Electricity Versus Drift Velocity Of 6.0 X 10^-4 Ml S In A Silver Conductor. Find The Field Strength

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Understanding the relationship between electricity and drift velocity is fundamental in the field of electromagnetism and electrical engineering. In particular, analyzing how electrons move through conductors like silver provides insight into the conduction process, the strength of electric fields involved, and the efficiency of electrical transmission systems. This article explores the concept of drift velocity, its significance, and how to determine the electric field strength in a silver conductor when given a specific drift velocity of 6.0 × 10^-4 m/s.

What is Drift Velocity?

Drift velocity is a key concept in understanding electrical conduction in metals and other conductive materials. It describes the average velocity attained by free charge carriers, such as electrons, due to the influence of an electric field.

Definition of Drift Velocity

- It is the average velocity of electrons as they drift under the influence of an electric field.
- It is generally very small compared to the thermal velocities of electrons.

Significance of Drift Velocity

- It determines the current flow in a conductor.
- It helps in calculating the current using the relation:

$$
I = n \, e \, A \, v_d
$$

where:
- I = current
- n = number density of electrons
- e = elementary charge ($1.6 \times 10^{-19} \, C$)

- A = cross-sectional area
- v_d = drift velocity

Electrical Conductivity of Silver

Silver is renowned for its excellent electrical conductivity, which makes it a preferred material for high-quality electrical contacts and conductors.

Properties of Silver Relevant to Conductivity

- Electrical Conductivity (σ): Approximately $6.3 \times 10^7 \, S/m$.
- Resistivity (ρ): The reciprocal of conductivity, approximately $1.59 \times 10^{-8} \, \Omega \cdot m$.

Number Density of Electrons in Silver

- Silver's atomic density is roughly $5.86 \times 10^{28} \, atoms/m^3$.
- Each atom contributes approximately one free electron.
- Therefore, the electron number density n is approximately $5.86 \times 10^{28} \, electrons/m^3$.

Calculating the Electric Field Strength

Given:
- Drift velocity $v_d = 6.0 \times 10^{-4} \, m/s$,
- Electron number density $n = 5.86 \times 10^{28} \, m^{-3}$,
- Elementary charge $e = 1.6 \times 10^{-19} \, C$.

The electric field strength E can be derived from the relation between drift velocity and electric field:

$$
v_d = \mu E
$$

where:
- μ = mobility of electrons in silver,
- E = electric field strength.

However, since mobility μ is related to conductivity and electron properties, an easier approach is to use the drift velocity relation:

$$
v_d = \frac{e \, \tau}{m} E
$$

where:
- τ = mean free time between collisions,
- m = mass of an electron ($9.11 \times 10^{-31} \, kg$).

Alternatively, using conductivity:

$$
J = \sigma E
$$
and

$$
J = n e v_d
$$
which leads to:

$$
n e v_d = \sigma E
$$
Thus,

$$
E = \frac{n e v_d}{\sigma}
$$

Calculating the Electric Field E

Plugging in the known values:

$$
E = \frac{(5.86 \times 10^{28}) \times (1.6 \times 10^{-19}) \times (6.0 \times 10^{-4})}{6.3 \times 10^7}
$$

Calculating numerator:

$$
5.86 \times 10^{28} \times 1.6 \times 10^{-19} = 5.86 \times 1.6 \times 10^{28 - 19} = 9.376 \times 10^{9}
$$

Now multiply by drift velocity:

$$
9.376 \times 10^{9} \times 6.0 \times 10^{-4} = 9.376 \times 6.0 \times 10^{9 - 4} = 56.256 \times 10^{5} = 5.6256 \times 10^{6}
$$

Finally, divide by conductivity:

$$
E = \frac{5.6256 \times 10^{6}}{6.3 \times 10^{7}} \approx 0.0894 \, \text{V/m}
$$

Interpreting the Result

The electric field strength in the silver conductor corresponding to a drift velocity of $6.0 \times 10^{-4} \, m/s$ is approximately 0.0894 V/m.

This value is quite small, which aligns with the understanding that drift velocities in conductors are typically very low. Despite the small drift velocity, the high conductivity of silver allows significant current flow with minimal electric fields, making it highly efficient for electrical conduction.

Additional Factors Influencing Drift Velocity and Field Strength

While the calculation above provides a theoretical value under ideal conditions, real-world situations involve several factors that influence drift velocity and electric field:

- **Temperature:** As temperature increases, the resistivity of silver increases, which affects conductivity and drift velocity.
- **Material Purity:** Impurities and defects can scatter electrons more frequently, decreasing drift velocity.
- **Conductor Geometry:** Cross-sectional area impacts current capacity but not directly the drift velocity unless current density changes.

- **Applied Voltage:** The electric potential difference across the conductor determines the electric field strength.

Conclusion

Understanding the relationship between electric field strength and drift velocity is essential for optimizing electrical systems and materials. In the context of silver conductors, the high conductivity allows for efficient current flow even with relatively small electric fields. When the drift velocity of electrons is as low as $6.0 \times 10^{-4} \, m/s$, the corresponding field strength is approximately 0.0894 V/m, illustrating the high efficiency of silver as a conductor. This insight is invaluable for designing electrical circuits, selecting appropriate materials, and understanding conduction mechanisms at a fundamental level.

References

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Frequently Asked Questions

What is the relationship between electric field strength and drift velocity in a silver conductor?

The electric field strength (E) is related to drift velocity (v_d) by the equation $E = (v_d) / (\mu)$, where μ is the mobility of electrons in silver. As drift velocity increases, so does the electric field strength, assuming constant mobility.

How do you calculate the electric field strength

given the drift velocity of electrons in a conductor?

The electric field strength can be calculated using the formula $E = v_d / \mu$, where v_d is the drift velocity and μ is the mobility of electrons in the material. Alternatively, if mobility is unknown, other methods involving current density and charge density may be used.

What is the significance of the drift velocity value 6.0 x 10^-4 m/s in the context of electrical conductivity?

A drift velocity of 6.0×10^{-4} m/s indicates the average speed at which electrons move through the silver conductor under an applied electric field, reflecting the material's conductivity and the strength of the electric field applied.

How can the electric field strength be determined in a silver conductor if the drift velocity is known?

If the drift velocity is known and the mobility of electrons in silver (approximately 8.5×10^{-4} $m^2/V\cdot s$) is available, the electric field strength can be calculated using $E = v_d / \mu$. For example, $E = (6.0 \times 10^{-4} \text{ m/s}) / (8.5 \times 10^{-4} \text{ m}^2/\text{V}\cdot\text{s}) \approx 0.706$ V/m.

Why is understanding drift velocity important in analyzing electrical conduction in metals like silver?

Understanding drift velocity helps in analyzing how electrons respond to electric fields, which influences current flow, resistance, and energy dissipation in conductors. It provides insights into the efficiency and behavior of electrical systems.

What assumptions are made when calculating electric field strength from drift velocity in a silver conductor?

Assumptions include that the drift velocity is uniform throughout the conductor, the mobility of electrons remains constant, and effects like collisions and temperature variations are negligible or accounted for in the mobility value.

Additional Resources

Electricity Versus Drift Velocity of 6.0 x 10-4 m/s in a Silver Conductor: An In-Depth Analysis

Understanding the fundamental principles of electricity, especially the concept of drift velocity, is crucial for grasping how electrical conduction occurs in metals like silver. Silver, renowned for its exceptional electrical conductivity, serves as an ideal medium for studying charge transport phenomena. This comprehensive review explores the relationship between electric current, drift velocity, and the electric field strength required to sustain a specific drift velocity in a silver conductor. We will dissect the concepts step-by-step, providing clarity on each component, and culminate with the calculation of the electric field strength necessary to produce a drift velocity of 6.0 x 10-4 m/s.

Understanding Key Concepts

Before delving into calculations, it’s important to define and understand the foundational concepts involved:

Electric Current

- Definition: The rate at which electric charge flows through a conductor.
- Mathematically:

$$
I = \frac{dq}{dt}
$$

where I is the current, dq is the charge, and dt is the time.
- In conductors: Electric current results from the movement of free electrons under the influence of an electric field.

Drift Velocity (v_d)

- Definition: The average velocity attained by charge carriers (electrons in metals) due to an electric field.
- Significance: It is typically very small compared to thermal velocities but crucial for understanding conduction.
- Expression:

$$
v_d = \frac{I}{n e A}
$$

where:
- I = current,

- n = number density of free electrons,
- e = elementary charge (1.6×10^{-19} C),
- A = cross-sectional area of the conductor.

Electric Field (E) and Field Strength

- Definition: A measure of the force experienced by a unit positive charge in the space surrounding an electric charge or distribution.
- In conductors: The electric field inside a conductor drives the electrons, resulting in a drift velocity.
- Relation to potential difference:
$$
E = \frac{V}{L}
$$
where V is the potential difference across the conductor of length L.

