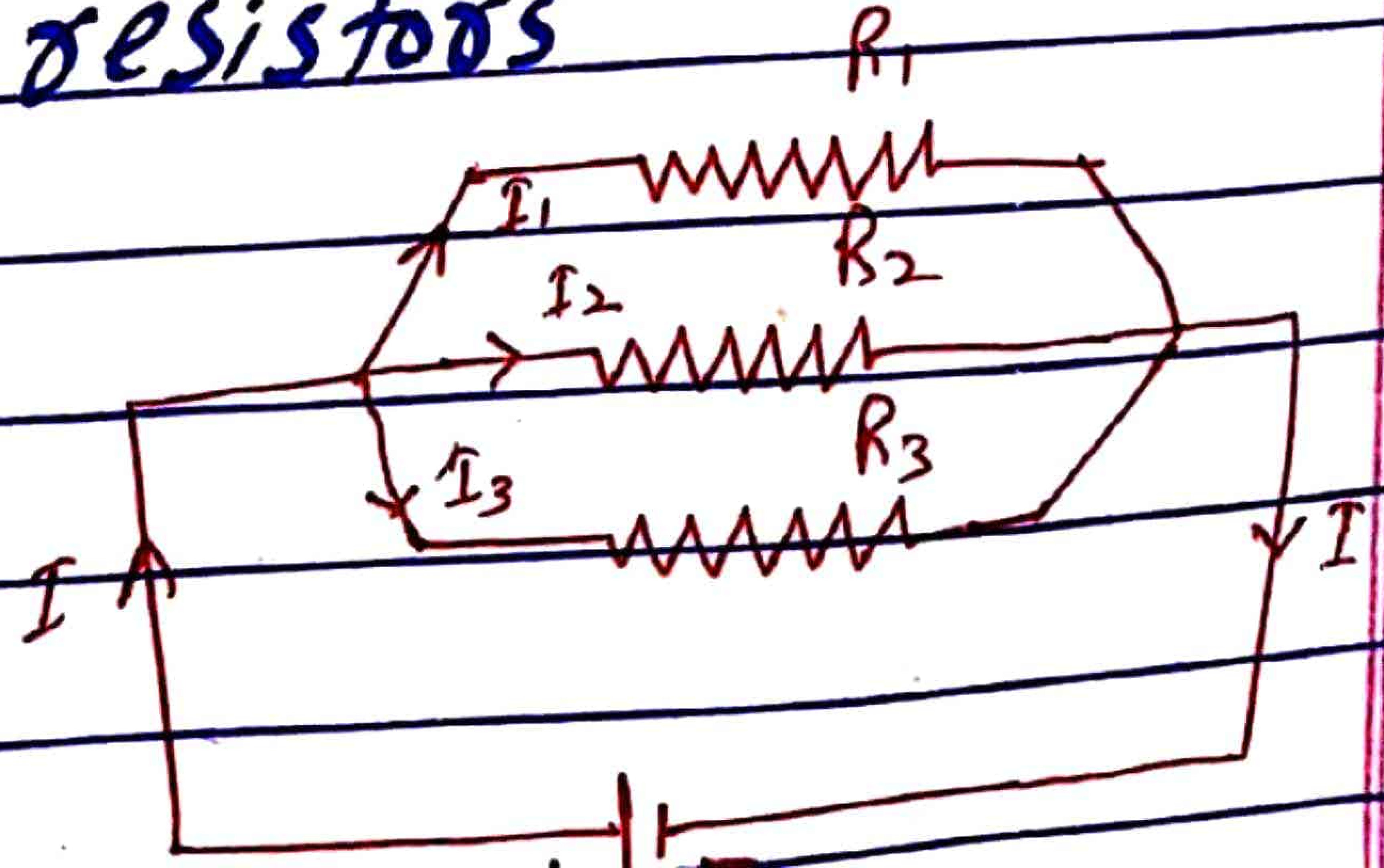
$$R_e = R_1 + R_2 + R_3$$

4- For n number of resistors

$$R_e = R_1 + R_2 + R_3 + \dots + R_n$$

5- The equivalent resistance is greater than any individual resistance for series combination.

Parallel Combination of resistors



pakcity.org
www.pakcity.org

1- when all the resistors are directly connected to the terminals of the battery.

2- The voltage across the resistor is same

$$V_1 = V_2 = V_3 = V$$

3- The current is divided across the resistors according to their value.

$$I = I_1 + I_2 + I_3$$

$$\frac{V}{R_e} = \frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}$$

$$= \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\frac{V}{R_e} = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

$$\frac{1}{R_e} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

4- For n number of resistors

$$\frac{1}{R_e} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots + \frac{1}{R_n}$$

www.pakcity.org
EDUCATION
pakcity.org

5. The equivalent resistance is less than any individual resistance for parallel combination.

pakcity.org

Resistivity And Its Dependence Upon Temperature:

Resistance: The opposition to the flow of electrons through a conductor is called resistance. Its unit is ohm (Ω)

www.pakcity.org

The resistance of a conductor is directly proportional to the length (L). and inversly proportional to the cross sectional area (A)

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

$$R = (\text{constant}) \frac{L}{A}$$

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

Here ρ is the

proportionality constant called the resistivity or specific resistance of the conductor.

Resistivity: The resistance of the conductor will be equal to the specific resistance/resistivity if its length is 1m and cross sectional area is $1m^2$.

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

www.pakcity.org

EDUCATION pakcity.org

Unit: The SI unit of resistivity is ohm meter (Ωm)

Conductance: The reciprocal of resistance is called conductance.

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

Unit: Its unit is Ω^{-1} or mho or siemen.

Conductivity: The reciprocal of resistivity is called conductivity. It is denoted by σ

$$\text{conductivity}(\sigma) = \frac{1}{\text{Resistivity}(\rho)}$$

Unit: Its unit is $\Omega^{-1} m^{-1}$ or mho m^{-1} or siemen m^{-1}

Effect Of Temperature Upon Resistivity And Resistance:

When the temperature of a specific conductor increases, the kinetic energy of the electrons and atoms also increases. Then they vibrate with greater amplitude and collision also increases. Therefore, the resistance of the conductor increases.

www.pakcity.org
pakcity.org
pakcity.org

Comparison of resistance and resistivity:

The resistance of a conductor is its

characteristic due to its length and cross sectional area where as the resistivity is the property of the material of which the conductor is made.

Temperature Coefficient:

The fractional change in resistance per kelvin is known as temperature coefficient of the resistance. It is denoted by α. mathematically.

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

Here R_t is the resistance of conductor at temperature $t°C$ and R_o is the resistance at $0°C$.

As

$$R_t = \rho_t \frac{L}{A} \quad , \quad R_o = \rho_o \frac{L}{A}$$

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

$$= \frac{\frac{L}{A}(\rho_t - \rho_o)}{\rho_o \frac{L}{A} t}$$

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

So, the fractional change in resistivity per kelvin is also temperature coefficient.

Unit: The unit of temperature coefficient (α) is per kelvin (K^{-1})

www.pakcity.org
pakcity.org

Positive temperature coefficient:

Such materials whose resistance increases with the increase in temperature have positive temperature coefficient. For example, metals.

Negative temperature coefficient:

Such materials whose resistance decreases with the increase in temperature have negative temperature coefficient. For example, silicon and germanium.

www.pakcity.org

COLOUR CODE FOR CARBON RESISTANCES.

pakcity.org

Carbon Resistors:

Carbon Resistors are most Common in electric equipment. They Consist of a high-grade ceramic rod or Cone on which is deposited a thin resistive film of carbon. The numerical Value of their resistance is indicated by the Colour code which consist of band of different colours printed on the body of the resistor.

Tolerance:

Possible variation for the marked value of resistance called tolerance.

Example:

A 100 Ω resistor with a tolerance of ±10% will have an actual resistance anywhere between 900 Ω and 1100 Ω.

pakcity.org
www.pakcity.org

⇒ Silver band indicate the tolerance of ±10%.

⇒ Gold band shows the tolerance of ~~±20%~~ ±5%.

⇒ If there is no fourth band tolerance is understood to be ±20%.

Black	0	Violent	7
Brown	1	Gray	8
Red	2	White	9
Orange	3		
Yellow	4		
green	5		
Blue	6		

pakcity.org

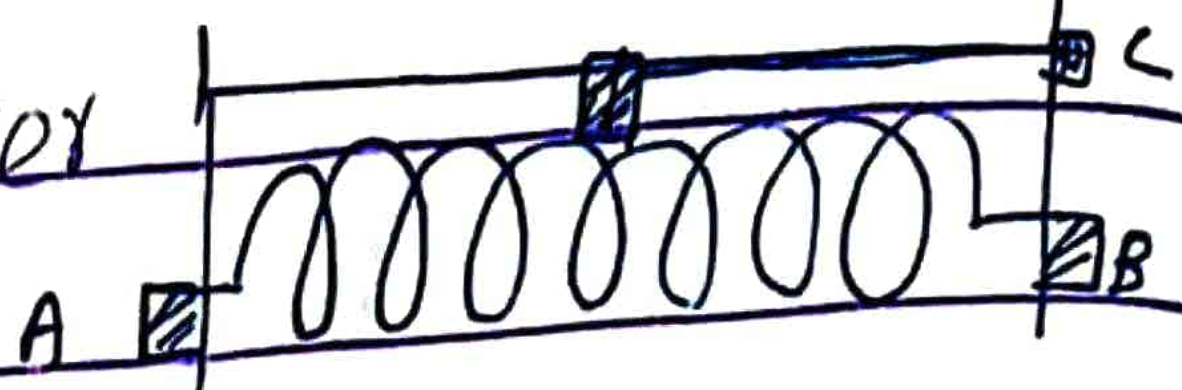
Rheostat:

Defination:

A wire wound variable Resistor called Rheostat.

