VIVEKANAND EDUCATION SOCIETY'S POLYTECHNIC

Study Material

Program Code: All Program

Semester: First

Course Name: Basic Science (Physics)

Course Code: 22102

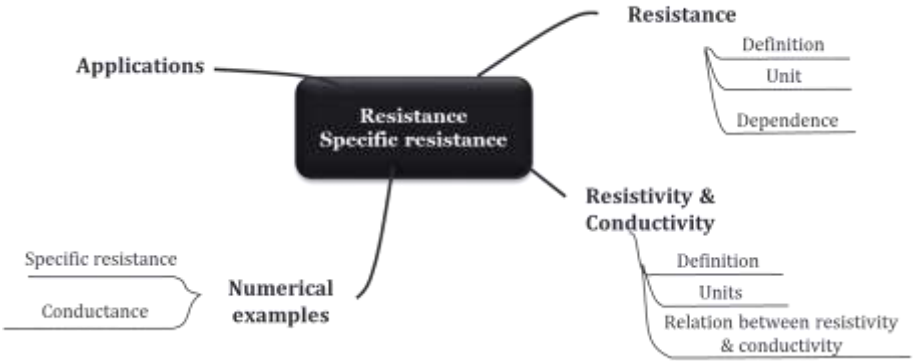
Topic Name: Electricity, Magnetism & Semiconductors

UO2d: Apply laws of series and parallel combination in the given electric circuits.

LO6: Student will be able to solve problems on specific resistance.

Course Expert: S. K. Rawat	**Date: 27/08/2020**

Concept Map:



Key words: electric resistance, specific resistance, conductance, conductivity

Key Questions:

1. What is resistance and specific resistance?
2. What are the factors on which specific resistance depends?

Key Definition:

1. The opposition offered to flow of current by the conductor.
2. If the potential difference across the two ends of a conductor is 1 V and the current through it is 1 A, then the resistance R, of the conductor is 1 Ω.
3. Resistivity of material is defined as the resistance of material of unit length having unit area of cross section.
4. Conductance of a conductor is a measure of ease with which the current will flow through it and is the reciprocal of resistance.
5. It is the property of material which easily allows flow of current through it.

Formula:

1. Specific resistance $\rho = \frac{RA}{\ell}$
2. Conductance $G = \frac{1}{R}$
3. Conductivity $\sigma = \frac{1}{\rho}$

Notes

Resistance

It is the property of a conductor to resist the flow of charges across it. Or The opposition offered to flow of current by the conductor.

According to Ohm's law, $R = \frac{V}{I}$

One Ohm

If the potential difference across the two ends of a conductor is 1 V and the current through it is 1 A, then the resistance R, of the conductor is 1 Ω. i.e.,

Its SI unit is ohm, represented by the Greek letter Ω.

Factors on which resistance depends

Practically, it has been observed that the resistance of the conductor depends on –

(i) length of conductor,
(ii) area of cross-section, and
(iii) the nature of its material.

Precise measurements shows that resistance of a uniform metallic conductor is directly proportional to its length (l) and inversely proportional to the area of cross-section (A). i.e.,

$$R \propto \ell$$

and $$R \propto \frac{1}{A}$$

Combining above equation, we get

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

or $$R = \rho \frac{\ell}{A}$$

where ρ (rho) is a constant of proportionality and is called the specific resistance or resistivity of conductor.

Resistivity:

As resistance depends on nature of the material and temperature, therefore resistance of different materials of same dimensions will be different. Hence resistivity is characteristics property of the material.

As we know $R = \rho \frac{\ell}{A}$

$$\therefore \quad \rho = \frac{RA}{\ell}$$

Thus if A = 1 and $\ell = 1$, then $\rho = R$

Definition

Resistivity of material is defined as the resistance of material of unit length having unit area of cross section.

Unit As we know $\rho = \frac{RA}{\ell}$ In terms of unit, $\rho = \frac{1\Omega \ 1m^2}{1m} = 1\Omega m$

The SI unit of resistivity is Ωm.

Conductance

Conductance of a conductor is a measure of ease with which the current will flow through it and is the reciprocal of resistance. The conductance is denoted by symbol G.

$$G = \frac{1}{R}$$

The unit of conductance is termed mho.

Conductance and Conductivity

Conductance

It is the measure of ease with which the current will flow through conductor or It is the reciprocal of resistance.
SI Unit: Symbol is G and unit is mho or Siemens.

Conductivity

Conductivity depends on resistivity of the material. It is the property of material which easily allows flow of current through it.

