

Electrostatics Study Guide

You should understand the basic properties of electric charge, including the two types of charge, induced charges, charge conservation, conductors, and insulators.

Coulomb's law for the electrostatic force:

$$|\vec{F}_e| = \frac{K|q_1q_2|}{r^2}, \quad K = \frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \frac{\text{N} \cdot \text{m}^2}{\text{C}^2}.$$

Definition of the electric field:

$$\vec{E}(x, y, z) \equiv \vec{F}_{\text{on } q_0}/q_0,$$

where q_0 is any "test charge" that you could hypothetically put at the point (x, y, z) .

Field created by a point charge:

$$|\vec{E}_{\text{out } Q}| = \frac{K|Q|}{r^2}.$$

For more complicated sources, the field is the vector sum of the individual fields ("principle of superposition"). You should be able to draw qualitatively accurate sketches of electric fields for various situations, especially those involving symmetry.

Definition of flux:

$$\Phi = |\vec{E}|A \cos \theta,$$

summed over pieces of the surface if necessary. For a closed surface, outward fluxes are positive, inward fluxes are negative. Gauss's law says that

$$\text{total flux of } \vec{E} \text{ through closed surface} = 4\pi K Q_{\text{inside}} = \frac{Q_{\text{inside}}}{\epsilon_0}.$$

Properties of conductors in equilibrium: $\vec{E} = 0$ inside; $\vec{E}$ is perpendicular to surface outside; all excess charge is on the surface, and tends to concentrate around sharp points.

Definition of voltage (potential):

$$V(x, y, z) = U_e/q_0,$$

where q_0 is any "test charge" that you could hypothetically put at the point (x, y, z) . Like the potential energy U_e , the voltage is always relative to some arbitrary reference point ("ground"). If the source is a single point charge Q and the reference point is at infinity, then $U = KQq_0/r$. For a proton, $q_0 = 1.6 \times 10^{-19}$ C; the charge of an electron is the same size but negative. An "electron-volt" (eV) is a unit of energy equal to 1.6×10^{-19} J.

Relation between V and $\vec{E}$:

$$\Delta V = -\vec{E} \cdot d\vec{r}.$$

In other words, $\vec{E}$ points from high voltage to low voltage, and the magnitude $|\vec{E}|$ is the change in voltage per unit distance as you move in that direction.

A capacitor is a device that stores positive charge Q and negative charge $-Q$, separated from each other, when a voltage difference ΔV is applied. The capacitance is defined as

$$C = Q/\Delta V,$$

charge per unit voltage. The simplest capacitor consists of two parallel plates separated by a small gap. Using the formula for the field near a plane of charge, you can show that in this case the capacitance is $\epsilon_0 A/d$, where A is the plate area and d is the separation.

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ML Morrison



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Table of Contents Physics Electrostatics Study Guide

1. Understanding the eBook Physics Electrostatics Study Guide
 - The Rise of Digital Reading Physics Electrostatics Study Guide
 - Advantages of eBooks Over Traditional Books
2. Identifying Physics Electrostatics Study Guide
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Physics Electrostatics Study Guide
 - User-Friendly Interface
4. Exploring eBook Recommendations from Physics Electrostatics Study Guide
 - Personalized Recommendations
 - Physics Electrostatics Study Guide User Reviews and Ratings

- Physics Electrostatics Study Guide and Bestseller Lists
- 5. Accessing Physics Electrostatics Study Guide Free and Paid eBooks
 - Physics Electrostatics Study Guide Public Domain eBooks
 - Physics Electrostatics Study Guide eBook Subscription Services
 - Physics Electrostatics Study Guide Budget-Friendly Options
- 6. Navigating Physics Electrostatics Study Guide eBook Formats
 - ePub, PDF, MOBI, and More
 - Physics Electrostatics Study Guide Compatibility with Devices
 - Physics Electrostatics Study Guide Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Physics Electrostatics Study Guide
 - Highlighting and Note-Taking Physics Electrostatics Study Guide
 - Interactive Elements Physics Electrostatics Study Guide
- 8. Staying Engaged with Physics Electrostatics Study Guide
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Physics Electrostatics Study Guide
- 9. Balancing eBooks and Physical Books Physics Electrostatics Study Guide
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Physics Electrostatics Study Guide
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Physics Electrostatics Study Guide
 - Setting Reading Goals Physics Electrostatics Study Guide
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Physics Electrostatics Study Guide
 - Fact-Checking eBook Content of Physics Electrostatics Study Guide
 - Distinguishing Credible Sources

13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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