Construction:

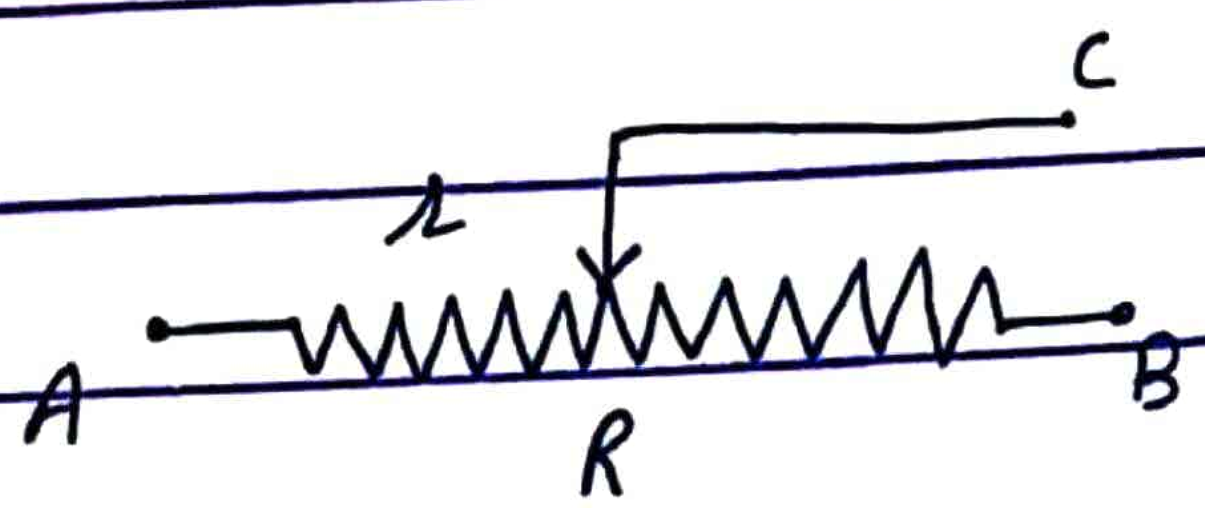
It consist of the bare maganin wire wound over an insulating cylinder. The end of the wire is connected to two fix terminals A and B. A third terminal C is attached to the sliding contact which can also be moved over the wire.



Explanation: Rheostat is a very useful instrument. It has two main uses.

Rheostat as variable resistor:

If the external circuit is connected between the terminals A and C then that resistance is used only. So,



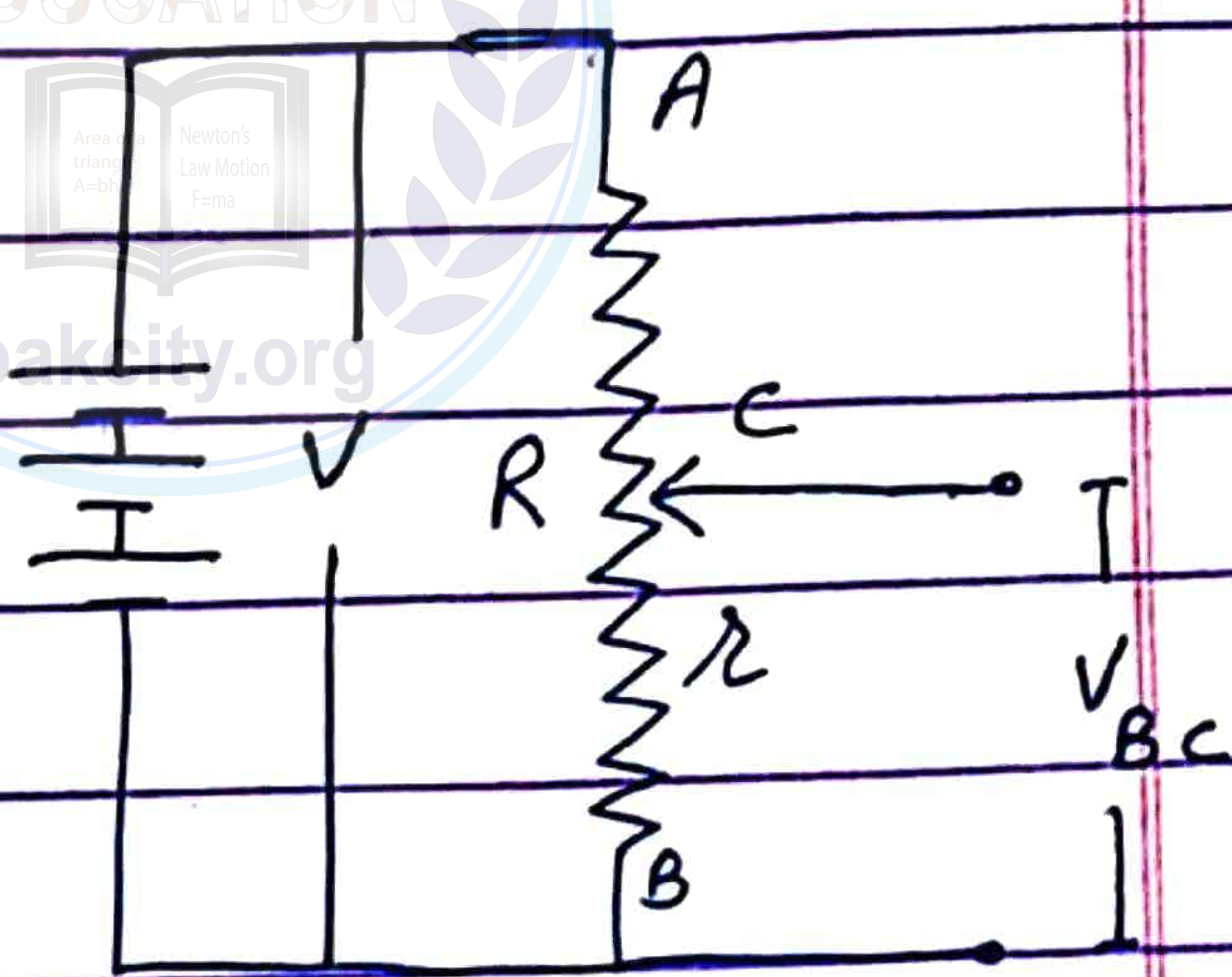
www.pakcity.org

i- If the sliding contact C is moved towards the terminal A the length and resistance decreases.

ii- If the sliding contact C is moved away from the terminal A, the length and resistance increases.

Rheostat as potential divider:

Consider a voltage source with voltage V connected to the rheostat as shown in the figure.



The output voltage is V_{BC} that is given by:

$$V_{BC} = \text{current} \times \text{resistance}$$

The total current in

pakcity.org
www.pakcity.org

the circuit is

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

so,

$$V_{BC} = \frac{V}{R}(r)$$

$$V_{BC} = \frac{r}{R} V$$

The above expression shows that the output voltage V_{BC} is directly proportional to the corresponding resistance r.

i- when the sliding contact c is moved towards the terminal A, the resistance r and voltage V_{BC} increases. At point A the output voltage will be maximum equal to the voltage (V) of the battery.

ii- when the sliding contact c is moved towards the terminal B, the resistance r and voltage V_{BC} decreases. At point B the output voltage will be zero.

www.pakcity.org

Thermistors.

Definition: A thermistor is a heat Sensitive Resistor. Most thermistors has negative Temperature co-efficient of resistance i.e the thermistor of such resistors decreases when their Temperature is increases. Thermistors with positive ~~termina~~ temperature co-efficient are also available.

www.pakcity.org
pakcity.org
EDUCATION
pakcity.org

Construction:

Thermistors are made by heating under high pressure semiconductors ceramic made from mixture of metalic oxides of maganese, nickel, cobalt, copper, iron etc. These are pressed into desired shapes of ~~thermistors are shown~~ and then badked with high temperature. Different types of thermistors are shown. They may be in the form of beads, rods or washers

Uses:

→ They are used for measuring low temperatures especially near 10k

→ They also used to convert changes of temperature in to electrical voltage which is duly processed.

ELECTRIC POWER AND POWER DISSIPATION IN RESISTORS.

www.pakcity.org

Power:

The rate at which the battery is supplying electrical energy is the power output or electrical power of the battery.

$$\text{Electrical power} = \frac{\text{Energy supplied}}{\text{Time taken}}$$

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

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

Electrical power $= V \times I$

Power dissipator (P) = V x I.

$V = IR$

$I = V/R$.

$P = V \times I$

$= IR \times I$

$P = I^2R$.

pakcity.org

$P = V \times I$

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

$P = V^2/R$.

→ The unit of (Power) is "watt",

→ The unit of (V) is "Volt",

→ The unit of (I) is "ampere".

www.pakcity.org
EDUCATION
pakcity.org

Electromotive Force (EMF) AND POTENTIAL DIFFERENCE.

Definition:

Energy supplied to the unit charge by cell.

