Relation of drift velocity, mobility with electric current

CLASS-XII

SUBJECT : PHYSICS
CHAPTER NUMBER: 03
CHAPTER NAME : CURRENT ELECTRICITY

CHANGING YOUR TOMORROW

Website: www.odmegroup.org
Email: info@odmps.org
Toll Free: **1800 120 2316**
Sishu Vihar, Infocity Road, Patia, Bhubaneswar- 751024

LEARNING OUTCOME

After this lesson, students will be able:

- To derive relationship between drift velocity and mobility.
- To state the mathematical definition of current density.
- To use an understanding of the convention for electric field direction to identify the electric field direction around a source charge.
- To derive relationship of Mobility in terms of relaxation time
- To derive relationship between Mobility and conductivity.

Slide 2

3

@Format for content and slide heading is missing? Just like you have mentioned in DOC., We need to specify, for each slide's heading and text content, what will be the font style +amanrouniyar@odmegroup.org
Assigned to you
-Swoyan Satyendu
, 6/17/2020

REVIEW

1. What is a drift velocity?
2. Are the paths of electrons straight lines between successive collisions (with positive ions of the metal) in the

   (i) Absence of electric field

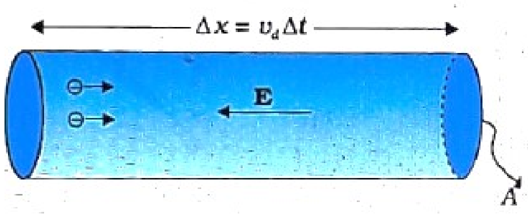
   (ii) Presence of electric field.
3. How does drift velocity depend upon temperature?
4. How is drift velocity related to current?

ODM EDUCATIONAL GROUP
Changing your Tomorrow

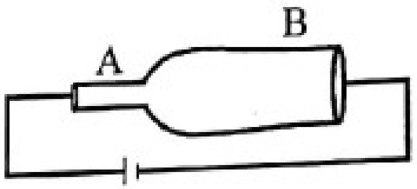
THE RELATION BETWEEN ELECTRIC CURRENT AND DRIFT VELOCITY :

Hence current through the conductor is

$$I = \frac{\Delta q}{\Delta t} = \frac{nA(\Delta x)e}{\Delta x / v_d} = nAv_d e \Rightarrow I = nAv_d e$$



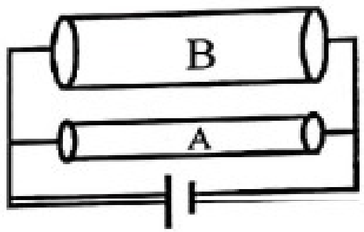
NOTE



(i) Since A, n, and e are constants I α v_d

(ii) If I = constant $\Rightarrow v_d \alpha \frac{1}{A}$ (since $v_d = \frac{I}{nAe}$)

In the given figure $(v_d)_A > (v_d)_B$



(iii) As drift speed can be, $v_d = \frac{I}{nAe} = \frac{V}{RnAe} = \frac{V}{\left(\frac{\rho l}{A}\right)nAe} = \frac{V}{n\rho le}$

Hence if V = constant then v_d is independent of the area of cross-section.

In the given figure $(v_d)_A = (v_d)_B$

ODM EDUCATIONAL GROUP
Changing your Tomorrow

Numerical

Question: For two nichrome wires connected in series with a battery, how does the ratio of drift velocities of electrons in them depend on their (i) lengths (ii) diameters.

Numerical

Question: For two nichrome wires connected in series with a battery, how does the ratio of drift velocities of electrons in them depend on their (i) lengths (ii) diameters.

Solutions: In series connection current is constant.

