What Must The Charge (sign And Magnitude) Of A Particle Of Mass 1.45 G Be For It To Remain Stationary

What Must The Charge (sign And Magnitude) Of A Particle Of Mass 1.45 G Be For It To Remain Stationary

Understanding the conditions under which a charged particle remains stationary in an external electric and magnetic field is fundamental in electromagnetism. When analyzing a particle of mass 1.45 grams, determining its required charge—including both magnitude and sign—to stay stationary involves examining the balance of forces acting upon it. This article explores the physics principles involved, the mathematical derivations, and practical considerations to find the specific charge needed for a particle of this mass to remain at rest.

Fundamental Concepts in Force Balance of Charged Particles

Before calculating the required charge, it is essential to review the principal forces acting on a charged particle within electromagnetic fields.

Electric Force (F_e)

- Defined as Fe = qE, where:
- q is the charge of the particle.
- E is the electric field vector.
- The force acts in the direction of the electric field if the charge is positive, opposite if negative.

Magnetic Force (Lorentz Force, F_b)

- Given by Fb = q(v × B), where:
- v is the velocity of the particle.
- B is the magnetic field vector.
- For a stationary particle (v = 0), the magnetic force is zero.

Gravitational Force (F_g)

- The weight of the particle: Fg = mg, where:
- m is the mass.
- g is the acceleration due to gravity (~9.81 m/s^2).

Normal and Other Forces

- If the particle is on a surface or in a confined environment, normal forces may come into play.
- For free space analysis, gravitational force is typically considered unless specified otherwise.

Analyzing the Conditions for a Stationary Particle

To keep the particle stationary, the net force acting on it must be zero:

Fnet = 0

This implies that all forces acting on the particle balance each other out, resulting in no acceleration.

Case 1: Presence of Electric and Magnetic Fields

- The particle is subjected to electric and magnetic fields, which can be configured to balance gravitational pull.
- The key is to determine the sign and magnitude of the charge such that the force from the electric field counteracts gravity.

Case 2: No Magnetic Field or Magnetic Field Perpendicular to Electric Field

- If magnetic fields are absent or oriented perpendicularly, the analysis simplifies to balancing electric and gravitational forces.

Step-by-Step Calculation for the Required Charge

Given the mass, the gravitational force is straightforward to compute:

m = 1.45 g = 1.45 × 10-3 kg

Assuming the particle is in a uniform electric field E, and that the goal is to keep it stationary in the vertical direction, the electric force must exactly balance its weight.

1. Calculating the Gravitational Force

- Fg = mg
- Fg = (1.45 × 10-3 kg) × 9.81 m/s^2 ≈ 1.422 × 10-2 N

2. Balancing with the Electric Force

- To keep the particle stationary, electric force must satisfy:

$Fe = -Fg$

- The negative sign indicates opposite directions; depending on the sign of q, the electric field E must be oriented accordingly.

- Therefore,

$qE = -mg$

- Rearranged to find q:

$q = - (mg) / E$

3. Sign of the Charge

- If gravity pulls downward, to counteract this force with an electric field pointing upward, the particle must have a positive charge (since E points upward).

- Conversely, if the electric field points downward, the charge must be negative.

4. Determining the Magnitude of the Charge

- The magnitude of q depends on the strength of the electric field E.

- For example, if the electric field E is known, the charge magnitude is:

$|q| = (mg) / |E|$

- Without a specified electric field, the problem remains generic: the magnitude of the charge is directly proportional to the weight of the particle and inversely proportional to the electric field strength.

Practical Examples and Typical Values

Suppose an electric field of 1000 N/C is applied:

- $|q| = (1.422 \times 10-2 \text{ N}) / (1000 \text{ N/C}) = 1.422 \times 10-5 \text{ C}$

- To keep the particle stationary:

- If E points upward, the charge must be positive (~ +14.2 μC).

- If E points downward, the charge must be negative (~ -14.2 μC).

Note: The actual magnitude of the charge depends heavily on the electric field strength. Larger fields require smaller charges to balance gravity, and vice versa.

Additional Factors to Consider

While the above analysis assumes ideal conditions, real-world scenarios involve other considerations:

Influence of Magnetic Fields

- If magnetic fields are present, and the particle has a velocity component, magnetic forces can influence the equilibrium.
- For a stationary particle, magnetic forces are zero unless the particle is moving or the magnetic field varies with time.

Dynamic Equilibrium and Stability

- Achieving a perfect balance requires precise control of electric fields.
- Small perturbations may cause the particle to move unless additional stabilization mechanisms are employed.

Charge Sign and Material Considerations

- The sign of the charge directly affects the direction of the electric force.
- The particle's material properties determine how easily it can acquire charge and how stable that charge remains over time.

Summary: What Charge Is Needed for a 1.45 G Particle to Remain Stationary?

To summarize, the key points are:

- The weight of the particle is approximately 1.422×10^{-2} N.
- To keep the particle stationary, an electric force equal in magnitude but opposite in direction to gravity must act on it.
- The required charge magnitude is $|q| = (mg) / |E|$, where E is the electric field strength.
- The sign of the charge depends on the electric field's direction relative to gravity and the desired equilibrium position.