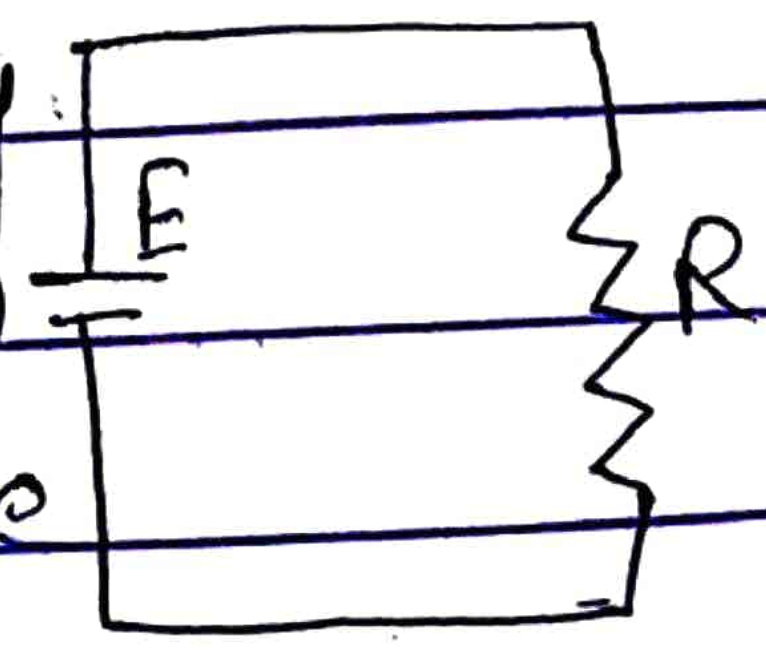
$$E = \frac{\Delta W}{\Delta Q}$$

Unit:

It may be noticed that electromotive force is not a force and we donot measure it in newton. The unit of emf is Joul/Coloumb which is Volt (V)

Explanation:

The cell continously supply energy which is dissipated in the resistance of the circuit.



Suppose when a steady current has been established in the circuit. The charge ΔQ passes through

www.pakcity.org

any cross section of the circuit in time Δt. During the course of motion this charge enters the cell at its low potential and leave at its high potential. The source must supply energy so to the positive charge to force it to go to the point of high potential.

Source of emf:

The energy supplied by the cell to the charge carrier is derived from the conversion of chemical energy into electrical energy inside the cell.

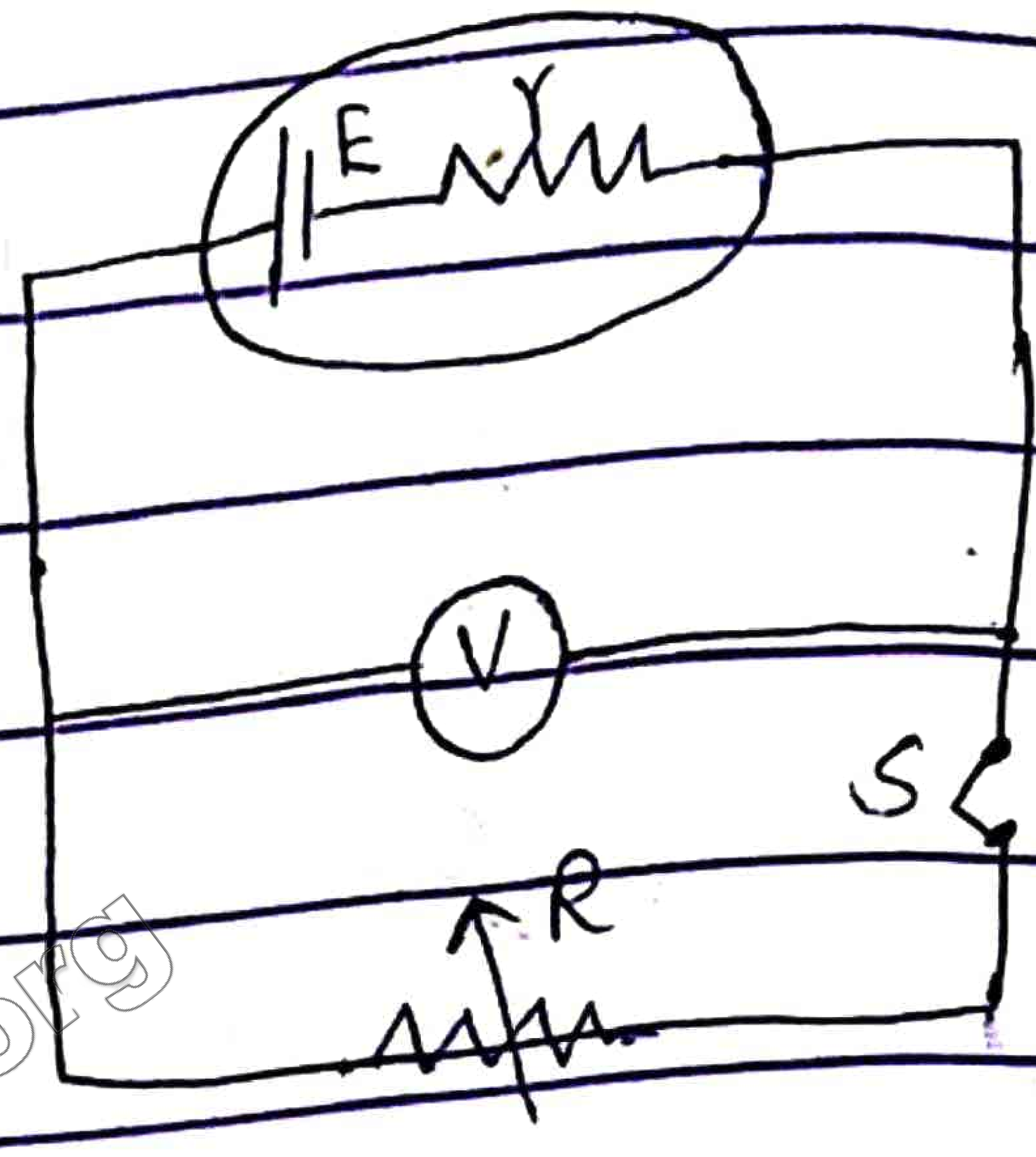
Internal Resistance:

like other components in the circuit a cell also offers some resistance. The Resistance is due to the electrolyte present between the two electrods of the cell is

www.pakcity.org
pakcity.org

Called internal Resistance 'r' of the cell.

Mathematical Expression:



let us Consider the performance of a cell of emf E and internal resistance r as shown in the figure. A voltmeter of infinite resistance measure the potential difference across the external resistance R or the potential difference V across the terminal of the cell the current I flowing through the circuit is given by.

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

$$E = IR + Ir.$$

$$E = V_t + Ir$$

Terminal potential difference:

IR = V is the terminal potential difference of the cell in the presence of current I. When the switch S is open no current passes through the resistance. In this case the Volt meter reads the emf as terminal voltage. Thus terminal voltage in the presence of the current would less then the emf by Ir.

Emf and law of conservation of energy:

The left side of the equation is the emf of the cell which is equal to energy gained by unit charge as its passes through the cell from its negative to positive terminal. The right side of the equation gives

www.pakcity.org
pakcity.org

an account of the utilization of this energy as the current passes the circuit. It states that, as a unit charge passes through the circuit a part of this energy is Ir is dissipated in the cell and the rest of energy is dissipated in to the external resistance R.

www.pakcity.org

Comparison between emf and potential difference.

- The emf is the "cause" and potential difference is its "effect"
- The emf is also present even when no current is drawn through the battery or the cell
- The potential difference across the conductor is zero when no current flows through it.

Maximum Power Output:

When the current I flows in the circuit due to potential difference V. Then the power delivered by the battery or power dissipated across the resistance is given by:

$$P = VI$$

According to Ohm's law:

$$V = IR$$

$$P = (IR)I$$

$$P = I^2R$$

We know that if r is the internal resistance of the battery.

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

So,

$$P = \left(\frac{E}{R+r}\right)^2 R$$

$$P = \frac{E^2R}{(R+r)^2}$$

$$P = \frac{E^2R}{R^2+r^2+2Rr} = \frac{E^2R}{R^2+r^2+2Rr+2Rr-2Rr}$$

$$P = \frac{E^2R}{}$$

pakcity.org

For the maximum power output. The denominator should be minimum.

$$R - r = 0$$

$$R = r$$

So,

$$P_{max.} = \frac{E^2 R}{0 + 4RR} = \frac{E^2 R}{4R^2}$$

$$\boxed{P_{max.} = \frac{E^2}{4R}}$$

So, the power output is maximum when the internal resistance of the battery is equal to the external resistance.

Kirchhoff's Rules:

For any simple circuit Ohm's law is valid But for a complex circuit Kirchhoff's rules are applied. A complex circuit may consists many resistors and many batteries. There are two rules for Kirchhoff's observations.

