4.6: Potential and Field Relationships (Summary)

Key Terms

bonding	connecting multiple electrical devices together with a conductor to make them have a common electric potential
electric breakdown	the condition when a sufficient electric field exists to enable an insulator to conduct charge
electric potential	potential energy per unit charge
electric potential difference	the change in potential energy of a charge q moved between two points, divided by the charge.
electrophysiology	branch of physiology that studies the electrical properties of cells and tissue
equipotential curve	two-dimensional representation of an equipotential surface
equipotential surface	surface (usually in three dimensions) on which all points are at the same potential
Faraday cage	an enclosure used for screening electric field from a region of space
grounding	process of attaching a conductor to the earth to ensure that there is no potential difference between it and Earth
lightning rod	a sharp-tipped conductor used to draw charge from the air and minimize the probability of a lightning strike
screening	the use of a cavity in a conductor to minimize or eliminate the electric field in the cavity

Key Equations

Potential difference between two points in terms of the integral of the dot product of the electric field with displacement along a path	$\Delta V_{AB} = V_B - V_A = -\int_A^B \vec{E} \cdot \vec{dl}$
Potential difference in a uniform electric field over a distance	$V_{AB} = Ed$
Electric field as gradient of potential	$\vec{E} = -\vec{\nabla} V$
Electric field components in Cartesian coordinates	$E_x = -\frac{\partial V}{\partial x}, E_y = -\frac{\partial V}{\partial y}, E_z = -\frac{\partial V}{\partial z}$
Del operator in Cartesian coordinates	$\vec{\nabla} = \hat{i}\frac{\partial}{\partial x} + \hat{j}\frac{\partial}{\partial y} + \hat{k}\frac{\partial}{\partial z}$
Electric field components in Cartesian coordinates	$E_x = -\frac{\partial V}{\partial x}, E_y = -\frac{\partial V}{\partial y}, E_z = -\frac{\partial V}{\partial z}$
Del operator in cylindrical coordinates	$\vec{\nabla} = \hat{r}\frac{\partial}{\partial r} + \hat{\varphi}\frac{1}{r}\frac{\partial}{\partial \varphi} + \hat{z}\frac{\partial}{\partial z}$
Del operator in spherical coordinates	$\vec{\nabla} = \hat{r}\frac{\partial}{\partial r} + \hat{\theta}\frac{1}{r}\frac{\partial}{\partial \theta} + \hat{\varphi}\frac{1}{r \sin\theta}\frac{\partial}{\partial \varphi}$

Summary

Electric Potential from Electric Field

- The potential difference between points can be computed from the negative line integral of the electric field over a path between the two points.

Electric Field from Electric Potential

- Just as we may calculate the negative integral over the electric field to calculate the potential difference, we may take the negative derivative of the potential to calculate the electric field.
- This may be done for individual components of the electric field, or we may calculate the entire electric field vector with the gradient operator.

Equipotential Curves and Surfaces

- An equipotential surface is the collection of points in space that are all at the same potential. Equipotential lines are the two-dimensional representation of equipotential surfaces.
- Equipotential surfaces are always perpendicular to electric field lines.

Conductors in Electrostatic Equilibrium

- Conductors in static equilibrium are equipotential surfaces.
- The electric field is zero inside a conductor and, if charged, everywhere perpendicular to its surface.
- The electric potential is constant throughout a conductor.
- The electric field magnitude and surface charge density is inversely proportional to the radius of curvature of the surface.

Applications of Electric Potential and Conductors in Electrostatic Equilibrium

- Grounding and bonding use conductors to maintain a constant potential throughout a set of connected devices.
- The Earth has a natural electric field that is directed toward the earth's surface.
- The human body has cells and tissues that use changes in electric potential to achieve their function. Muscles and nerves are examples.
- Lightning rods can draw current from the air and minimize the probability of lightning strikes.
- Screening of electric fields can be accomplished through the use of enclosed conductors (Faraday cage).

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