Definition

The reciprocal of the resistivity is called conductivity of the material. i.e.,

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

Unit

As $\sigma = \frac{1}{\rho}$, therefore unit of $\sigma = \frac{1}{\Omega m}$

SI unit of conductivity is siemens/metre or 1/(ohm metre)

Calculate the conductance of a wire if 400 mA of current flows through the wire having p.d of 10 V between its end.

Given: $I = 400\,mA$ and $V = 10\,V$

Find: G

Formula: $R = \frac{V}{I}$ and $G = \frac{1}{R}$

Solution: We know $R = \frac{V}{I}$

$$\therefore \quad R = \frac{10}{400 \times 10^{-3}} = 25\,\Omega$$

The conductance G is calculated as $G = \frac{1}{R}$

$$\therefore \quad G = \frac{1}{25} = 0.04 \text{ mho}$$

Ans: Thus, the conductance is 0.04 mho.

The resistance of a copper wire of 5 m long is 0.5Ω. If the diameter of wire is 0.045 cm, determine its specific resistance.

Given: $R = 5\Omega, \ell = 0.5\,m$ and $d = 0.045\,cm$

Find: ρ

Formula: $A = \frac{\pi}{4}d^2$ and $\rho = \frac{RA}{\ell}$

Solution: As area of cross-section is $A = \frac{\pi}{4}d^2$

$$\therefore \quad A = \frac{\pi}{4} \times \left(0.045 \times 10^{-2}\right)^2 = 1.6 \times 10^{-7}\ m^2$$

The specific resistance is calculated as $\rho = \frac{RA}{\ell}$

$$\therefore \quad \rho = \frac{0.5 \times 1.6 \times 10^{-7}}{5} = 16 \times 10^{-9}\,\Omega m$$

Ans: Thus, the specific resistance is $16 \times 10^{-9}\,\Omega m$.

The resistance of a copper wire 200 m long is 21Ω. If its thickness is 0.022 cm, calculate its specific resistance and conductivity.

Given: $R = 21\Omega, \ell = 200\,m$ and thickness $(t) = 0.022\,cm$

Find: ρ and σ

Formula: $A = \frac{\pi}{4}d^2, \rho = \frac{RA}{\ell}$ and $\sigma = \frac{1}{\rho}$

Solution: As area of cross-section is $A = \frac{\pi}{4}d^2$

$$\therefore \quad A = \frac{\pi}{4} \times \left(0.022 \times 10^{-2}\right)^2 = 3.8 \times 10^{-8}\,m^2 \quad \text{As } t = \text{diameter } (d) = 0.022\,cm$$

The specific resistance is calculated as $\rho = \frac{RA}{\ell}$

$$\therefore \quad \rho = \frac{21 \times 3.8 \times 10^{-8}}{200} = 4 \times 10^{-9}\,\Omega m$$

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

$$\therefore \quad \sigma = \frac{1}{4 \times 10^{-9}} = 2.5 \times 10^{8}\,S/m$$

Ans: Thus, the specific resistance is $4 \times 10^{-9}\,\Omega m$ and conductivity is $2.5 \times 10^{8}\,S/m$.

Applications

Entertainment
Today, the modern sources of entertainment starting from listening to music from MP3 players, watching Television, playing movies in DVDs or VCDs or VCRs runs on electricity.

Healthcare
We can see the use of electricity for operating modern technologies every day. These surgical operations won't even start without electricity. For example, the doctors need a powerful light during an operation on a patient and without electricity, the light won't function, and operation can prove fatal.

Engineering
Constructions of buildings and structures for the convenience of people require electricity in every step. Building houses, installing gates and windows, welding of materials require current electricity to operate the machines.

Transport and Communication
Reaching places or communicating from a different corner of the world is only possible because of electricity. A power cut during airline travel can be dangerous.

Outdoors
The street lights on the road use electricity to function, even the pool requires electricity to heat the water in colder regions. The lawnmower, which is used to cut grass uses electricity to operate. The water sprinkler for the grass on the lawn uses electricity as well.

Household
Starting from toaster to refrigerator, microwave, washing machine, dishwasher, electrical chimney, and many more appliances which are simple to use and made for the convenience of day to day activities use electricity to function.

Commercial purposes
For the production of various materials, the factory uses heavy machinery which always runs on electricity. Even the magnets which are of a giant like structures require electricity to keep it charged for lifting heavy metals.

Offices
We go to work in offices in which most things run on electricity. The lights, lifts, AC, coffee machine, ID card reader, biometric scanners and everything else require electricity.