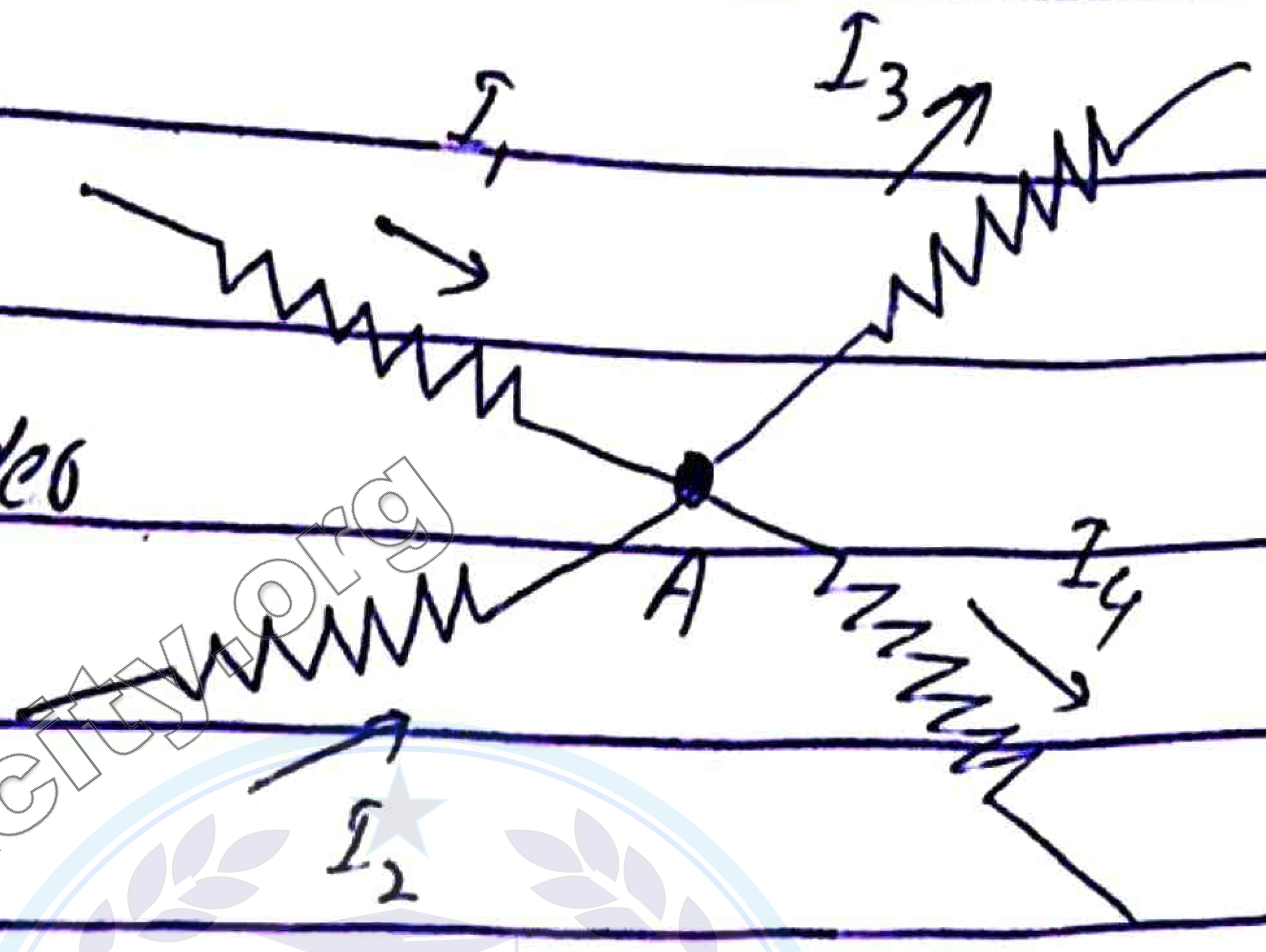
www.pakcity.org
EDUCATION
pakcity.org

Kirchhoff's First Rule:

Statement: The sum of all the current meeting at a point in a circuit is zero. mathematically,

$$\Sigma I = 0$$

Example:



For example, consider a point A through which four currents I_1, I_2, I_3 and I_4 are passing. The currents flowing towards the point are taken as positive while the currents flowing away from that point are taken as negative.

$$I_1 + I_2 + (-I_3) + (-I_4) = 0$$

$$I_1 + I_2 - I_3 - I_4 = 0$$

$$I_1 + I_2 = I_3 + I_4$$

www.pakcity.org

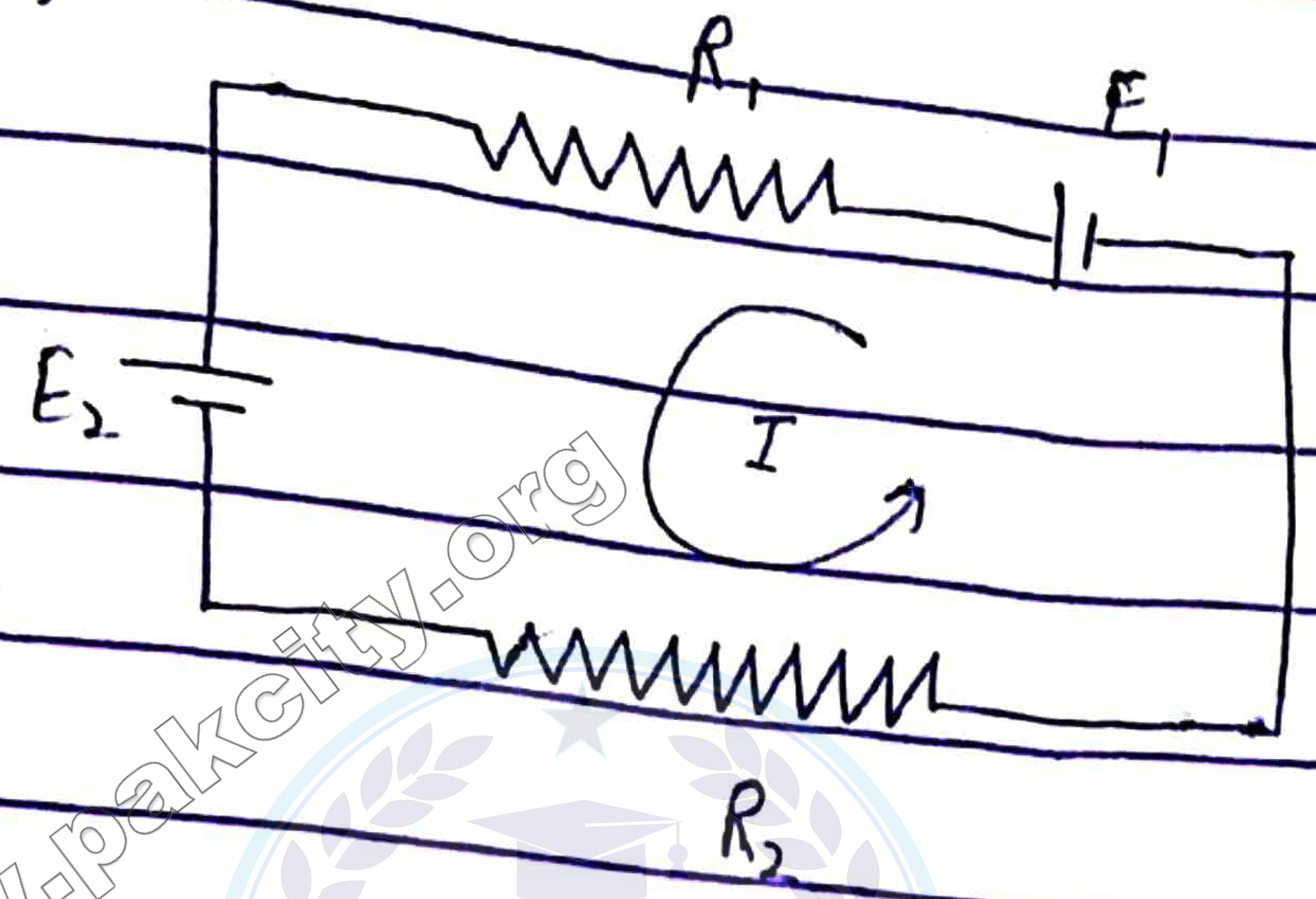
2nd Statement:
The sum of all the currents flowing towards a point is equal to the sum of all the currents flowing away from that point.

Condition: Kirchhoff's first rule satisfy the law of conservation of charge. This rule is also called Kirchhoff's point rule.
The point through which all the currents are passing should neither act as sink nor as source.

Kirchhoff's Second Rule:
Statement:
The algebric sum of potential changes in a closed surface is zero.

www.pakcity.org
pakcity.org

Explanation: consider a circuit in which two batteries of emf E_1 and E_2 and two resistors R_1 and R_2 are connected in series as shown in the figure. The terminals of batteries are opposite in the circuit.



So, the current will flow due to the battery having greater emf. We suppose that $E_1 > E_2$ so the current will flow in anti-clockwise direction. If ΔQ amount of charge is passing in the circuit. we will consider the energy changes in the circuit.

Energy gain through E_1:

The charges ΔQ are moving from low potential to high potential through E_1. So, they will gain energy.

Energy gained through $E_1 = \Delta Q E_1$

Energy loss through R_1:

When the charges ΔQ pass through R_1, they loss energy given by.

Energy loss through $R_1 = -\Delta Q V_1$

$= -\Delta Q I R_1$

Energy loss through E_2.