- Precise control of electric fields can enable a particle of 1.45 grams to remain stationary by balancing gravitational pull with electrostatic force.

In conclusion, the charge (sign and magnitude) necessary for a particle of mass 1.45 grams to remain stationary depends primarily on the external electric field applied. By carefully choosing the field's strength and direction, and matching it to the particle's charge, it is possible to achieve a state of equilibrium where the particle remains perfectly still in space. This principle is fundamental in applications ranging from particle trapping in physics experiments to designing electrostatic levitation systems.

Frequently Asked Questions

What is the condition for a charged particle to remain stationary in a magnetic and electric field?

The particle remains stationary when the electric force balances the magnetic force, i.e., $qE = qvB$, with $v = 0$, so the net force must be zero, implying the electric force alone must be zero or the fields are configured such that the net force is zero.

Given a particle of mass 1.45 g, what is the magnitude of the charge required for it to stay stationary in a uniform electric and magnetic field?

If the particle remains stationary, the electric force must balance the magnetic force. The charge magnitude is given by $q = m a / (E + vB)$. Since $v = 0$ for stationarity, the magnetic force is zero, so the charge must be such that the electric force balances any other forces present, often simplifying to $q = m g / E$ if gravity is considered.

Does the sign of the charge affect whether the particle remains stationary?

Yes, the sign of the charge determines the direction of the force experienced in the electric and magnetic fields, affecting whether the forces balance to keep the particle stationary.

How does the mass of 1.45 g influence the calculation of the charge sign and magnitude?

The mass affects the gravitational force acting on the particle. To keep it stationary, the electric and magnetic forces must counteract gravity, so the charge magnitude depends on balancing these forces, considering the particle's mass.

In what scenario would a particle of mass 1.45 g remain stationary without an electric field?

If there's only a magnetic field present, a charged particle cannot remain stationary unless it moves with a velocity that results in zero net magnetic force, which is not stationary. Therefore, an electric field must be present to balance gravity and magnetic forces for stationarity.

What is the formula to determine the charge sign and magnitude for a stationary particle of given mass in combined electric and magnetic fields?

The force balance condition is $qE + qvB = mg$ (if gravity acts downward). For the particle to be stationary ($v=0$), the electric force must counteract gravity: $qE = mg$. The sign of q depends on the directions of E and B fields; magnitude is $q = mg / E$.

Additional Resources

Understanding the Charge and Its Magnitude for a Stationary Particle of Mass 1.45 g

When examining the conditions required for a particle to remain stationary in an electromagnetic environment, it is crucial to analyze the interplay between the particle's charge, the forces acting upon it, and the external fields involved. In this detailed discussion, we will explore what the charge (both in magnitude and sign) of a particle with a mass of 1.45 grams must be to maintain a state of rest. This involves delving into the fundamental principles of electromagnetism, Newtonian mechanics, and the specific parameters that influence a particle’s equilibrium.

Fundamental Concepts Underpinning the Problem

Before proceeding to calculations and specific conditions, it’s essential to understand the core physical principles involved:

Newton’s First Law and Equilibrium Conditions

- For a particle to remain stationary, the net force acting upon it must be zero.
- This implies that all forces—electromagnetic, gravitational, and possibly others—must balance precisely.
- In most classical electromagnetic scenarios, the dominant forces are electric (electrostatic) and magnetic forces, with gravity playing a secondary role unless specified.

Electromagnetic Force Fundamentals

- The Lorentz Force Law describes the force on a charged particle:

$$
\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})
$$

where:
- q is the particle's charge,
- $\vec{E}$ is the electric field,
- $\vec{B}$ is the magnetic field,
- $\vec{v}$ is the velocity of the particle.

- For a particle at rest ($\vec{v} = 0$), the magnetic component drops out:

$$
\vec{F} = q \vec{E}
$$

- The gravitational force acting on the particle is:

$$
\vec{F}_g = m \vec{g}
$$

where m is the mass and $\vec{g}$ is the acceleration due to gravity.

Determining the Conditions for Stationarity

Given the above, the key is to identify the external forces necessary to keep the particle stationary.

Scenario 1: Particle in a Uniform Electric Field

- Suppose the particle is placed in a uniform electric field $\vec{E}$, and no magnetic field is present.
- To keep the particle stationary, the electric force must precisely counteract the gravitational force:

$$
q E = m g
$$

where:
- E is the magnitude of the electric field.

- Solving for q:

$$
q = \frac{m g}{E}
$$

- Sign of the charge:
- To balance gravity, the charge must be of a sign opposite to that of the gravitational attraction if considering electrostatic repulsion (e.g., if gravity pulls downward, the charge should be positive if the electric field is directed upward).

- Magnitude of the charge:
- To determine the exact magnitude, we need the strength and direction of the electric field.

Scenario 2: Particle in a Magnetic Field (e.g., in a magnetic trap)

- If the particle is stationary in a magnetic field, then:

$$
\vec{F} = q (\vec{v} \times \vec{B}) = 0
$$

since $\vec{v} = 0$.