Properties of Silver as a Conductor

Silver is known for its exceptional electrical conductivity, characterized by:
- High conductivity (σ): Approximately $6.30 \times 10^7 \, \text{S/m}$.
- High free electron density (n): About $5.9 \times 10^{28} \, \text{electrons/m}^3$.
- Favorable for studying drift velocities because the high electron density and conductivity influence the electric field required to achieve a certain drift velocity.

Calculating the Drift Velocity in Silver

Given the drift velocity:

$$
v_d = 6.0 \times 10^{-4} \, \text{m/s}
$$

we aim to find the electric field strength E that produces this drift velocity.

Step 1: Recall the Relation Between Drift Velocity and Electric Field

In metals, the drift velocity is related to the electric field through the electron mobility (μ):

$$
v_d = \mu E
$$

or via the Drude model:

$$
v_d = \frac{e \tau}{m} E
$$

where:
- e = elementary charge (1.6×10^{-19} C),
- τ = mean free time between collisions,
- m = effective mass of an electron (~9.11×10^{-31} kg).

Alternatively, since $v_d = \frac{I}{n e A}$, and current I relates to electric field through the conductivity of the material, we can proceed via the conductivity.

Step 2: Use Electron Mobility or Conductivity

Method A: Using Electron Mobility (μ)

- Typical mobility of electrons in silver:
$$
\mu \approx 1.06 \times 10^{-3} \, \text{m}^2/(\text{V}\cdot\text{s})
$$

- Calculate E:
$$
E = \frac{v_d}{\mu}
$$

- Plugging in the values:

$$
E = \frac{6.0 \times 10^{-4}}{1.06 \times 10^{-3}} \approx 0.566 \, \text{V/m}
$$

Method B: Using Conductivity (σ)

- Relation:

$$
v_d = \frac{\sigma E}{n e}
$$

- Rearranged:

$$
E = \frac{v_d n e}{\sigma}
$$

- Values:

$$
n = 5.9 \times 10^{28} \, \text{m}^{-3}
$$

$$
e = 1.6 \times 10^{-19} \, \text{C}
$$

$$
\sigma = 6.30 \times 10^{7} \, \text{S/m}
$$

- Calculate numerator:

$$
v_d n e = (6.0 \times 10^{-4}) \times (5.9 \times 10^{28}) \times (1.6 \times 10^{-19})
$$

$$
= 6.0 \times 10^{-4} \times 5.9 \times 10^{28} \times 1.6 \times 10^{-19}
$$

$$
= (6.0 \times 5.9 \times 1.6) \times 10^{-4 + 28 - 19}
$$

$$
= (6.0 \times 5.9 \times 1.6) \times 10^{5}
$$

$$
= (6.0 \times 5.9 = 35.4; \quad 35.4 \times 1.6 = 56.64)
$$

$$
\Rightarrow \text{Numerator} \approx 56.64 \times 10^{5} = 5.664 \times 10^{6}
$$

- Finally, compute E:

$$
E = \frac{5.664 \times 10^{6}}{6.30 \times 10^{7}} \approx 0.0899 \, \text{V/m}
$$

Summary of Results:

- Using mobility: $\approx 0.566 \, \text{V/m}$
- Using conductivity: $\approx 0.09 \, \text{V/m}$

The discrepancy arises because these are different models; the mobility approach is more direct for drift velocity calculations, so the value around 0.566 V/m is more consistent with typical drift velocity relations.

Interpreting the Results

The calculated electric field strength necessary to produce a drift velocity of 6.0×10^{-4} m/s in a silver conductor is approximately 0.566 V/m. This indicates that even a relatively small electric field can induce such a drift velocity due to silver's high electron mobility.

Implications:

- Low Electric Field: The low field strength needed reflects the high conductivity and mobility of electrons in silver.
- Current Density: To determine the current density (J), multiply the electric field by the conductivity:

$$
J = \sigma E \approx 6.3 \times 10^{7} \times 0.566 \approx 3.57 \times 10^{7} \, \text{A/m}^2
$$

- Current in a Specific Conductor:

For a given cross-sectional area, the current can be calculated:

$$
I = J \times A
$$

Additional Considerations

While the calculations above provide a solid theoretical foundation, real-world factors can influence the actual electric field required:

- Temperature Dependence: Increased temperature reduces electron mobility and conductivity, requiring higher fields.
- Impurities and Defects: These can scatter electrons more, decreasing mobility and affecting drift velocity.
- Material Dimensions: The length and cross-sectional area of the conductor influence the total current and local electric field.

Conclusion

The relationship between electricity and drift velocity in a silver

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