When the charges ΔQ pass through E_2 they move from high potential to low potential. So, they will loss energy. given by:

Energy loss through $E_2 = -\Delta Q E_2$

www.pakcity.org
pakcity.org

Energy loss through R_2:

When the charges ΔQ pass through R_2, they loss energy given by

Energy loss through $R_2 = -\Delta Q V_2$

$= -\Delta Q I R_2$

In this way the charges ΔQ move in the circuit and total change in energy for the closed circuit should be zero. According to law of conservation of energy.

www.pakcity.org
EDUCATION
pakcity.org

$$\Delta Q E_1 - \Delta Q I R_1 - \Delta Q E_2 - \Delta Q I R_2 = 0$$

$$\Delta Q(E_1 - IR_1 - E_2 - IR_2) = 0$$

$$E_1 - IR_1 - E_2 - IR_2 = 0$$

This is the mathematical expression for Kirchhoff's second rule. It satisfies the law of conservation of energy.

Rules for finding potential changes:

1- If the source of emf is traversed from negative to positive terminal the potential change is positive. It is negative in the opposite direction.

2- If the resistor is traversed in the direction of current the change in potential is negative. It is positive in opposite direction.

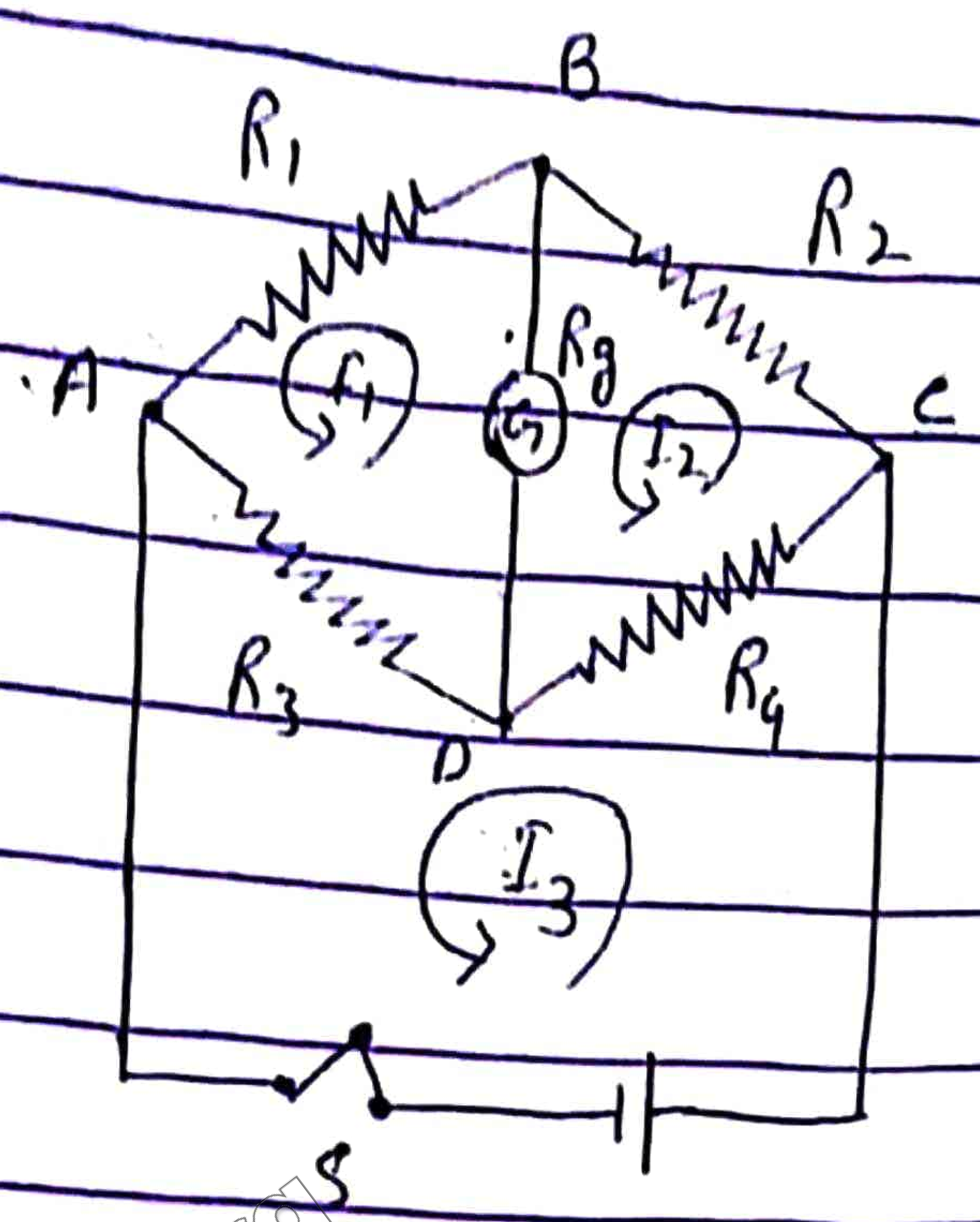
www.pakcity.org
EDUCATION
pakcity.org

Wheatstone Bridge:

Purpose:

Wheatstone bridge is an electrical circuit which is used to measure the unknown resistance.

Construction: Wheatstone bridge consists of four resistors R_1, R_2, R_3 and R_4 connected in the form of a mesh ABCDA. The resistors are connected to the switch S and battery. when the switch is closed



pakcity.org

the current flows in the circuit through three different loops I_1 through ADBA, I_2 through DCBD and I_3 through ADCA.

Condition: To calculate the value of unknown resistance The circuit is adjusted such that the current through galvanometer is zero.

Mathematical Expression:
when the switch is closed the currents I_1, I_2 and I_3 flows in the circuit

through different loops. Now we will apply Kirchhoff's second rule on the loops to calculate the mathematical expression.

For loop ADBA: The energy will be lost through R_1, R_3 and R_g in this loop. So, algebraic sum of potential changes will be:

$$-I_1R_1 - (I_1 - I_2)R_g - (I_1 - I_3)R_3 = 0 \rightarrow (1$$

For loop DCBD: The algebraic sum of potential changes will be:

$$-I_2R_2 - (I_2 - I_1)R_g - (I_2 - I_3)R_4 = 0 \rightarrow (2$$

According to the condition of wheatstone bridge. The current through galvanometer should be zero. So,

$$I_1 = I_2 = I$$

$$I_1 - I_2 = 0 \quad \text{and} \quad I_2 - I_1 = 0$$

www.pakcity.org
EDUCATION
pakcity.org

Now above equations can be modified as:

1) ⇒ $-IR_1 - 0 - (I - I_3)R_3 = 0$

$$-IR_1 = (I - I_3)R_3 \rightarrow (3$$

2) ⇒ $-IR_2 - 0 - (I - I_3)R_4 = 0$

$$-IR_2 = (I - I_3)R_4 \rightarrow (4$$

By dividing eq. (3 by eq. (4

$$\frac{-IR_1}{-IR_2} = \frac{(I - I_3)R_3}{(I - I_3)R_4}$$

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

This is the mathematical expression for wheatstone bridge.

www.pakcity.org

pakcity.org

Result:

If we connect three Resistance R_1, R_2 and R_3 of known adjustable values and the 4th Resistance

R_4 of unknown values and the resistances R_1, R_2 and R_3 are so adjusted that the galvanometer shows no deflection. then, from the known resistances R_1, R_2 and R_3 the unknown resistance R_4 can be determined by using equation.

Potentiometer

Defination:

Potentiometer is an eletrical instrument which measures the potential difference of a battery or some other source. It can also compare the potential difference of two sources.

Comparison with other potential measuring instruments:

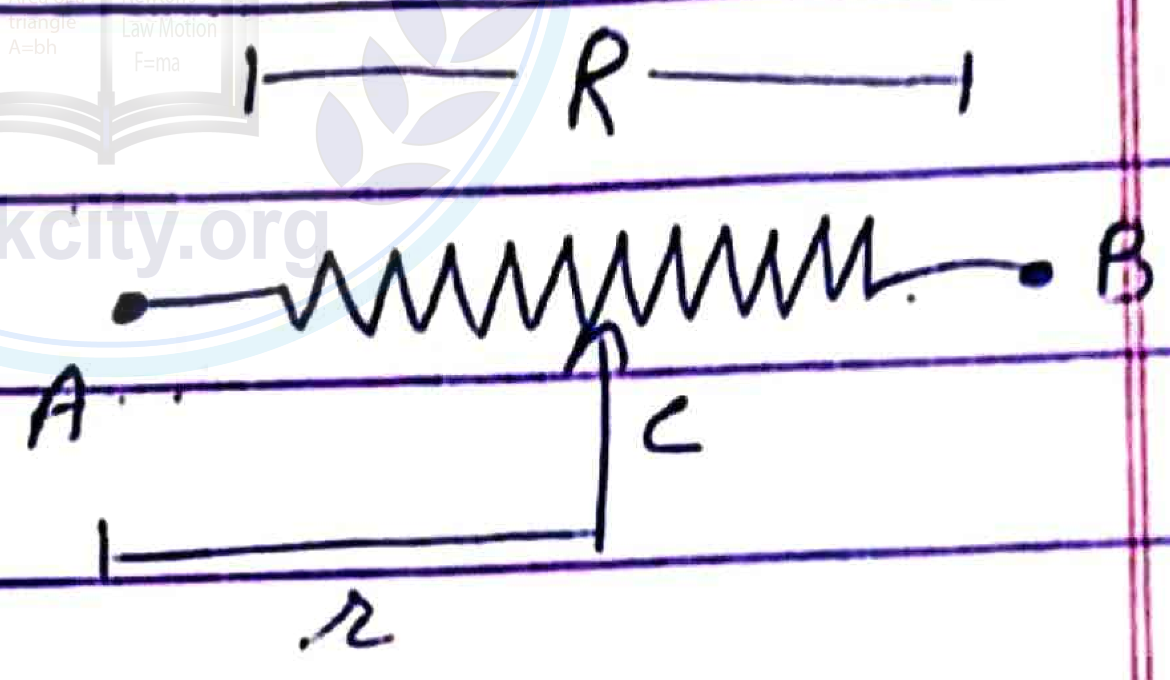
Some instruments like voltmeter and cathode ray oscilloscope (CRO) are also used to measure the potential difference. These instrument are expansive and difficult to use as compared to potentiometer

pakcity.org

Working: A potentiometer also works as variable resistor and potential divider.

As variable Resistor:

Consider the two fix terminals A and B while C is the movable sliding contact

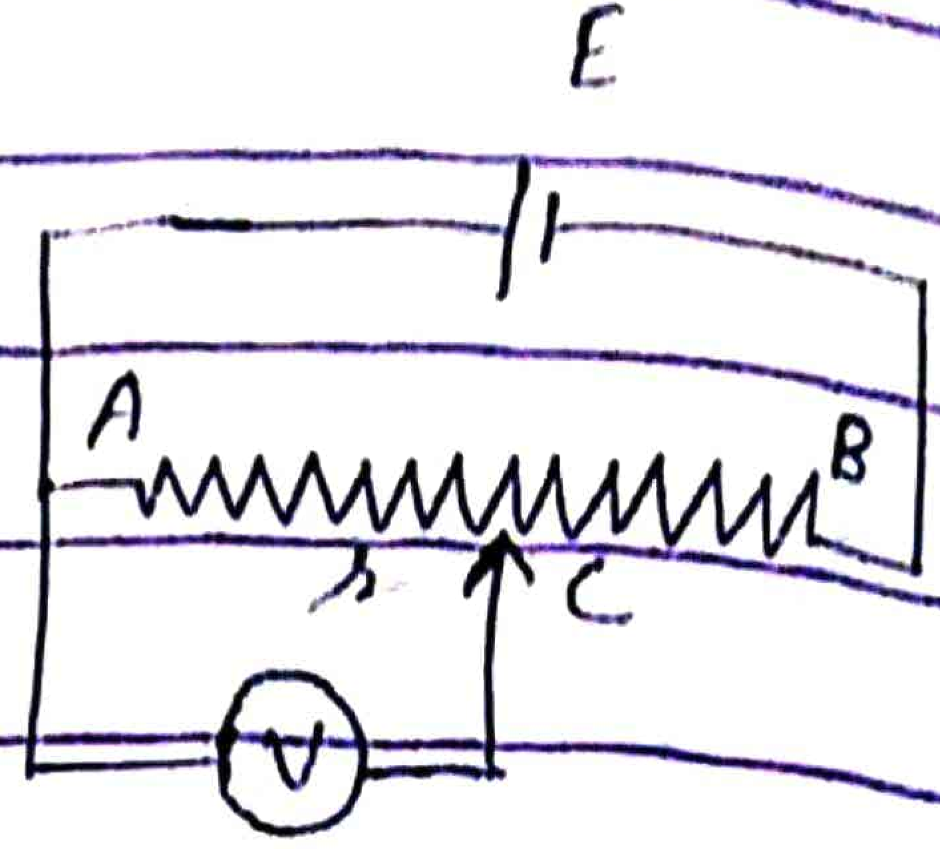


The total resistance is R and used resistance between A and C is r. If sliding contact moves from A to B its resistance increases from 0 to R.

www.pakcity.org
EDUCATION
pakcity.org

As potential divider:

Potentiometer can also act as potential divider. The voltage drop across the points A and C is given by:



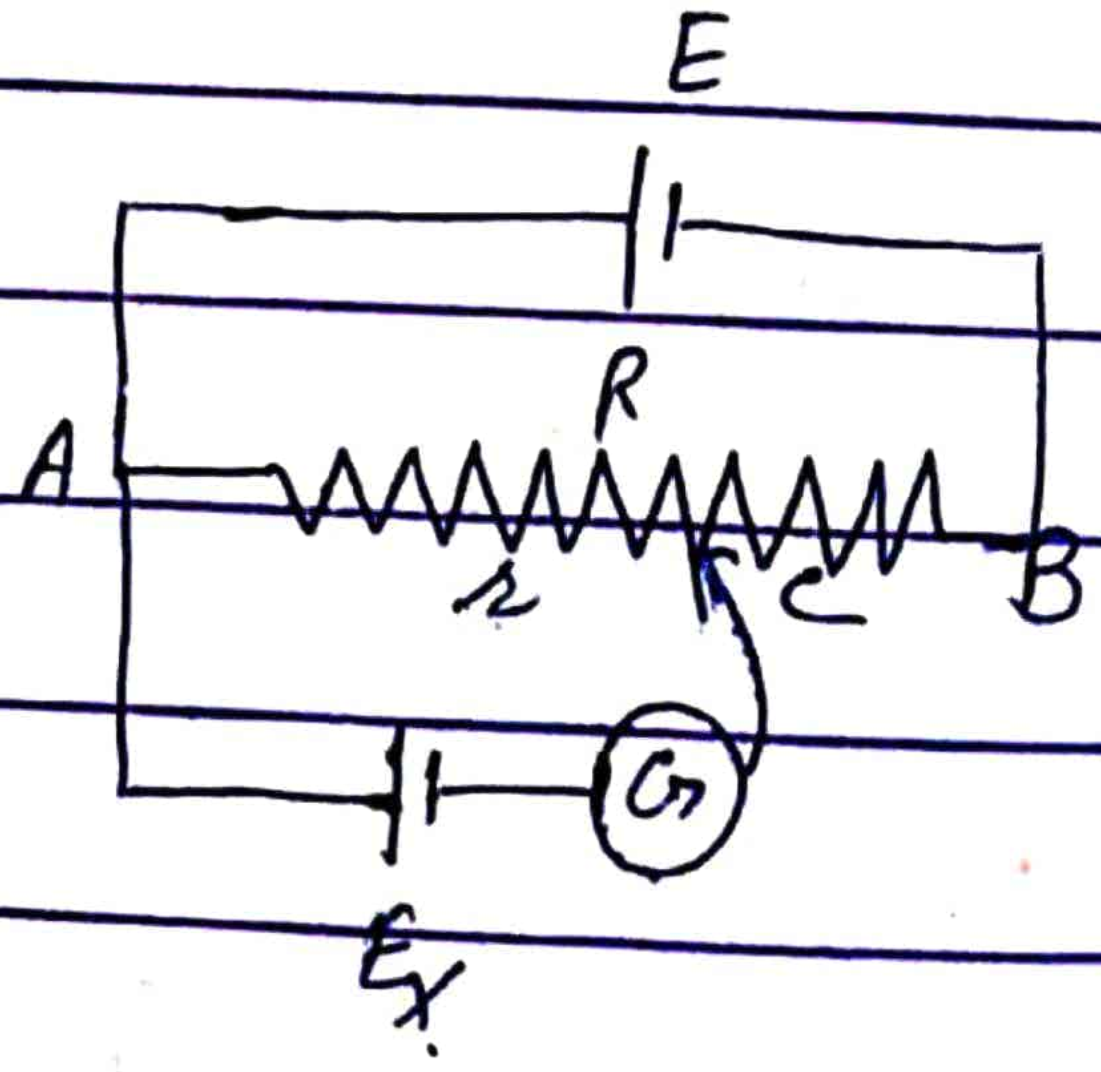
$$\text{voltage drop across A and C} = \frac{r}{R} E$$

When sliding contact C moves from A to B the potential drop increases from 0 to E.

www.pakcity.org
pakcity.org

Measurement of unknown emf:

To measure the unknown emf E_x the positive terminal of battery is



connected with the positive terminal of the potentiometer. Then we adjust the sliding contact. c such that the galvanometer shows zero deflection. At this point the emf of unknown source and that of potentiometer will become equal. So, the unknown emf E_x can be calculated as:

$$E_x = \frac{r}{R} E$$

The resistance is proportional to the length. So,

$$E_x = \frac{l}{L} E$$

Here l is the length between A and c while L is the total length of AB.

www.pakcity.org
EDUCATION
pakcity.org
pakcity.org

Comparison of emf of two cells:

The method to measuring the emf of the cell can be used to compare the emfs E_1 and E_2 of cells the balancing length l_1 and l_2 are found seperatly from the two cells.

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

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

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

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

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

www.pakcity.org
pakcity.org

Short Questions

13.1: The average velocity of the electrons while passing through the conducting copper wire is called drift velocity.

i- By increasing the potential difference across the copper wire, the energy of the electrons will be increased so, drift velocity will increases

ii- By decreasing the length and temperature of the wire resistance of wire will decreases. So, drift velocity will increase.

www.pakcity.org

EDUCATION pakcity.org

pakcity.org

13.2: NO, bends in a wire does not effect its electrical resistance. Because the resistance of a wire depends upon the length, cross sectional area and resistivity of the wire.

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

Due to bends none of

the above factor changes So, resistance does not change due to bends.

13.3: The possible variation from the marked value called tolerance
silver band indicate tolerance of $\pm 10\%$ and gold band indicate the tolerance of $\pm 5\%$. If there is no fourth band tolerance is $\pm 20\%$.

Resistance = $1500\,\Omega \pm 5\%$

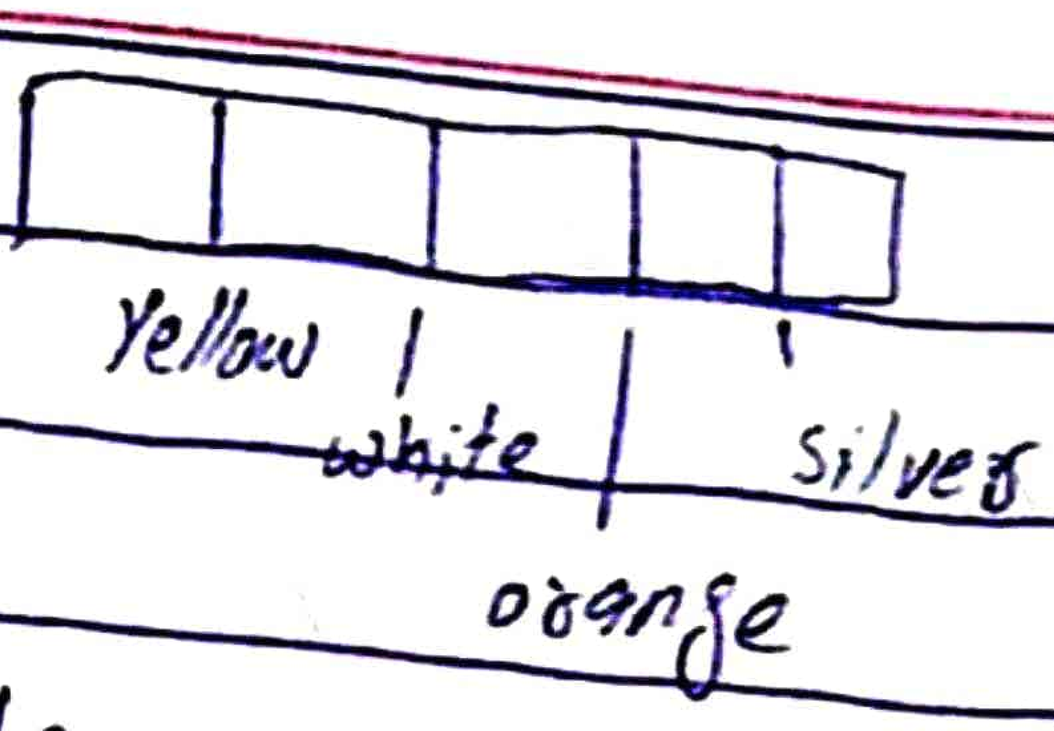
Tolerance = $75\,\Omega$

The resistance will lie between

$1500 + 75$ and $1500 - 75$

$1575\,\Omega$ and $1425\,\Omega$

www.pakcity.org



Resistance = 49000 Ω ± 10%

Tolerance = 4900 Ω

The resistance will lie between:

49000 + 4900 and 49000 − 4900

53900 Ω and 44100 Ω

www.pakcity.org
pakcity.org

13.6

Case.1

$R = ?$, $P = 500W$

$V = 220\ V$

$$P = \frac{V^2}{R}$$

$$R = \frac{V^2}{P}$$

$$= \frac{(220)^2}{500}$$

$$R = 96.8\ \Omega$$

Case.2

$R = ?$, $P = 100W$

$V = 220V$

$$R = \frac{V^2}{P}$$

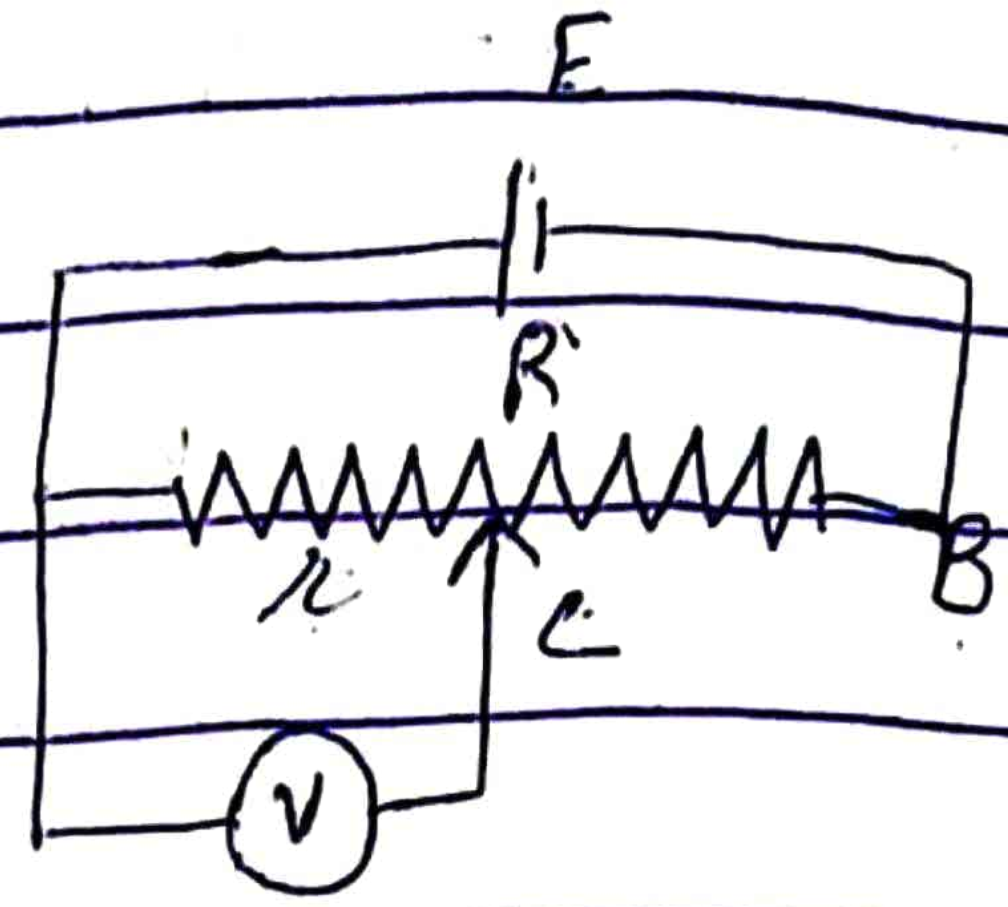
$$= \frac{(220)^2}{100}$$

$$R = 484\ \Omega$$

So, the resistance for case.1 is less than case.2

13.7: The circuit which will give continuously varying potential is shown.

The voltage drop across a point A and C as given by



$$\frac{r}{R}E$$

when sliding contect C move from A to B the potential drop increases from zero to E.

www.pakcity.org
pakcity.org
pakcity.org

13.8: The terminal potential difference is given by

$$V_t = E - Ir$$

when the current drawn from the battery increases The voltage drop across the battery (Ir) also increase. Therefor the terminal potential difference will decrease.

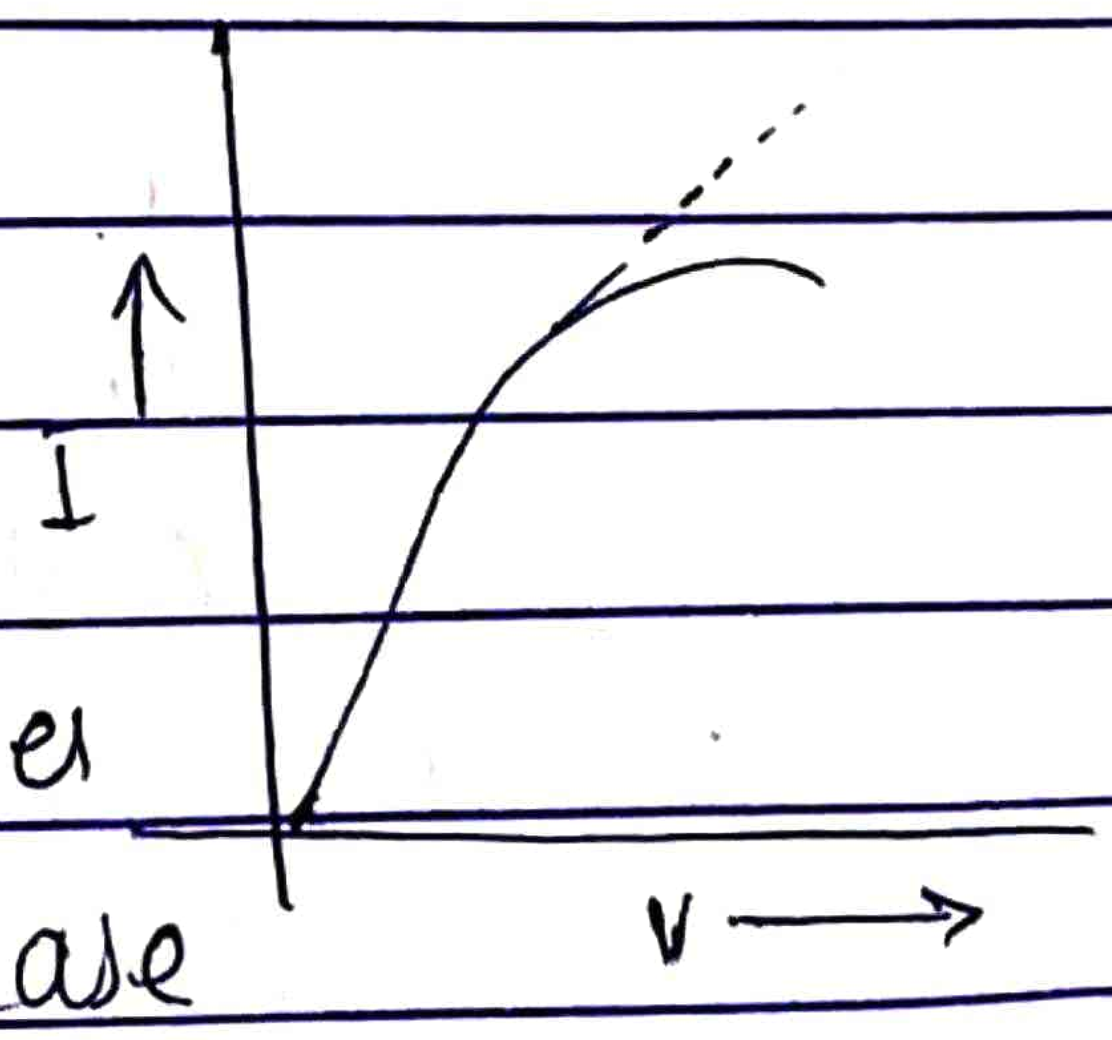
13.4:

