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Introduction

In the realm of electromagnetism, understanding the interaction between magnetic fields and moving charges or currents is fundamental. When a magnetic field is uniform and directed along a specific axis, such as the +z-direction, it influences charged particles and current-carrying conductors in predictable ways. This article explores the scenario where a uniform magnetic field of magnitude 2.2 Tesla (T) exists along the +z-axis, and we aim to determine the magnitude of a force, denoted as F_1 , acting on a particular object or charge within this field.

We will delve into the principles governing magnetic forces, analyze the given parameters, and provide step-by-step calculations to find F_1 . Whether you are a student studying physics or an enthusiast eager to deepen your understanding of magnetic forces, this comprehensive guide will clarify the concepts and calculations involved.

Understanding Magnetic Fields and Forces

What Is a Magnetic Field?

A magnetic field is a vector field around magnetic materials and moving electric charges, indicating the magnetic force experienced by other moving charges or magnetic materials within the field. It is measured in Tesla (T), where 1 Tesla equals 1 Weber per square meter.

Characteristics of a Uniform Magnetic Field

A uniform magnetic field has a constant magnitude and direction throughout the region. In our case, the magnetic field is specified as 2.2 T in the +z-direction, meaning:

- The magnetic field vector points along the positive z-axis.
- Its magnitude remains consistent across the space considered.

Magnetic Force on Moving Charges and Currents

The force exerted by a magnetic field on a moving charge or current-carrying conductor is described by the Lorentz force law:

$\vec{F} = q\vec{v} \times \vec{B}$

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where:

- q is the electric charge,
- $\vec{v}$ is the velocity vector of the charge,
- $\vec{B}$ is the magnetic field vector.

Similarly, for a current-carrying wire segment of length $\vec{L}$, the magnetic force is:

$$\vec{F} = I\vec{L} \times \vec{B}$$

where:

- I is the current,
- $\vec{L}$ is a vector in the direction of the current with magnitude equal to the length of the wire segment.

Analyzing the Problem Scenario

Suppose we are provided with the details of a particle or conductor within the magnetic field, including:

- The charge or current involved,
- The velocity or current direction,
- The length of the conductor segment,
- The angle between the current/velocity and the magnetic field.

Key Data to Determine F

To find the magnitude F , we need the following:

1. Magnitude of the magnetic field: $B = 2.2 \text{ T}$
2. Velocity or current: v or I , depending on the context
3. Direction of motion or current relative to the magnetic field: angle θ
4. Length of the conductor or distance involved: L

Assuming the problem provides or assumes these parameters, the general formula for the magnitude of the magnetic force on a moving charge or current is:

$$F = qvB \sin \theta$$

for a point charge, or:

$$F = I L B \sin \theta$$

for a current-carrying conductor.

Step-by-Step Calculation of F1

Step 1: Identify the Known Parameters

Suppose the problem states:

- The charge (q) of the particle: e.g., $(q = 1.6 \times 10^{-19} \text{ C})$
- The speed (v) : e.g., $(v = 3.0 \times 10^5 \text{ m/s})$
- The angle (θ) between velocity and magnetic field: e.g., (45°)

Alternatively, if the problem involves a current, parameters would include:

- Current (I) : e.g., (0.5 A)
- Length (L) : e.g., (0.3 m)
- Angle (θ) : e.g., (60°)

Step 2: Calculate the Force Using the Appropriate Formula

For a particle with charge (q) :

$$F = q v B \sin \theta$$

For a current-carrying wire:

$$F = I L B \sin \theta$$

Step 3: Plug in the Values and Compute

Example (assuming a current (I) , length (L) , and angle (θ))

$$F_1 = I \times L \times B \times \sin \theta$$

Suppose:

- $(I = 0.5 \text{ A})$
- $(L = 0.3 \text{ m})$
- $(B = 2.2 \text{ T})$

$$- (\theta = 60^\circ)$$

Calculations:

$$F_1 = 0.5 \times 0.3 \times 2.2 \times \sin 60^\circ$$

$$F_1 = 0.5 \times 0.3 \times 2.2 \times \frac{\sqrt{3}}{2}$$

$$F_1 = 0.5 \times 0.3 \times 2.2 \times 0.8660$$

$$F_1 \approx 0.5 \times 0.3 \times 2.2 \times 0.8660 \approx 0.5 \times 0.3 \times 1.905 \approx 0.5 \times 0.5715 \approx 0.28575 \text{ N}$$

So, the force $(F_1 \approx 0.286 \text{ N})$.

Special Cases and Additional Considerations

When the Direction Is Parallel or Perpendicular

- Parallel ($\theta = 0^\circ$ or 180°): $(\sin \theta = 0)$, so no force acts.
- Perpendicular ($\theta = 90^\circ$): $(\sin \theta = 1)$, so the force is maximized.

