SUBJECT : SCIENCE (PHY)

CHAPTER-12:
ELECTRICITY

TOPIC-4:

FACTORS ON WHICH THE RESISTANCE OF A CONDUCTOR DEPENDS
&
RESISTIVITY

OBJECTIVES:

Upon completion of the topic, you will be able to

1. NAME THE FACTORS ON WHICH RESISTANCE DEPEND
2. EXPLAIN THE WAYS HOW RESISTANCE DEPEND ON THOSE FACTORS
3. DEFINE RESISTIVITY OR SPECIFIC RESISTANCE OF MATERIAL
4. WRITE RELATION BETWEEN RESISTANCE AND RESISTIVITY
5. DIFFERENTIATE BETWEEN RESISTANCE AND RESISTIVITY
6. SOLVE NUMERICAL BASED ON RESISTIVITY
7. WRITE THE UNIT OF RESISTIVITY
8. EXPLAIN CONDUCTIVITY AND RESISTIVITY OF MATERIALS

Factors affecting Resistance

i. Length of conductor.

ii. Area of cross section of the conductor (or thickness of the conductor).

iii. Nature of the material of the conductor, and

iv. Temperature of conductor.

FACTORS AFFECTING RESISTANCE: DIAGRAM

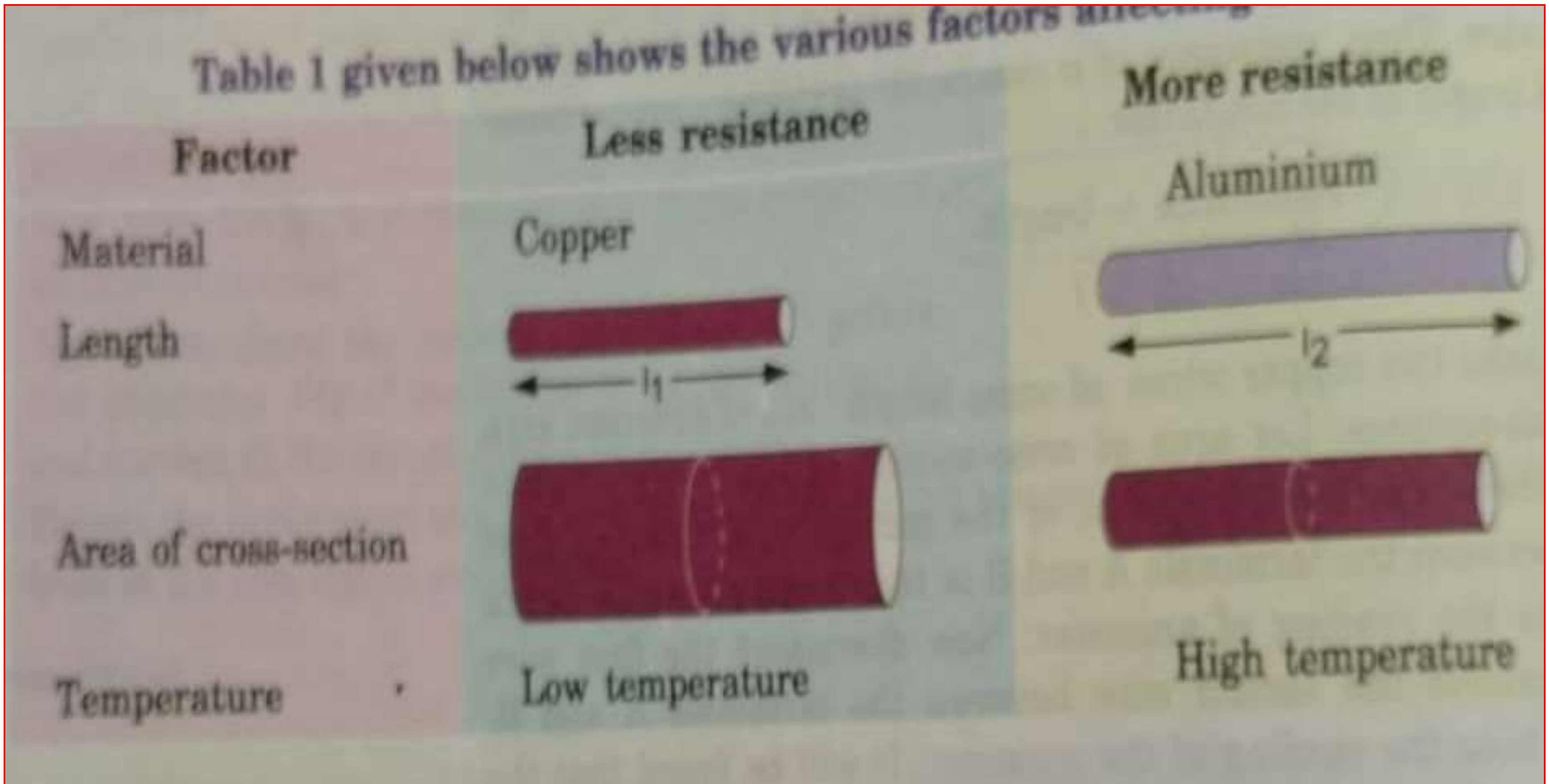

Table 1 given below shows the various factors affecting

Factor	Less resistance	More resistance
Material	Copper	Aluminium
Length	l_1	l_2
Area of cross-section		
Temperature	Low temperature	High temperature