When a temperature of the specific conductor increases, the kinitic energy of the electrons and the atoms also increases. Then they vibrate with greater amplitude and collision also increases. Therefor the resistance of the conductor increases.

pakcity.org

13.5:

when the current flowing through the blub. The current increases due to increase



in potential difference. After some time the filament heats up. As a result the resistance increases and current decreases. So, the proportionality is no longer obeyed. Therefore filament bulb does not obey ohm's law.

pakcity.org

13.9: Definition

It is an electrical ~~instrument~~ circuit which is used to measure the unknown resistance.

Result:

If we connect three resistance R_1, R_2 and R_3 of ~~un~~known adjustable values and the 4th resistance R_4 of unknown value. The Resistance R_1, R_2 and R_3 are so adjusted then the galvanometer show no deflection. Then from the known resistance, the unknown resistance can be determined by using equation

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

www.pakcity.org

13.1 Data

number of electrons $n = ?$

time $= t = 1\ min = 60\ s$

current $= I = 300\ mA$

$I = 300 \times 10^{-3}\ A$

charge on one electron $= e = 1.6 \times 10^{-19}\ C$

Solution: we know that

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

here

total charge $= Q = ne$

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

$$It = ne$$

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

$$n = \frac{300 \times 10^{-3} \times 60}{1.6 \times 10^{-19}}$$

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

pakcity.org
www.pakcity.org
EDUCATION
pakcity.org

13.2 Data

charge = Q = 90 C

time = t = 1 hour 15 min.

= 75 min

= 75(60) s

t = 4500 s

current = I = ?

Solution:

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

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

$$I = 0.02\ A$$

$$= 20 \times 10^{-3}\ A$$

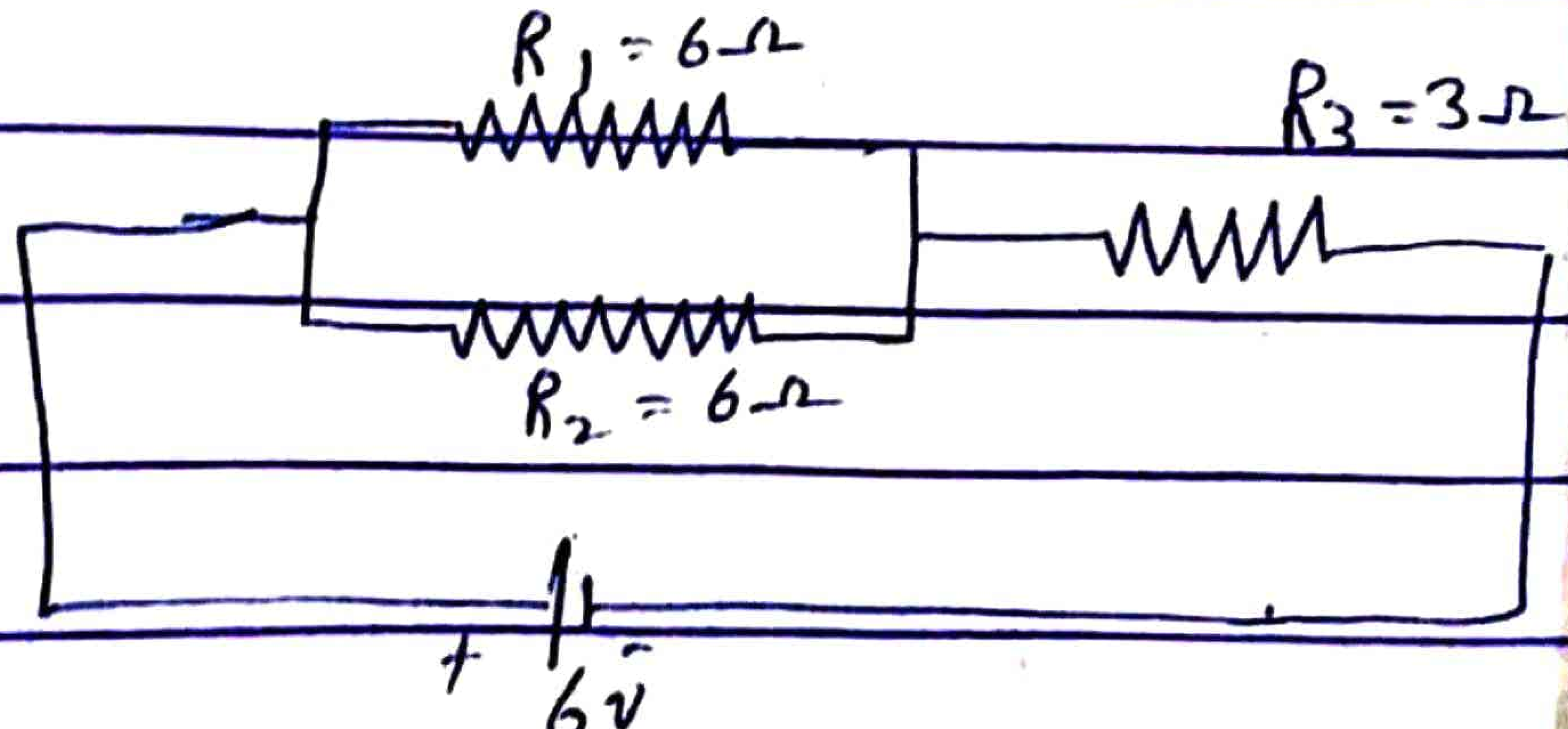
$$\boxed{I = 20\ mA}$$

13.3 Data

Equivalent resistance = R_e = ?

Total current = I = ?

I_1 = ? , I_2 = ? , I_3 = ?



pakcity.org
www.pakcity.org
EDUCATION
pakcity.org

Solution:

pakcity.org

As R_1 and R_2 are connected parallel

$$\frac{1}{R'} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$= \frac{1}{6} + \frac{1}{6}$$

$$= \frac{1+1}{6} = \frac{2}{6}$$

$$\frac{1}{R'} = \frac{1}{3}$$

$$R' = 3\,\Omega$$

www.pakcity.org

Now R' and R_3 are in series.

$$R_e = R' + R_3$$

$$= 3 + 3$$

$$R_e = 6\,\Omega$$

Total current $= I = \frac{V}{R_e}$

$$I = \frac{6}{6}$$

$$I = 1\,A$$

As the resistors R' and R_3 are in series - so, current will same through R_3 as the circuit current.

$$I_3 = 1\,A$$

While the current through R_1 and R_2 will be divided half.

$$I_1 = 0.5\,A$$

$$I_2 = 0.5\,A$$

www.pakcity.org

pakcity.org

13.4 Data

cross-sectional Area of rectangular iron bar

$$= A = 2\,cm \times 2\,cm$$

$$A = \frac{2}{100}\,m \times \frac{2}{100}\,m$$

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

length of bar $= L = 40\,cm$

$$L = \frac{40}{100}\,m$$

$$L = 0.4\,m$$

resistance $= R = ?$

resistivity of iron $= \rho = 11 \times 10^{-8}\,\Omega m$

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

$R = \frac{11 \times 10^{-8} \times 0.4}{4 \times 10^{-4}}$

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

pakcity.org

13.5 Data

temperature $= t_1 = 0°C = 0 + 273\ K$

$t_1 = 273\ K$

resistance $= R_o = 1 \times 10^{4}\ \Omega$

resistance $= R_t = ?$

second temperature $= t_2 = 500°C$

$t_2 = 500 + 273\ K$

$t_2 = 773\ K$

$t = t_2 - t_1$

$= 773 - 273$

$t = 500\ K$

temperature coefficient

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

Solution: $\alpha = \frac{R_t - R_o}{R_o t}$

$\alpha R_o t = R_t - R_o$

$R_o + \alpha R_o t = R_t$

www.pakcity.org

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

$$R_t = 36000\ \Omega$$

$$R_t = 3.6 \times 10^4\ \Omega$$

www.pakcity.org
pakcity.org
pakcity.org