- Therefore, magnetic fields alone cannot keep a particle stationary unless combined with electric fields or other forces.

Scenario 3: Combined Electric and Magnetic Fields (e.g., in a Penning Trap)

- In more sophisticated setups, such as Penning traps, both electric and magnetic fields are used to confine charged particles.
- The equilibrium conditions involve balancing:
- The electric force,
- The magnetic Lorentz force (which can produce a centripetal force),
- Gravitational force, if significant.

- The precise charge and field strengths depend on the trap design, but for the purpose of this discussion, we assume a simplified case where gravity is balanced by an electric field.

Calculating the Necessary Charge Magnitude

Given the mass of the particle, we can compute the charge magnitude needed under specific assumptions:

Given Data:

- Mass, $m = 1.45\, \text{g} = 1.45 \times 10^{-3}\, \text{kg}$
- Acceleration due to gravity, $g \approx 9.8\, \text{m/s}^2$

Assumption 1: Electric Field Strength

- To proceed, assume an electric field strength E. Typical values for lab electric fields range from a few hundred V/m to several kV/m.
- Let's choose $E = 1000\, \text{V/m}$ as a representative value.

Charge Calculation:

$$
q = \frac{m g}{E} = \frac{(1.45 \times 10^{-3}\, \text{kg})(9.8\, \text{m/s}^2)}{1000\, \text{V/m}} = \frac{1.421 \times 10^{-2}\, \text{N}}{1000\, \text{V/m}}
$$

Since $1\, \text{N} = 1\, \text{V·C/m}$, the units are consistent:

$$
q \approx 1.421 \times 10^{-5}\, \text{C}
$$

- Result: The particle must carry approximately 14.2 microcoulombs of charge.

Implications of the Magnitude

- A charge of this magnitude is quite large for elementary particles (where charges are often on the order of $1.6 \times 10^{-19} \, \text{C}$).
- For comparison:

$$
\frac{14.2 \times 10^{-6}\, \text{C}}{1.6 \times 10^{-19}\, \text{C}} \approx 8.88 \times 10^{13}
$$

which is roughly 88 trillion elementary charges.

- Such a large charge suggests that for microscopic particles, electrostatic forces of this magnitude are practically impossible to sustain without breakdown or discharge phenomena.

Sign and Directionality of the Charge

- To determine whether the particle's charge must be positive or negative, consider the direction of the external electric field:

- If the electric field points upward, and gravity pulls downward:
- To counteract gravity, the particle must have a positive charge (since qE acts upward).
- Conversely, if the field points downward, the particle would need a negative charge to produce an upward electrostatic force.

- The sign of the charge directly influences the particle’s equilibrium position relative to the field.

Factors Affecting Realistic Conditions

While the above calculations give a theoretical charge magnitude necessary for equilibrium, real-world factors complicate the scenario:

1. Particle Size and Material

- Spherical particles or dust particles tend to acquire charge through triboelectric effects or induction.
- The maximum sustainable charge depends on the particle size, surface properties, and breakdown voltage in the surrounding medium.

2. Medium and Dielectric Breakdown

- Air and other gases have a breakdown voltage (~3 million V/m for air at standard conditions).
- Applying fields higher than this causes ionization and discharge, preventing the maintenance of large static charges.

3. External Field Limitations

- Generating strong, uniform electric fields over large areas is technologically challenging.
- The electrostatic forces must be balanced precisely, which is difficult due to environmental disturbances and field inhomogeneities.

4. Gravitational vs. Electromagnetic Forces

- For microscopic particles, gravity is negligible compared to electrostatic forces, especially with small charges.
- For macroscopic particles like 1.45 g masses, significant electric fields are needed to counteract gravity, as shown.

Practical Examples and Applications

Understanding the charge required for a stationary state has applications across various fields:

Electrostatic Levitation

- Used in materials science to levitate and analyze particles without physical contact.
- Requires precise control of electric fields and knowledge of particle charge.

Particle Trapping and Manipulation

- Techniques such as Paul traps and Penning traps rely on combined electric and magnetic fields to confine charged particles.
- The particle charge and mass determine the trap parameters.

Electrostatic Precipitators

- Used in pollution control to remove particles from gases.
- The particles acquire charge and are collected on oppositely charged plates.

Conclusion and Summary

To summarize, the charge (both in magnitude and sign) of a

What Must The Charge Sign And Magnitude Of A Particle Of Mass 1 45 G Be For It To Remain Stationary

What Must The Charge Sign And Magnitude Of A Particle Of Mass 1 45 G Be For It To Remain Stationary

Related Articles

- What Is A 95% Ci For The Standard Deviation Of The Lifetime Distribution? [hint: What Is The Standard
- What Are The Five Factors To Consider When Determining How Many White Papers Or E-books To Publish As
- 20 Points.Cynthia Has A Bag Of Jellybeans. There Are Two Red Jellybeans, One Yellow Jellybean, And Two

Back to Home