Introduction

Electric Charges and Coulomb's Law

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Introduction

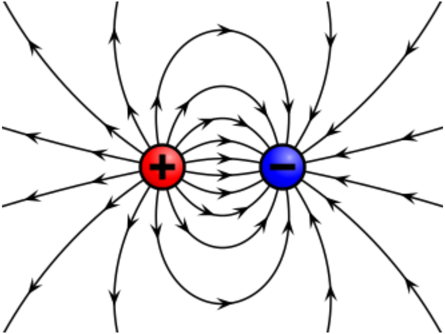
Definition

Electromagnetism is the physical interaction among electric charges, magnetic moments, and electromagnetic fields. An electromagnetic field can be static, slowly changing, or form waves

Electromagnetism is one of the four fundamental forces of nature. It is the force responsible for the attraction of oppositely charged particles and the repulsion of like-charged particles. It is also the force that creates and interacts with electromagnetic fields, which include electric fields, magnetic fields, and light.

Electric Charge

Electric charge is a fundamental property of some particles, like electrons and protons. It comes in two types: positive and negative. Like charges repel, while unlike charges attract.



- The unit of electric charge is the Coulomb (C).
- Protons have a positive charge of $+1.602 \times 10^{-19}$ C.
- Electrons have a negative charge of -1.602×10^{-19} C.

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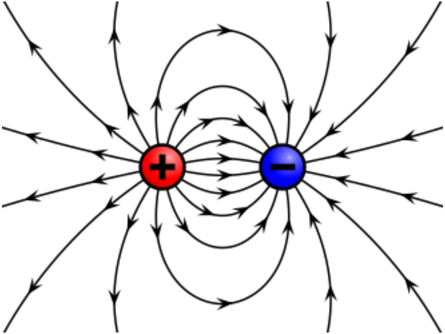

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Electric Field

Electric fields are a fundamental concept in electromagnetism, describing the influence of electrically charged particles on their surrounding space. This frame introduces the basic ideas of electric fields.

Definition

The electric field $(\vec{E})$ is a vector quantity describing the force exerted on a unit positive charge at a specific point in space.

- Equation for the electric field

$$\vec{E} = \frac{\vec{F}}{q_0}$$

  where:
  - $\vec{F}$ is the force acting on a test charge (q_0)
  - q_0 is a positive test charge (conventionally $1\,\mathrm{C}$)
- The electric field points in the direction of the force on a positive test charge.

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Electric Field due to a Point Charge

Imagine a point charge, denoted by Q. This point charge creates an electric field throughout space. We can't directly measure this electric field, but we can introduce a hypothetical test charge, q (positive by convention). The electric field at a specific point is defined as the force (per unit charge) exerted on this tiny test charge placed at that point.

Key Points

- The electric field is a vector quantity, meaning it has both magnitude (strength) and direction.
- The direction of the electric field is the same as the direction of the force the electric field would exert on a positive test charge.
- The magnitude of the electric field depends on the source charge (Q) and the distance (r) from the source charge to the point of interest.

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Coulomb's Law and Formula

Description Coulomb's Law describes the force between two point charges.

Coulomb's Law Formula The force (F) between two point charges (q_1 and q_2) separated by a distance (r) is given by:

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

where:

- k is the Coulomb constant (approximately $8.99 \times 10^9\,\mathrm{Nm}^2/\mathrm{C}^2$)

Note:

The force is attractive for unlike charges and repulsive for like charges.

Sample Problem

Let's solve a sample problem to solidify the concepts. Imagine a point charge of +2 nC (nanocoulombs) placed at the origin. We want to find the magnitude and direction of the electric field at a point 0.1 meters away on the positive x-axis.

- Converting source charge to Coulombs:

$$Q = 2\ \text{nC} \times (1 \times 10^{-9}\ \text{C/nC}) = 2 \times 10^{-9}\ \text{C}$$

- Electric field formula:

$$E = \frac{k \cdot |Q|}{r^2}$$

- Substituting values:

$$E = \frac{(8.99 \times 10^{9}\ \text{N} \cdot \text{m}^2/\text{C}^2) \cdot (2 \times 10^{-9}\ \text{C})}{(0.1\ \text{m})^2}$$

- Calculating:

$$E \approx 1.798 \times 10^{2}\ \text{N/C}$$

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- Calculating:

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Sample Problem

Direction: Since the source charge is positive, the electric field points radially outward, along the positive x-axis. Therefore, the electric field vector has a magnitude of 1.798×10^2 N/C and points in the positive x-direction.

Home Task

1. **Problem 1: Electric Field and Force**
   Given a point charge of $+3$ nC located at the origin, calculate the electric field strength and direction at a distance of 0.02 m along the positive y-axis.
2. **Problem 2: Electric Field and Multiple Charges**
   Consider two point charges: $Q_1 = +4$ nC at coordinates $(0, 0)$ and $Q_2 = -2$ nC at coordinates $(0.03 \text{ m}, 0)$. Calculate the net electric field strength and direction at a point along the positive x-axis, 0.04 m away from the origin. Again, use Coulomb's constant $k = 8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2$.

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Conclusion

In conclusion, electric fields are a foundational concept in electromagnetism, providing a framework for understanding the interactions between charged particles. From the basic principles of electric charge to advanced applications in various fields, the study of electric fields is integral to the field of physics and engineering.

Note

$\boxed{\text{Using Chatgpt for Home tasks}}$