A Particle Has A Charge Of Q = 2e, Where E Is The Charge On An Electron. (a) Determine The Electric Potential

A Particle Has A Charge Of Q = 2e, Where E Is The Charge On An Electron. (a) Determine The Electric Potential

Understanding electric potential and charge interactions is fundamental in physics, especially in electrostatics. When dealing with particles carrying electric charge, calculating the electric potential they produce is crucial for analyzing various phenomena, from atomic interactions to large-scale electromagnetic systems. In this article, we focus on a specific scenario: a particle with a charge $Q = 2e$, where e is the elementary charge (the charge of a single electron). Our goal is to determine the electric potential created by this particle under given conditions.

Fundamentals of Electric Charge and Electric Potential

Before delving into the specific problem, it’s essential to understand some basic concepts.

What Is Electric Charge?

Electric charge is a property of matter that causes it to experience a force when placed in an electric field. The two types of electric charges are positive and negative. The elementary charge, denoted by e, is approximately:

- $e = 1.602 \times 10^{-19}$ coulombs (C)

A particle with charge $Q = 2e$ thus has a positive charge twice that of an electron.

What Is Electric Potential?

Electric potential, often simply called potential, is the electric potential energy per unit charge at a point in space due to electric charges. It is a scalar quantity, measured in volts (V), where:

- 1 volt = 1 joule/coulomb (J/C)

Physically, it represents the work done in bringing a unit positive charge from infinity to that point without acceleration.

Electric Potential Due to a Point Charge

The electric potential V at a distance r from a point charge Q is given by Coulomb's law:

$$
V = \frac{1}{4\pi \varepsilon_0} \times \frac{Q}{r}
$$

where:
- ε_0 is the vacuum permittivity, approximately $8.854 \times 10^{-12} \, \text{F/m}$
- Q is the charge in coulombs
- r is the distance from the charge in meters

This formula assumes the point charge is isolated in free space, and the potential is measured relative to a point at infinity where the potential is zero.

Given Data and Problem Statement

The problem specifies:
- The particle's charge: $Q = 2e$
- e: elementary charge $\approx 1.602 \times 10^{-19} \, \text{C}$

Our task:
- To determine the electric potential V at a specific point or distance, based on the information provided.

Note: Since the problem statement does not specify the distance r, for comprehensive understanding, we will analyze the potential at an arbitrary distance r from the particle, and later, if needed, evaluate for specific distances.

Step-by-Step Calculation of Electric Potential

1. Expressing the Charge Q

Since $Q = 2e$:

$$
Q = 2 \times 1.602 \times 10^{-19} \, \text{C} = 3.204 \times 10^{-19} \, \text{C}
$$

2. Applying the Electric Potential Formula

Using Coulomb's law:

$$
V(r) = \frac{1}{4\pi \varepsilon_0} \times \frac{Q}{r}
$$

The constant $\frac{1}{4\pi \varepsilon_0}$ is known as Coulomb's constant k:

$$
k = 8.9875 \times 10^9 \, \text{Nm}^2/\text{C}^2
$$

Thus,

$$
V(r) = k \times \frac{Q}{r}
$$

Substituting the known values:

$$
V(r) = (8.9875 \times 10^9) \times \frac{3.204 \times 10^{-19}}{r}
$$

$$
V(r) = \frac{(8.9875 \times 10^9) \times 3.204 \times 10^{-19}}{r}
$$

Calculating numerator:

$$
8.9875 \times 10^9 \times 3.204 \times 10^{-19} \approx 2.880 \times 10^{-9}
$$

Therefore,

$$
V(r) = \frac{2.880 \times 10^{-9}}{r}
$$

where r is in meters, and $V(r)$ will be in volts.

Understanding the Significance of the Electric

Potential

The potential $V(r)$ reflects how the particle's charge influences the space around it. Key points include:

- Potential at different distances: As r increases, the potential decreases proportionally, approaching zero at infinity.
- Sign of potential: Since Q is positive ($2e$), the potential is positive at all points, indicating a repulsive effect on other positive charges.

Applications and Examples

To contextualize the calculation, here are some typical scenarios:

Example 1: Potential at 1 nm from the particle

Given $r = 1\, \text{nm} = 1 \times 10^{-9} \, \text{m}$:

$$
V(1\, \text{nm}) = \frac{2.880 \times 10^{-9}}{1 \times 10^{-9}} = 2.880\, \text{V}
$$

This implies that at 1 nanometer from the particle, the electric potential is approximately 2.88 volts.

Example 2: Potential at 1 µm from the particle

Given $r = 1\, \mu \text{m} = 1 \times 10^{-6} \, \text{m}$:

$$
V(1\, \mu \text{m}) = \frac{2.880 \times 10^{-9}}{1 \times 10^{-6}} = 2.88 \times 10^{-3} = 0.00288\, \text{V}
$$

The potential drops significantly with increasing distance.

Considerations and Limitations

While the calculations above are straightforward for point charges in free space, several factors can influence real-world scenarios:

- Medium effects: The presence of materials other than vacuum, such as dielectric substances, alters the permittivity and thus the potential.
- Charge distribution: If the charge is not concentrated at a point but spread out, the potential calculation becomes more complex.
- Boundary conditions: Near conductive surfaces or in systems with specific boundary conditions, potential calculations need to incorporate additional factors.

Summary and Conclusion

In this comprehensive analysis, we have:

- Clarified the concept of electric potential and its relation to point charges.
- Calculated the electric potential generated by a particle with charge $Q = 2e$ at an arbitrary distance r.
- Demonstrated how the potential diminishes with increasing distance.
- Provided practical examples to illustrate the potential at nanoscale and microscale distances.

Final formula:

$$
V(r) = \frac{2.880 \times 10^{-9}}{r} \quad \text{(volts, with } r \text{ in meters)}
$$

This fundamental calculation forms the basis for more complex electrostatic problems involving multiple charges, distribution of charge, and potential energy considerations in physics and engineering.

Additional Resources for Further Study

- Textbook: Introduction to Electrodynamics by David J. Griffiths
- Online simulations: Coulomb’s Law and Electric Potential calculators
- Educational videos: Electrostatics and Electric Potential explanations on platforms like Khan Academy

---

Remember: Precise calculation of electric potential is essential for designing electronic devices, understanding atomic interactions, and exploring electromagnetic phenomena across various scientific fields.

Frequently Asked Questions

What is the value of the charge Q in terms of the elementary charge e?

The charge Q is given as Q = 2e, meaning it is twice the elementary charge e.

How is the electric potential V related to the charge Q and the electric potential due to a single electron?

The electric potential V at a point due to a charge Q is given by V = (k Q) / r, where k is Coulomb's constant and r is the distance from the charge to the point of interest.

How do you calculate the electric potential for a particle with charge Q = 2e?

To calculate the electric potential, multiply Coulomb's constant k by the charge Q = 2e, then divide by the distance r from the charge to the point where potential is measured: V = (k 2e) / r.

What is Coulomb's constant and its approximate value?

Coulomb's constant k is approximately 8.99 x 10^9 N·m²/C², and it relates electric force and charge.

If the distance r from the charge to the point of measurement is 1 meter, what is the electric potential for Q = 2e?

Using V = (k Q) / r with Q = 2e (~3.2 x 10^-19 C), r = 1 m, V ≈ (8.99 x 10^9 N·m²/C²) (3.2 x 10^-19 C) / 1 m ≈ 2.88 volts.

Why is understanding the electric potential important in analyzing charged particles like Q = 2e?

Electric potential helps determine the energy per unit charge at a point in the electric field, which is essential for understanding the behavior of charged particles, their interactions, and energy exchanges in electrostatic systems.

Additional Resources

Electric Potential of a Particle with Charge Q = 2e: A Comprehensive Analysis

Understanding the electric potential associated with charged particles is fundamental to the study of electromagnetism. When dealing with particles such as electrons, protons, or hypothetical charges, the concept of electric potential provides insight into the energy per unit charge at a specific point in space due to the presence of a charge distribution. In this detailed review, we'll explore the calculation of electric potential for a particle with a charge Q = 2e, where e is the elementary charge, and delve into the underlying principles, mathematical derivations, and physical implications.

Introduction to Electric Potential

Electric potential is a scalar quantity that represents the electric potential energy per unit charge at a specific point in an electric field. It provides a measure of the work needed to bring a unit positive charge from infinity (or a reference point) to a particular point in the field without acceleration.

Key points:
- It is measured in volts (V), where 1 volt = 1 joule/coulomb.
- Electric potential is related to the electric field but offers a more straightforward way to compute energy considerations in electrostatics.
- The potential depends solely on the position relative to the charge distribution and the geometry involved.

Fundamental Concepts and Definitions

Elementary Charge (e)

- The elementary charge e ≈ 1.602×10^{-19} C.
- It is the magnitude of the charge of a proton or the negative of that for an electron.
- For the particle in question, Q = 2e, indicating it carries twice the elementary charge, making it a positively charged particle with Q ≈ 3.204×10^{-19} C.

Electrostatic Potential Energy and Potential

- The electric potential energy (U) of a charge Q at a point in an electric field created by another charge q is given by:

$U = \frac{k_e \, q \, Q}{r}$,

where:
- k_e is Coulomb's constant, $k_e \approx 8.9875 \times 10^9\, \mathrm{Nm^2/C^2}$,
- r is the distance between the charges.

- The electric potential V at a point due to a point charge q is then:

$V = \frac{U}{Q} = \frac{k_e \, q}{r}$.

Note: When calculating the potential due to a single point charge, the reference point (usually infinity) is chosen such that the potential is zero at $r \to \infty$.

Calculating the Electric Potential for Q = 2e

Assumptions and Setup

- The particle with charge Q = 2e is considered a point charge.
- We are interested in the electric potential at a point located a distance r from this point charge.
- The potential at this point is independent of other charges unless specified, so the calculation simplifies to the classical Coulomb potential due to a point charge.

Mathematical Derivation

The electric potential V at a distance r from a point charge Q is given by:

$$
V(r) = \frac{k_e Q}{r} = \frac{8.9875 \times 10^9 \times 2e}{r}
$$

Substituting $Q = 2e$, with $e = 1.602 \times 10^{-19} \, C$:

$$
V(r) = \frac{8.9875 \times 10^9 \times 2 \times 1.602 \times 10^{-19}}{r}
$$

Calculating numerator:

$$
8.9875 \times 10^9 \times 2 \times 1.602 \times 10^{-19} \approx 8.9875 \times 2 \times 1.602 \times 10^{-10} \approx (8.9875 \times 2) \times 1.602 \times 10^{-10}
$$

$$
= 17.975 \times 1.602 \times 10^{-10} \approx 28.8 \times 10^{-10} = 2.88 \times 10^{-9} \, \mathrm{V \cdot m}
$$

Thus, the potential:

$$
V(r) \approx \frac{2.88 \times 10^{-9}}{r}
$$

where r is in meters.

Final formula:

$$
V(r) = \frac{2.88 \times 10^{-9}}{r}
$$

This expression indicates that the potential diminishes as the distance from the charge increases, following the inverse relationship characteristic of Coulomb potential.

Physical Interpretation and Significance

Understanding the magnitude
- For a particle with Q = 2e, the potential is twice that of a single elementary charge at the same point.
- At very close distances (on the order of nanometers or less), the potential becomes extremely large, theoretically approaching infinity as $r \to 0$.

Implications in practical scenarios
- In atomic and molecular physics, such high potentials influence the behavior of nearby electrons and other particles.
- The energy required to bring a charge Q from infinity to a distance r is $U = QV$. For Q = 2e, the energy is:

$$
U(r) = Q \times V(r) = 2e \times \frac{k_e \times e}{r} = \frac{2 k_e e^2}{r}
$$

which can be used in energy calculations for various electrostatic phenomena.

Relevance in fields and forces
- The potential field created by this charge affects other charges in the vicinity, leading to attractive or repulsive forces depending on their signs.
- The force F between two point charges is given by Coulomb's law:

$$
F = \frac{k_e |Q q|}{r^2}
$$

where q is another charge in the field.

Special Cases and Variations

Potential at infinity
- By definition, the electric potential at infinity is zero.
- Moving closer to the charge increases the potential, which can be positive or negative depending on the sign of Q.

Potential at the surface of a sphere
- If the charge Q is distributed uniformly over a sphere of radius R, the potential at the surface is:

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

- For a sphere with radius R, the potential is finite and can be used to determine the breakdown voltage or the stability of the charge distribution.

Potential in multi-charge systems
- When multiple charges are present, the total potential at a point is the algebraic sum of the potentials due to each individual charge, owing to the superposition principle.

Practical Applications and Examples

Example 1: Potential at 1 nm from the particle
- Using $r = 1\, \text{nm} = 1 \times 10^{-9}\, \text{m}$:

$$
V(1\, \text{nm}) \approx \frac{2.88 \times 10^{-9}}{1 \times 10^{-9}} = 2.88\, \text{V}
$$

- The potential is significant even at nanometer scales, which is relevant in nanotechnology and atomic physics.

Example 2: Energy required to bring another elementary charge from infinity to 1 nm
- The energy:

$$
U = Q \times V = 2e \times 2.88\, \text{V} \approx 2 \times 1.602 \times 10^{-19} \times 2.88 \approx 9.22 \times 10^{-19}\, \text{J}
$$

which is comparable to thermal energies at room temperature (~ $4 \times 10^{-21} \, \text{J}$), indicating strong electrostatic interactions at nanoscales.

Limitations and Considerations

Point charge idealization
- The calculation assumes a point charge, which is an approximation. Real particles have finite sizes, and at extremely small distances, quantum effects become significant.

Quantum effects
- For distances comparable to atomic dimensions, quantum mechanics must be considered, as classical electrostatics no longer suffices.

Relativistic considerations
- When charges move at relativistic speeds or possess extremely high potentials, relativistic effects may alter the simple Coulomb picture.

Summary and Conclusions

- The electric potential created by a particle with charge Q = 2e at a distance r is given by:

$$
V(r) = \frac{k_e \times 2e}{r}
$$

- Numerically, this simplifies to:

$$
V(r) \approx \frac{2.88 \times 10^{-9}}{r}
$$

- The potential decreases inversely with distance, emphasizing the long-range nature of electrostatic interactions.

- Understanding this potential is essential in fields ranging from atomic physics to electrical engineering, as it underpins the behavior of charges in various

A Particle Has A Charge Of Q 2e Where E Is The Charge On An Electron A Determine The Electric Potential

A Particle Has A Charge Of Q 2e Where E Is The Charge On An Electron A Determine The Electric Potential

Related Articles

- In The Waclawski And Church (2002), Author William Kahnweiler Defines Process Consultation As An Organization
- What Can Scientists Considering The Morality Of Trading In Myanmar Amber Learn From The Debate Over Conflict
- Question 13Anne Went To The Post Office And Bought A Sheet Of 30 Stamps For $10.00. How Much Is A Singlestamp

Back to Home