Significance of the Magnetic Field Magnitude

A higher magnetic field strength directly increases the magnitude of the force, assuming other parameters remain constant.

Effects of Particle Charge and Velocity

- The force is proportional to the charge (q) and the velocity (v) .
- Larger charges or faster velocities yield greater forces.

Practical Applications of Magnetic Force Calculations

Understanding and calculating magnetic forces are critical in various fields, including:

- Electric motors and generators: Designing components that utilize magnetic forces for motion.
- Particle accelerators: Controlling charged particles with magnetic fields.

- Magnetic resonance imaging (MRI): Utilizing magnetic fields to produce images.
- Electromagnetic braking systems: Using magnetic forces to slow down moving objects.

Conclusion

Determining the magnitude of the magnetic force (F_1) in a uniform magnetic field involves understanding the fundamental principles of electromagnetism. By knowing the magnetic field's magnitude and direction, as well as the relevant parameters such as charge, velocity, current, length, and angle, one can accurately calculate the force exerted on charges or conductors within the field.

In our specific scenario, with a magnetic field of 2.2 T aligned along the +z-direction, the force magnitude depends on the motion or current's orientation relative to this field. Whether dealing with a moving charge or a current-carrying conductor, applying the appropriate formula and plugging in the known values yields the value of (F_1) .

Mastery of these calculations not only reinforces core physics concepts but also underpins technological advancements across multiple industries. Accurate assessment of magnetic forces enables engineers and scientists to design efficient electrical devices, medical imaging equipment, and particle physics experiments.

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Keywords

Magnetic field, magnetic force, Tesla, Lorentz force, electromagnetism, uniform magnetic field, force calculation, charged particles, current-carrying conductors, physics problem-solving

Frequently Asked Questions

What is the force experienced by a charged particle moving in a uniform magnetic field of 2.2 T in the +z

direction?

The force magnitude depends on the charge, velocity, and angle between them. The general formula is $F = qvB \sin\theta$, where θ is the angle between velocity and magnetic field. Without specific values, the exact force cannot be determined.

How do you calculate the magnetic force on a moving charge in a uniform magnetic field?

The magnetic force is given by $F = qvB \sin\theta$, where q is the charge, v is the velocity, B is the magnetic field magnitude, and θ is the angle between v and B .

If a particle with charge q moves perpendicular to a 2.2 T magnetic field, what is the maximum magnetic force it can experience?

The maximum force is $F = qvB$, occurring when $\theta = 90^\circ$, meaning the velocity is perpendicular to the magnetic field. Here, $F = qv \times 2.2 \text{ T}$.

What factors influence the magnitude of the magnetic force F_1 in such a scenario?

The factors include the charge of the particle (q), its velocity (v), the magnetic field strength ($B = 2.2 \text{ T}$), and the angle between the velocity and the magnetic field (θ).

How does the direction of the magnetic force relate to the particle's velocity in a uniform magnetic field?

The magnetic force is always perpendicular to both the velocity of the particle and the magnetic field, following the right-hand rule, resulting in a force that can cause circular or helical motion.

What additional information is needed to compute the exact value of the force F_1 on a particle in this magnetic field?

You need to know the charge (q), the particle's velocity (v), and the angle between the velocity and magnetic field to calculate the exact magnitude of F_1 .

Additional Resources

There Is A Uniform Magnetic Field Of Magnitude 2.2 T In The +z-direction. Find The Magnitude F_1 Of The — this statement sets the stage for a fundamental exploration into the interactions between magnetic fields and moving charged particles. Understanding how to determine the force exerted on a charged particle within a magnetic field is crucial in

physics, especially in electromagnetism, particle physics, and engineering applications. This guide aims to walk you through the process of calculating the magnetic force acting on a charged particle, emphasizing the key concepts, formulas, and step-by-step procedures involved.

Introduction to Magnetic Forces on Moving Charges

Before diving into the calculations, it's essential to understand the basics of how magnetic fields influence moving charges. When a charged particle (say, an electron or proton) moves through a magnetic field, it experiences a force perpendicular to both its velocity and the magnetic field. This phenomenon is described by the Lorentz force law.

Key Concepts:

- Magnetic Field (B): A vector field that exerts force on moving charges.
- Force on a Moving Charge (F): Given by the Lorentz force law.
- Charge (q): The amount of electric charge of the particle.
- Velocity (v): The speed and direction of the particle's motion.
- Directionality: The force's direction is given by the right-hand rule.

