15-3 Electrical Potential Difference

Vocabulary **Potential Difference:** The work done to move a positive test charge from one location to another.

$$\textbf{potential difference} = \frac{\textbf{work}}{\textbf{test charge}} \qquad \text{or} \qquad V = \frac{W}{q_o}$$

The SI unit for potential difference is the **volt (V),** which equals a **joule per coulomb (J/C).**

Remember, the term "work" can be replaced with the term "energy," because to store energy in, or give energy to, an object, work must be done. Therefore, potential difference can also be defined as the electrical potential energy per unit test charge. **Voltage** is often used to mean potential difference.

The field that exists between two charged parallel plates is uniform except near the plate edges, and depends upon the potential difference between the plates and the plate separation.

$$\textbf{electric field} = \frac{\textbf{potential difference}}{\textbf{separation between plates}} \qquad \text{or} \qquad E = \frac{V}{\Delta d}$$

Here, the unit for electric field is the volt/meter. It was noted earlier that the unit for electric field is the newton/coulomb. This means that a volt/meter must equal a newton/coulomb.

$$\frac{\text{volt}}{\text{meter}} = \frac{\text{joule/coulomb}}{\text{meter}} = \frac{\text{newton}\cdot\text{meter}}{\text{coulomb}\cdot\text{meter}} = \frac{\text{newton}}{\text{coulomb}}$$

Solved Examples

Example 5: An electron in Tammie's TV is accelerated toward the screen across a potential difference of 22 000 V. How much kinetic energy does the electron lose when it strikes the TV screen?

Given: $q_o = 1.60 \times 10^{-19}$ C
$V = 22\ 000$ V

Unknown: $W = ?$
Original equation: $V = \dfrac{W}{q_o}$

Solve: $W = q_o V = (1.60 \times 10^{-19}\ \text{C})(22\ 000\ \text{V}) = \mathbf{3.5 \times 10^{-15}\ J}$

Example 6: Amir shuffles his feet across the living room rug, building up a charge on his body. A spark will jump when there is a potential difference of 9000 V between the door and the palm of Amir's hand. This happens when his hand is 0.3 cm from the door. At this point, what is the electric field between Amir's hand and the door?

Solution: First, convert cm to m. 0.3 cm = 0.003 m

Given: $V = 9000$ V
$\Delta d = 0.003$ m

Unknown: $E = ?$
Original equation: $V = E\Delta d$

Solve: $E = \dfrac{V}{\Delta d} = \dfrac{9000\ \text{V}}{0.003\ \text{m}} = \mathbf{3 \times 10^6\ V/m}$

Practice Exercises

Exercise 10: James recharges his dead 12.0-V car battery by sending 28 000 C of charge through the terminals. How much electrical potential energy must James store in the car battery to make it fully charged?

Answer: ____________________

Exercise 11: If an electron loses 1.4×10^{-15} J of energy in traveling from the cathode to the screen of Jeffrey's personal computer, across what potential difference must it travel?

Answer: ____________________

Exercise 12: A "bug zapper" kills bugs that inadvertently stray between the charged plates of the device. The bug causes sudden dielectric breakdown of the air between the plates. If two plates in a bug zapper are separated by 5.0 cm and the field between them is a uniform 2.8×10^6 V/m, what is the potential difference that kills the unsuspecting bugs?

Answer: ____________________

Exercise 13: While getting out of a car, Victor builds up a charge on his body as he slides across the cloth car seats. When he attempts to shut the car door, his hand discharges 12 000 V through a uniform electric field of 3.0×10^6 V/m. How far is his hand from the door at the time the spark jumps?

Answer: ____________________

Exercise 14: A lightning bolt from a cloud hits a tree after traveling 200 m to the ground through an electric field of 2.0×10^6 V/m. a) What is the potential difference between the cloud and the tree just before the lightning bolt strikes? b) If you are in an open field during a lightning storm and the only thing you see nearby is a tall tree, is it a good idea to stand under the tree for protection from the lightning? Why or why not?

Answer: **a.** ____________________

Answer: **b.** ____________________

11. 8800 V
13. 4.0×10^{-3} m