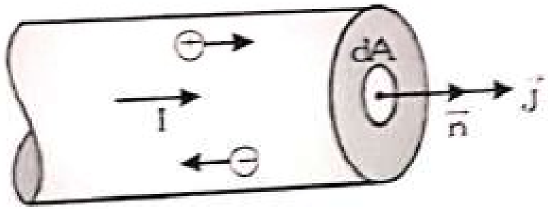
$$\therefore v_d = \frac{I}{nAe} \Rightarrow v_d \alpha \frac{1}{A} \qquad \Rightarrow \frac{(v_d)_1}{(v_d)_2} = \frac{A_2}{A_1} = \frac{\pi d_2^2}{\pi d_1^2} = \frac{d_2^2}{d_1^2}$$

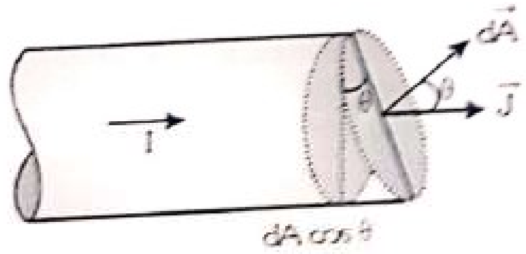
In this case, drift speed is independent of length.

Current Density ($\vec{J}$)

Definition: Current density at any point inside a conductor is defined as the magnitude of current passing through an infinitesimal area at that point provided that the area is being held perpendicular to the direction of flow of charge.

- It is denoted by $\vec{J}$. So current density is a vector quantity.
- Its direction is along the direction of flow of +ve charge.





Numerical

Question: A steady current of 2 A flows through a conductor of the uniform circular cross-section of radius 2mm. Find

(i) The current density at any point inside the conductor

(ii) Total number of free electrons crossing a cross-section in 5 minutes.

Expression for conductivity in term of average relaxation time

We know that current in term of drift speed is ; $I = nAv_d e$ ....(i)

Drift speed depends upon potential difference by the relation ; $v_d = \frac{eE}{m}\tau$ ....(ii)

Mobility

- Mobility of electrons is defined as the drift velocity acquired by the electrons due to a unit strength of the electric field.

If v_d is the drift velocity of free electrons due to a field strength E, Mobility of the electrons is defined as $\mu = \frac{v_d}{E}$

<u>Mobility in terms of relaxation time</u>

As $\mu = \frac{v_d}{E} \Rightarrow \mu = \frac{eE\tau}{mE} = e\frac{\tau}{m}$ (As $v_d = \frac{eE\tau}{m}$)

<u>Relation between conductivity and mobility</u>

$$\sigma = ne\mu$$

ODM EDUCATIONAL GROUP
Changing your Tomorrow

Numerical

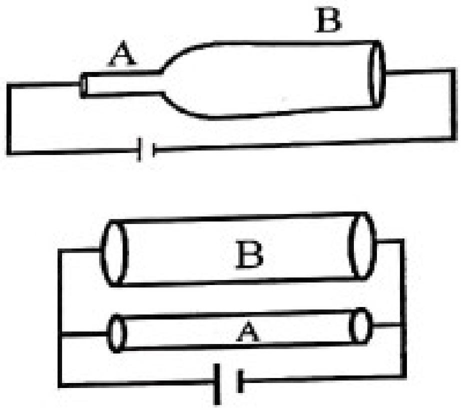
Question: In the given figures between the points A and B

(i) where drift velocity is high

(ii) where current is high

(iii) where the current density is high.

Explain the cause.



ODM EDUCATIONAL GROUP
Changing your Tomorrow

Numerical

Question: The number density of free electrons in copper is estimated to be 8.5 x $10^{28}\ m^{-3}$ .How long does an electron take to drift from one end of a wire 3.0 m long to its other end ? The area of cross-section of the wire is 2.0 x $10^{-6}\ m^{2}$ and it is carrying a current of 3.0 A.

HOME ASSIGNMENT

1. Using the concept of drift velocity of charge carriers in a conductor, deduce the relationship between current density and resistivity of the conductor.
2. Define mobility of a charger carrier. Write the relation expression mobility in terms of relaxation time. Give its SI unit.
3. Answer the following.
   a) Derive an expression for drift velocity of electrons in a conductor. Hence, deduce Ohm's law.
   b) A wire whose cross-sectional area is increasing linearly from its one end to the other, is connected across a battery of V volts. Which of the following quantities remain constant in the wire?
      i. Drift speed
      ii. Current density
      iii. Electric current
      iv. Electric field

      Justify your answer.

ODM EDUCATIONAL GROUP
Changing your Tomorrow

THANKING YOU

ODM EDUCATIONAL GROUP

ODM EDUCATIONAL GROUP
Changing your Tomorrow