***1. With temperature the resistance of a metallic conductor increases**

2. Different materials have different resistance as they have their own characterictics

Resistivity

- It has been found by experiments that :
- The resistance of a given conductor is directly proportional to its length.

$$R \propto l \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

- The resistance of a given conductor is inversely proportional to its area of cross section.

$$R \propto 1/A \quad \ldots\ldots\ldots\ldots\ldots (2)$$

Combining (1) and (2), we get :

$$R \propto l/A$$

$$R = p \times \frac{l}{A} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

- Where p(rho) is a constant known as resistivity of the material.
- The resistivity of a substance is numerically equal to the resistance of a rod of that substance which is 1 meter long and 1 square meter in cross section.
- Resistivity, $p = \frac{R \times A}{l}$.
- The unit of resistance R is ohm.
- The unit of area of cross-section A is $(\text{meter})^2$.
- The unit of length l is meter.

putting these unit in the above equation –

$$p = \frac{ohm \times (meter)^2}{meter}.$$

$$p = \text{ohm-meter}.$$

The S.I. unit of resistivity is ohm-meter (Ωm)

DEFINITION OF RESISTIVITY: Resistivity of a conductor is defined as the resistance of the conductor of unit length and unit area of cross section.

Note: 1. resistivity is also known as specific resistance
2. Resistivity depends on temperature and nature of material
3. Resistivity does not depend on length and cross sectional area of the conductor.

Resistivity of some common substances (20^0 C)

	Material	Resistivity (Ω m)
Conductors	Silver	1.60×10^{-8}
	Copper	1.62×10^{-8}
	Aluminium	2.63×10^{-8}
	Tungsten	5.20×10^{-8}
	Nickel	6.84×10^{-8}
	Iron	10.0×10^{-8}
	Chromium	12.9×10^{-8}
	Mercury	94.0×10^{-8}
	Manganese	1.84×10^{-6}
Alloys	Constantan (alloy of Cu and Ni)	49×10^{-6}
	Manganin (alloy of Cu, Mn and Ni)	44×10^{-6}
	Nichrome (alloy of Ni, Cr, Mn and Fe)	100×10^{-6}
Insulators	Glass	$10^{10} - 10^{14}$
	Hard rubber	$10^{13} - 10^{16}$
	Ebonite	$10^{15} - 10^{17}$
	Diamond	$10^{12} - 10^{13}$
	Paper (dry)	10^{12}

Note : the value of resistivity is as like: **1.60×10^{-8}**

- The resistivity of alloys are much more than those of pure metals (from which they are made).
- For example the resistivity of maganine (which is an alloy of copper, manganese and nickel)is about 25 times more than that of copper.
- Alloys are used in making heating a materials as –

i. Alloys have very high resistivity (due to which heating elements produce a lot of heat on passing current).

ii. Alloys do not undergo oxidation easily even at high temprature.

Formula of Resistivity

The resistivity formula is expressed as

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

Where p is the resistivity, ***R*** is the resistance, ***l*** is the length of the material and ***A*** is the area of cross-section.

Resistivity Solved Examples

Problem 1: Compute the resistivity of the given material whose resistance is 2 Ω; area of cross-section and length are 25cm^2 and 15 cm respectively?
Answer:

Given

R = 2 Ω

l = 15 cm = 0.15 m

A = 25 cm^2 = 0.25 m^2

Resistivity formula is

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

$$\rho = \frac{2 \times 0.25}{0.15} = 3.333\Omega m$$

Problem 2: The length and area of wire are given as 0.2 m and 0.5 m^2 respectively. The resistance of that wire is 3 Ω, calculate the resistivity?
Answer:

Given

R = 3 Ω

l = 0.2 m and

A = 0.5 m^2

Resistivity formula is

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

$$\rho = \frac{3 \times 0.5}{0.2} = 7.5\Omega m$$

Question 1:

On what factors does the resistance of a conductor depend?

Answer 1:

The resistance of a conductor depends upon the following factors:

- Length of the conductor
- Cross-sectional area of the conductor
- Material of the conductor
- Temperature of the conductor.

Question 2:

Will current flow more easily through a thick wire or a thin wire of the same material, when connected to the same source? Why?

Answer 2:

Resistance (R) is inversely proportional to the area of cross-section (A) of the wire. So, thicker the wire, lower is the resistance of the wire and vice-versa. Therefore, current can flow more easily through a thick wire than a thin wire.

Question 3:

Let the resistance of an electrical component remains constant while the potential difference across the two ends of the component decreases to half of its former value. What change will occur in the current through it?

Answer 3:

According to the Ohm's law $V = IR$

If the resistance remains constant, V is directly proportional to I.

$$V \propto I$$

Now, if potential difference is reduced to half of its value, the current also become half of its original value

Question 4:

Why are coils of electric toasters and electric irons made of an alloy rather than a pure metal?

Answer 4:

The resistivity of an alloy is higher than the pure metal and it does not corrode easily. Moreover, even at high temperatures, the alloys do not melt readily. Hence, the coils of heating appliances such as electric toasters and electric irons are made of an alloy rather than a pure metal.

Problem 5: Compute the resistivity of the given material whose resistance is 2 Ω; area of cross-section and length are 25cm^2 and 15 cm respectively?

QUESTION-6:

TWO WIRES A and B ARE OF EQUAL LENGTH, DIFFERENT CROSS SECTIONAL AREAS AND MADE OF SAME METAL

a. Name the property which is same for both (Ans: resistivity)
b. . Name the property which is different for both (Ans: resistance)

QUESTION-7:

We have a copper wire of resistance R. this wire is pulled so that its length is doubled(temperature is same). Find the new resistance of the wire in terms of its original resistance.

SOLUTION:

Due to increase of length by two times, resistance also increases by 2 times. On increasing length double, area of cross section reduces to half and thus again resistance increases twice duce to cross sectional area. Hence the new resistance of the wire will be 4 times the original resistance

QUEESTION-8: An aluminium wire has diameter 0.5 mm and resistivity 2.8 x 10^{-6} ohm-cm. How much length of this wire is required to make a 10 ohm coil?

Solution. Here, diameter, $D = 0{\cdot}5$ mm

$\therefore$ Radius, $r = \frac{0{\cdot}5}{2} = 0{\cdot}25 \text{ mm} = 0{\cdot}25 \times 10^{-3}\text{m}$

Resistivity, $\rho = 2{\cdot}8 \times 10^{-6}$ ohm–cm $= 2{\cdot}8 \times 10^{-8}$ ohm-m

Since area of cross-section of wire is circular , so $A = \pi r^2$

Resistance, R = 10 ohm

Length, $l = ?$

Using $R = \rho\frac{l}{A} = \rho\frac{l}{\pi r^2}$, we get (Here $A = \pi r^2$)

$$l = \frac{\pi R r^2}{\rho} = \frac{22}{7} \times \frac{10 \times (0{\cdot}25 \times 10^{-3})^2}{2{\cdot}8 \times 10^{-8}} = \mathbf{70{\cdot}15\ m}$$

Question-9: A copper wire has diameter 0.5 mm and resisitivity 1.62 x 10^{-8} ohm-metre. What will be the length of this wire of resistance 10 ohm? How much does the resistance change if the diameter is doubled?

Solution. Here,

$$D = 0.5 \text{ mm} = 5\times10^{-4} \text{ m}$$

$$\rho = 1.62 \times 10^{-8} \ \Omega\text{–m}$$

$$R = 10 \ \Omega.$$

Step 1. Using,

$$R = \frac{\rho l}{A} = \frac{\rho l}{\pi r^2} = \frac{\rho l}{\pi\left(\frac{D}{2}\right)^2} = \frac{4\rho l}{\pi D^2}, \text{ we get}$$

$$l = \frac{\pi R D^2}{4\rho} = \frac{3.14\times 10\times(5\times10^{-4})^2}{4\times1.62\times10^{-8}} = 121.14 \text{ m}$$

Thus, length of wire = **121.14 m**

Step 2. If diameter is doubled, then

$$R' = \frac{4\rho l}{\pi(D')^2} = \frac{4\rho l}{\pi(2D)^2} = \frac{1}{4}\times\left(\frac{4\rho l}{\pi D^2}\right)$$

But

$$\frac{4\rho l}{\pi D^2} = R$$

$\therefore$

$$R' = \frac{1}{4}R$$

Thus, resistance of the wire will become $= \frac{1}{4}$ times the original resistance of the

Question-10: Calculate the resistance of 1 km long copper wire of radius 1 mm. (Resistivity of copper = 1.72 x 10^{-8}

SOLUTION:

L = 1 km = 1000 m
Radius r = 1 mm = 1 x 10^{-3}
p = 1.72 x 1 0-8 ohm- m

Area of cross section, A = ∏ r2 = 3.14 x 10^{-3} x 10^{-3} = 3.14 x 10^{-6}

R = pl/A = (1.72 x 1 0-8 x 1000) / 3.14 x 10^{-6} = 5.5 ohm

QUESTION-12: What is the role of resistance in an electric circuit?

ANSWER: It is used to control current in the circuit.

NOTE:

1. Resistivity of metals is low and hence their conductivity is high. Thus metal are good conductors.
2. Resistivity of insulators is very high and hence conductivity is very poor. Thus insulators are bad conductor of electricity.
3. Resistivity of alloy is greater than metal but less than insulators.