The Lorentz Force Law

The magnitude of the magnetic force $(\mathbf{F})$ on a particle with charge (q) moving at velocity $(\mathbf{v})$ in a magnetic field $(\mathbf{B})$ is given by:

$$F = |q| v B \sin \theta$$

where:

- $(|q|)$ = magnitude of the charge
- (v) = velocity of the particle
- (B) = magnetic field strength
- (θ) = angle between the velocity vector and the magnetic field

Given Data and Assumptions

In the problem, the magnetic field is specified as:

- Magnetic field magnitude, $(B) = 2.2 \text{ T}$
- Direction: In the $+z$ -direction

However, the problem statement as provided appears incomplete regarding the specifics of the particle, its velocity, or other parameters. Typically, such problems specify:

- The particle's charge (q)

- The particle's velocity (v) (magnitude and direction)
- The angle between (v) and (B)

Without these details, a general approach will be outlined, and then a specific example will be provided for clarity.

Step-by-Step Guide to Find the Magnetic Force (F_1)

Step 1: Identify the Particle's Charge and Velocity

To proceed, determine:

- Charge (q) : For example, an electron has $(q = -1.6 \times 10^{-19} \text{ C})$; a proton has $(q = +1.6 \times 10^{-19} \text{ C})$.
- Velocity (v) : The speed of the particle in meters per second (m/s).
- Direction of velocity: Relative to the magnetic field.

Step 2: Determine the Angle (θ)

The angle between the velocity vector $(\mathbf{v})$ and the magnetic field $(\mathbf{B})$ significantly affects the force:

- If $(\theta = 0^\circ)$ (parallel), then $(\sin \theta = 0)$, and the force is zero.
- If $(\theta = 90^\circ)$ (perpendicular), then $(\sin \theta = 1)$, and the force is maximized.

Step 3: Calculate the Magnitude of the Force

Using the formula:

$$F = |q| v B \sin \theta$$

Substituting known values, you get:

$$F = (|q|) \times v \times 2.2 \text{ T} \times \sin \theta$$

This provides a straightforward calculation once all parameters are known.

Example Calculation: Case Study

Let's consider a specific example to solidify understanding.

Given:

- Particle: Proton $(q = +1.6 \times 10^{-19} \text{ C})$

- Velocity: $(v = 3.0 \times 10^6 \text{ m/s})$
- Direction: Perpendicular to the magnetic field ($(\theta = 90^\circ)$, so $(\sin \theta = 1)$)
- Magnetic field: $(B = 2.2 \text{ T})$

Step 4: Plug into the Formula

$$F = (1.6 \times 10^{-19} \text{ C}) \times (3.0 \times 10^6 \text{ m/s}) \times 2.2 \text{ T} \times 1$$

Step 5: Compute

$$F = 1.6 \times 10^{-19} \times 3.0 \times 10^6 \times 2.2$$

$$F = (1.6 \times 3.0 \times 2.2) \times 10^{-19 + 6}$$

Calculate the numerical part:

$$1.6 \times 3.0 = 4.8$$

$$4.8 \times 2.2 = 10.56$$

Now, combine powers of ten:

$$F = 10.56 \times 10^{-13} \text{ N}$$

Expressed more cleanly:

$$F \approx 1.056 \times 10^{-12} \text{ N}$$

Thus, the magnitude of the magnetic force (F_1) acting on the proton is approximately $(1.06 \times 10^{-12} \text{ N})$.

Additional Considerations

1. Direction of the Force

Using the right-hand rule:

- Point your fingers in the direction of $\mathbf{v}$.
- Curl them toward $\mathbf{B}$.
- Your thumb points in the direction of the force for a positive charge.

For a negative charge, the force direction is opposite.

2. Variations with Angle θ

If the particle's velocity isn't perpendicular to the magnetic field, the force decreases proportionally to $\sin \theta$.

3. When $\theta = 0^\circ$

The force becomes zero, as the particle moves parallel to the magnetic field lines, experiencing no magnetic deflection.

Practical Applications

Understanding and calculating magnetic forces are fundamental in many technological and scientific contexts:

- Cyclotrons and particle accelerators: Control particle trajectories.
- Magnetic confinement in fusion reactors: Use magnetic fields to contain plasma.
- Magnetic sensors and Hall effect devices: Measure magnetic fields via force effects.
- Astrophysics: Study cosmic rays and magnetic field interactions.

Summary and Final Remarks

To find the magnitude F_1 of the magnetic force in a uniform magnetic field of magnitude 2.2 T in the +z-direction, follow these steps:

1. Identify the particle's charge q and velocity v .
2. Determine the angle θ between $\mathbf{v}$ and $\mathbf{B}$.
3. Use the Lorentz force formula:

$$F = |q| v B \sin \theta$$

4. Calculate the force by substituting known values.

This approach applies broadly to all scenarios involving magnetic forces on moving charges, from basic physics problems to complex engineering systems.

Final Tip

Always pay attention to the problem's specific details regarding the particle's velocity and direction, as these critically influence the magnitude and direction of the magnetic force. When data is incomplete, consider the most common or illustrative cases to gain intuition about the physics involved.

In conclusion, mastering the calculation of magnetic forces enhances your understanding of electromagnetism and prepares you for tackling real-world problems in physics, engineering, and beyond.

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