Fuel
Electrical energy comes under renewable energy, and we can produce it using most of the natural resources available to us. Today, things which were running on fossil fuels such as cars and bikes, are now made in such a way that it runs on electricity (like solar-powered), which will be more convenient in the future.

Space
The satellites and probes which are sent from the earth for space expeditions run on electricity. The electricity is generated with the help of a generator or is battery powered. The Apollo mission for the landing of humans on the moon, would not have been possible without the use of electricity.

Link to YouTube/ OER/ video/e-book:

1. http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html
2. https://learn.sparkfun.com/tutorials/what-is-electricity/all
3. https://www.studyrankers.com/2017/08/notes-of-ch-12-electricity-class-10th.html
4. https://byjus.com/physics/uses-of-electricity/

Key Take away:

1. Difference between electric resistance and electrical conductance.
2. Factors on which resistance of conductor depends.

Formative Assessments

<22102> : <All Program> : < All Program >: <Electricity, Magnetism & Semiconductors>: <UO2d> : <LO6> : <Assessments> : <Formative>

<S. K. Rawat>

Assessment Type: Formative Assessments: Embedded questions in video/ PPT

Set 1		
Question No 1	Question No 2	Question No 3
At constant temperature, the resistance of a material is _____ length of the material.	If the length and area of cross-section of a wire are doubled, then its resistance.	A length of wire has a resistance of 10 ohms. What is the resistance of a wire of the same material three times as long and twice the cross-sectional area?
Remembering	Understanding	Applications
a) directly proportional to	a) becomes four times	a) 30 ohms
a) independent of	b) becomes sixteen times	b) 20 ohms
b) inversely proportional to	c) remains the same	c) 15 ohms
c) equal to	d) becomes two times	d) 7 ohms
Ans: <directly proportional to>	Ans: < remains the same >	Ans: <15 ohms >

Set 2		
Question No 1	Question No 2	Question No 3
SI unit of conductance is _____.	_____ is the reciprocal of resistance.	If the resistance of a material 2 m long and 2 m2 in area of cross-section is 1.6 × 10-8 Ω, then its resistivity is
Understanding	Understanding	Application
a) Siemens	a) Conductance	a) 3.2×10^{-8} Ω-m
b) volt	b) Conductivity	b) 1.6×10^{-8} Ω-m
c) ohm	c) Resistivity	c) 0.64×10^{-8} Ω-m
d) farad	d) Specific resistance	d) 0.16×10^{-8} Ω-m
Ans: < Siemens >	Ans: < Conductance >	Ans: <0.64×10^{-8} Ω-m >

Practice Worksheets

<22102> : <All Program> : < All Program >: <Electricity, Magnetism & Semiconductors>: <UO2d> : <LO6> : <Assessments> : <Formative>

<S. K. Rawat>

A. The bigger the diameter of a wire, a) more current can pass b) less current can pass c) more heat is generated when current flow d) the higher is the electrical resistance	B. The longer the wire the _____ is the resistance a) higher b) lesser c) harder d) smaller
Ans A:	Ans B:
C. If a conductor's cross-sectional area is doubled and its length is halved, the value of its resistance will a) double b) quadruple c) decrease by a factor of two d) decrease by a factor of four	D. If the resistance of a material 2 m long and 2 m^2 in area of cross-section is 1.6×10^{-8} Ω, then its resistivity is _____. a) 3.2×10^{-8} Ω-m b) 1.6×10^{-8} Ω-m c) 0.64×10^{-8} Ω-m d) 0.16×10^{-8} Ω-m
Ans C:	Ans D:
E. The specific resistance of wire 5 m in length, having 1 mm2 cross-sectional area and resistance 500 Ω is _____. a) 1 μΩ-m b) 10 μΩ-m c) μΩ-m d) 0.01 μΩ-m	F. The conductivity of a conductor _____, with increase in temperature. a) decreases b) increases c) remain same d) none of the above
Ans E:	Ans F:
G. _____ is the reciprocal of resistance. a) Conductance b) Conductivity c) Resistivity d) Specific resistance	H. Calculate the conductance of a wire if 400 mA of current flows through the wire having p.d of 10 V between its end. a) 4 mho b) 0.4 mho c) 0.04 mho d) 40 mho
Ans G:	Ans H:
I. 1mho = _____ a) 1/Ω-m b) Ω-m c) S d) Ω	J. The resistance of a copper wire of 5 m long is 0.5Ω. If the diameter of wire is 0.045 cm, determine its specific resistance. a) 3.2 × 10 -9 Ω-m b) 1.6 × 10 -9 Ω-m c) 64 × 10 -9 Ω-m d) 16 × 10 -9 Ω-m
Ans I:	Ans J: