Two 3.1 MicroCoulomb Charges Are 1.1 M Apart. What Is The Potential At Each Charge Due To The Other In

Two 3.1 MicroCoulomb Charges Are 1.1 M Apart. What Is The Potential At Each Charge Due To The Other In this article, we will explore the fascinating concepts of electrostatics, focusing on calculating the electric potential created between two point charges. Understanding these principles is fundamental in physics and engineering, especially when dealing with electric fields, Coulomb's law, and potential energy. We will break down the problem step-by-step, discuss the relevant formulas, and provide practical insights into how these calculations are performed and interpreted.

Introduction to Electric Charges and Potential

What Are Electric Charges?

Electric charges are physical properties of particles that cause them to experience a force when placed in an electric field. The two types of charges are positive and negative. Like charges repel each other, whereas opposite charges attract. The fundamental unit of electric charge is the coulomb (C).

Understanding MicroCoulombs

MicroCoulomb (μC) is a unit of electric charge equal to one-millionth of a coulomb:
- 1 μC = 1 × 10-6 C

In our problem, each charge is 3.1 μC, which is a relatively small but significant charge in electrostatics.

Electric Potential and Its Significance

Electric potential at a point in space, due to a charge, is the work done per unit charge in bringing a test charge from infinity to that point. It is measured in volts (V). The potential due to a point charge is given by Coulomb’s law:

$$V = \frac{k \cdot q}{r}$$

where:
- V is the electric potential,
- k is Coulomb’s constant (\(8.988 \times 10^9 \,

\text{Nm}^2/\text{C}^2 \)),
- \(q \) is the magnitude of the charge (in coulombs),
- \(r \) is the distance from the charge to the point where potential is measured.

Given Data and Problem Restatement

- Charge \(q_1 = q_2 = 3.1 \, \mu C = 3.1 \times 10^{-6} \, C \)
- Separation distance \(r = 1.1 \, \text{m} \)

Question: What is the electric potential at each charge due to the other?

This involves calculating the potential at the position of each charge created solely by the other charge.

Step-by-Step Calculation of Electric Potential

1. Understanding the Setup

Since both charges are identical and separated by 1.1 meters, the electric potential at each charge due to the other is symmetric. We focus on the potential at one charge’s location due to the other.

2. Applying Coulomb’s Law for Potential

The potential at a point due to a point charge is:

\[V = \frac{k \cdot q}{r} \]

Because the charges are equal and separated by the same distance, the potential at each charge due to the other is:

\[V_{due \, to \, other} = \frac{k \cdot q}{r} \]

where:
- \(q = 3.1 \times 10^{-6} \, C \),
- \(r = 1.1 \, \text{m} \),
- \(k = 8.988 \times 10^9 \, \text{Nm}^2/\text{C}^2 \).

3. Numerical Calculation

Plugging in the numbers:

$$ V = \frac{(8.988 \times 10^9) \times (3.1 \times 10^{-6})}{1.1} $$

Calculating numerator:

$$ (8.988 \times 10^9) \times (3.1 \times 10^{-6}) = 8.988 \times 3.1 \times 10^{9 - 6} = 27.8628 \times 10^{3} = 27,862.8 $$

Now, divide by 1.1:

$$ V = \frac{27,862.8}{1.1} \approx 25,330.73 \, \text{V} $$

Result:

$$
\boxed{
V \approx 25,331 \, \text{volts}
}
$$

This is the potential at each charge due to the other’s presence.

Interpreting the Results

Significance of the Potential

- The calculated potential (~25,331 V) indicates a high electric potential at each charge's location caused by the other.
- Since both charges are positive, their electric potentials due to each other are positive, reflecting repulsive interactions.
- If the charges were negative, the potentials would be negative, indicating attractive interactions.

Implications in Real-World Scenarios

Understanding these potentials is essential in:
- Designing electrostatic devices,
- Analyzing charge distributions,
- Computing forces and energy stored in electric fields,
- Developing shielding and insulation systems.

Calculating the Electric Force Between the Charges

While the focus is on potential, it’s instructive to briefly mention the force involved.

Using Coulomb’s Law for Force

The electrostatic force between two point charges is:

$$ F = \frac{k \cdot |q_1 \cdot q_2|}{r^2} $$

Since $q_1 = q_2 = 3.1 \times 10^{-6} \, C$, and $r = 1.1 \, m$:

$$ F = \frac{(8.988 \times 10^9) \times (3.1 \times 10^{-6})^2}{(1.1)^2} $$

Calculating numerator:

$$ 8.988 \times 10^9 \times 9.61 \times 10^{-12} = 8.988 \times 9.61 \times 10^{-3} \approx 86.344 \times 10^{-3} = 0.086344 $$

Calculating denominator:

$$ (1.1)^2 = 1.21 $$

Force:

$$ F = \frac{0.086344}{1.21} \approx 0.0714 \, \text{N} $$

Result:

$$
\boxed{
F \approx 0.0714 \, \text{N}
}
$$

This force acts along the line connecting the two charges.

Additional Insights and Practical Applications

Energy Stored in the System

The electrostatic potential energy U stored in the two-charge system can be calculated as:

$$U = \frac{k \cdot q_1 \cdot q_2}{r}$$

Substituting our values:

$$U = \frac{(8.988 \times 10^9) \times (3.1 \times 10^{-6})^2}{1.1}$$

which simplifies to approximately 0.0863 Joules, indicating the energy required to assemble the charges at this separation.

Effect of Changing Distance and Charge Magnitude

- Increasing the separation distance r reduces the potential and force.
- Increasing the magnitude of charges increases the potential and force linearly and quadratically, respectively.

Real-World Examples

- Capacitors utilize the principles of charge and potential to store energy.
- Electrostatic shielding in electronic devices prevents unwanted interference.
- Particle accelerators rely on electric potentials to manipulate charged particles.

Conclusion

In summary, two 3.1 microcoulomb charges separated by 1.1 meters generate a significant electric potential at each other's location, approximately 25,331 volts. These calculations demonstrate fundamental principles of electrostatics rooted in Coulomb's law. Understanding how to compute potential and force between charges is crucial for various scientific and engineering applications, from designing electronic components to understanding natural phenomena. Mastery of these concepts allows scientists and engineers to predict behaviors of charged particles and develop technologies that harness electrostatic forces efficiently.

References & Further Reading

- Halliday, Resnick, and Walker, Fundamentals of Physics, 10th Edition
- Serway and Jewett, Physics for Scientists and Engineers

- HyperPhysics, Georgia State University: [Electrostatics](http://hyperphysics.phy-astr.gsu.edu/hbase/electric/electric.html)
- Khan Academy: [Coulomb's Law and Electric Potential](https://www.khanacademy.org/science/physics/electric-charge-electric-force)

Note: Always ensure your calculations use consistent units and double-check numerical results for accuracy. Understanding the underlying physics enhances your ability to apply these principles effectively in practical situations.

Frequently Asked Questions

What is the potential at each charge due to the other when two 3.1 μC charges are 1.1 m apart?

The potential at each charge is approximately 7.9 volts, calculated using $V = k q / r$, where $k = 9\times10^9\ Nm^2/C^2$, $q = 3.1\times10^{-6}$ C, and $r = 1.1$ m.

How do you calculate the electric potential between two point charges?

The electric potential due to a point charge at a distance r is given by $V = k q / r$, where k is Coulomb's constant, q is the charge, and r is the separation distance.

What is Coulomb's constant and its value?

Coulomb's constant, k, is approximately $9\times10^9\ Nm^2/C^2$, and it relates the electrostatic force between charges to their magnitudes and separation.

Why is the potential at each charge due to the other the same in this scenario?

Because both charges are identical and symmetrically placed, the potential at each due to the other is equal in magnitude but opposite in the sense that each experiences the other's potential equally.

How does the distance between the charges affect the potential they experience?

The potential is inversely proportional to the distance; increasing the separation decreases the potential, while decreasing the distance increases it.

If the charges were of different magnitudes, how would the potential at each charge change?

The potential at each charge depends on the other's charge magnitude; larger charges produce higher potentials at the location of the other charge.

Can the potential at a charge be zero if another charge is nearby?

Yes, if the potentials due to multiple charges cancel each other out at a certain point, the net potential can be zero; however, for a single other charge, the potential is never zero unless at infinite distance.

What is the significance of potential in electrostatics?

Electric potential represents the work done per unit charge in bringing a charge from infinity to a point in the electric field, helping to understand energy distribution in the system.

How does this problem illustrate Coulomb's Law and potential concepts?

It demonstrates how the electrostatic potential between two charges depends on their magnitudes and separation distance, directly applying Coulomb's Law to compute potential energy and potential differences.

Additional Resources

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In the realm of electrostatics, understanding the interactions between charged particles is fundamental to grasping the behavior of various physical systems—from atomic structures to large-scale electrical networks. Recently, a scenario has emerged involving two point charges, each possessing a charge of 3.1 microcoulombs (μC), situated 1.1 meters apart. A central question arises: What is the electric potential at each charge due to the other? This inquiry not only highlights core principles of Coulomb's law but also provides insight into the behavior of electric potentials in practical contexts.

This article aims to dissect this problem with clarity, blending rigorous physics with accessible explanations. We will explore the foundational concepts, step through the calculations meticulously, and discuss the implications of the results, all within a structured, reader-friendly framework.

Foundational Concepts in Electrostatics

Before delving into calculations, it’s essential to review some core concepts that underpin the problem:

Electric Charge and Coulomb’s Law

- Electric charge (Q): A fundamental property of matter that causes particles to experience electrostatic forces. Measured in coulombs (C).

- Microcoulomb (μC): A unit of charge equal to 10-6 C. In this scenario, each charge is 3.1 μC = 3.1 × 10-6 C.

- Coulomb’s Law: Describes the force between two point charges:

$$
F = k_e \frac{|Q_1 Q_2|}{r^2}
$$

where:
- F is the magnitude of the force,
- k_e is Coulomb’s constant (~8.988 × 109 N·m2/C2),
- Q_1, Q_2 are the magnitudes of the charges,
- r is the distance between charges.

Electric Potential and Potential Energy

- Electric potential (V): The electric potential at a point in space due to a charge is the work done per unit charge in bringing a test charge from infinity to that point, without acceleration.

- Potential due to a point charge:

$$
V = k_e \frac{Q}{r}
$$

- It’s a scalar quantity, additive for multiple charges.

- Potential energy (U): The work required to assemble the charges from infinity to their positions.

In this problem, since the charges are fixed in place, our focus is on the electric potential at each charge due to the other, which depends on the other charge's magnitude and their separation.

Calculating the Electric Potential at Each Charge

Given two identical charges separated by a known distance, the potential at each due to the other can be computed straightforwardly using the formula for the potential of a point charge.

Data Summary

Quantity	Value	Explanation
Charge Q	3.1 μC = 3.1 × 10-6 C	Each of the two charges
Separation r	1.1 meters	Distance between the charges
Coulomb’s constant k_e	8.988 × 109 N·m2/C2	Fundamental constant

Step-by-Step Calculation

Step 1: Convert all quantities into SI units

- $Q = 3.1 \times 10^{-6}$ C
- $r = 1.1$ m

Step 2: Apply the potential formula

The electric potential at a charge Q_1 due to Q_2:

$$
V_{Q_1} = k_e \frac{Q_2}{r}
$$

Since the charges are identical, $Q_1 = Q_2 = Q$:

$$
V = k_e \frac{Q}{r}
$$

Step 3: Plug in the values

\[

V = (8.988 \times 10^9) \times \frac{3.1 \times 10^{-6}}{1.1}
\]

Calculating numerator:

\[
8.988 \times 10^9 \times 3.1 \times 10^{-6} = 8.988 \times 3.1 \times 10^{9 - 6} = (8.988 \times 3.1) \times 10^{3}
\]

Calculating \(8.988 \times 3.1\):

\[
8.988 \times 3.1 \approx 27.86
\]

So,

\[
V \approx 27.86 \times 10^{3} / 1.1
\]

Dividing:

\[
V \approx \frac{27.86 \times 10^{3}}{1.1} \approx 25,332 \text{ volts}
\]

Result:

\[
V \approx 25,332 \text{ volts}
\]

This is the electric potential at each charge due to the other.

Interpreting the Results and Their Significance

The calculation reveals that each charge experiences an electric potential of approximately 25,332 volts due to the other. Several points are worth emphasizing:

Magnitude of the Potential

- The potential is quite high, in the order of tens of thousands of volts, reflecting the significant charge magnitude and relatively short separation distance.

- Despite the charges being modest at a few microcoulombs, the proximity (1.1 meters) amplifies the potential due to the inverse relationship with distance.

Implications for Electric Fields and Potentials

- The potential at each charge is symmetric; since the charges are identical and equally spaced, the potentials are equal in magnitude.

- The potential energy stored in this configuration can be derived from the potentials and charges, offering insight into the stability and interactions within electrostatic systems.

Broader Context and Applications

Understanding such potentials is crucial in various fields:

- Electronics: Designing capacitors and understanding electrostatic shielding.

- Atomic Physics: Visualizing interactions between subatomic particles.

- Engineering: Assessing insulation requirements and electrical safety.

- Research and Development: Simulating electrostatic environments for new materials.

Additional Considerations and Extensions

While the core calculation is straightforward, real-world scenarios often involve complexities that merit further discussion.

Effect of Charge Magnitude Variations

- Increasing the charge magnitude directly increases the potential proportionally, following the linear relation.

- Conversely, reducing the charge diminishes the potential, affecting the system's energy and stability.

Influence of Distance

- The potential is inversely proportional to the separation distance.

- Doubling the distance halves the potential, illustrating how spatial configurations influence electrostatic interactions.

Multiple Charges and Superposition Principle

- In systems with more than two charges, potentials are superimposed; the total potential at a point is the algebraic sum of potentials due to individual charges.

- This principle simplifies analyzing complex arrangements.

Limitations and Real-World Factors

- This calculation assumes point charges in a vacuum; in real environments, factors such as dielectric materials, charge distribution, and external fields can alter results.

- Charge movement, quantum effects, and non-idealities are beyond the scope of simple Coulombic calculations but are relevant in advanced applications.

Conclusion: Bridging Theory and Practice

The analysis of two microcoulomb charges separated by a meter-scale distance underscores the profound influence of electrostatic principles. Calculating the potential at each charge due to the other reveals a substantial voltage of approximately 25,332 volts, illustrating how significant potentials can arise even from modest charges when they are brought close together.

This exploration exemplifies the power of Coulomb’s law and electric potential formulas in predicting and understanding electrostatic phenomena. Whether in designing electronic components, studying atomic interactions, or developing new materials, mastering these concepts is essential for scientists and engineers alike.

In sum, the interplay between charge magnitude, distance, and resulting potentials forms the cornerstone of electrostatics, offering insights that resonate across multiple scientific and technological domains. As we deepen our understanding of these interactions, we open doors to innovation, safety, and the continued advancement of technology rooted in the fundamental laws of physics.

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