AP Physics C: Electricity and Magnetism — Luke Kim
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Chapter 7: Electric Potential

Background Information / Chapter Summary:

Chapter 7 explores electric potential, a fundamental aspect of electromagnetism. While electric fields describe the force experienced by a charged particle, electric potential provides a complementary perspective, describing the energy associated with a particle's position in an electric field.

Important Major Topics:

Electric Potential is the electric potential energy per unit charge at a given point in space. It is a scalar quantity measured in volts (V). Similar to how objects move from regions of high gravitational potential energy to low gravitational potential energy, charged particles move from regions of high electric potential to low electric potential.

Relation to Electric Field: The electric potential at a point in space is directly related to the electric field at that point. Specifically, the electric field is the negative gradient of the electric potential. This relationship allows for the calculation of electric potential from known electric fields and vice versa.

Equipotential Surfaces are surfaces where the voltage will be the same at every point on the surface. The electric field lines are always perpendicular to equipotential surfaces.

Potential Difference, often referred to as voltage, describes the difference in electric potential between two points in space. It is measured in volts (V) and is the work done per unit charge in moving a charge between those points.

Common Equations:

Electric Potential due to a Point Charge:
$V = kQ/r$

- (k is Coulomb's constant and is 8.99×10^9)

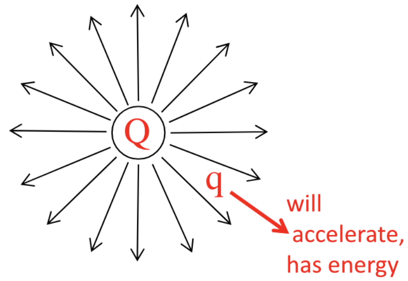
Electric Potential Energy of a Point Charge:
$U = qV$

Electric Potential Difference:
$\Delta V = V_f - V_i$

Conservation of Energy
$\Delta K = -\Delta U = -q\Delta V$

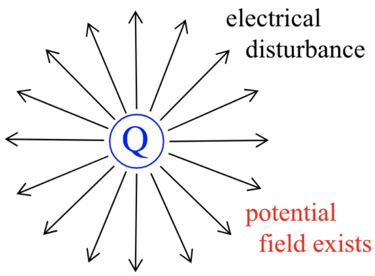
Work done in Moving Charge through a potential difference:
$W = q\Delta V$

Important Notes / Additional Information:



In this graphic, if we place a test charge (q) in this field, it will accelerate away from the point of disturbance.

This happens due to the potential energy present in the field. An electric potential field exists whenever there is either a charge or an electric field. There doesn't need to be a a secondary charge present for the effect to take place.



An electric potential field measures the amount of potential energy available at all points in the area of a charge. It is associated with any charge configuration.

Practice Problems:

1. The electric field in a region of space is given by the function $E = -30x + 2$, where x is in meters and E is in Volts/meter. What is the electric potential at $x = 2$ meters, relative to the origin?

Solution:

The relationship between electric field and electric potential is given by the integral $V = -\int E \bullet dr$, and determined for this problem as follows:

$$\Delta V = -\int_{x_i}^{x_f} E \bullet dx$$

$$\Delta V = -\int_{0}^{2m} -30x + 2 \bullet dx$$

$$\Delta V = -(-15x^2 + 2x)\Big|_0^2 = (60 - 4) - (0 - 0) = +56V$$

2. The electric potential in a region of space is given by the function $V = 3x^2 + \frac{4}{y^2}$. What is the *x*-component of the electric field in this area?

Solution:

The electric field in general is related to electric potential by the expression $E = -\frac{dV}{dr}$. In this case, the electric potential is given as a function of two dimensions, but to get the electric field component along a single dimension, one only needs to take the partial derivative of the function in that dimension. In other words, to get the *x*-component of the electric field, we'll consider *y* as a constant, and differentiate with respect to x:

$$V = 3x^2 + \frac{4}{y^2}$$

$$E_x = -\frac{\partial V}{\partial x} = -\frac{\partial}{\partial x}\left(3x^2 + \frac{4}{y^2}\right)$$

$$E_x = -\frac{d}{dx}\left(3x^2\right) = -6x$$

3. An electric field does 4 J of work on a charged particle, moving it from a potential of 1 V to a potential of 3 V. The particle has a charge of:

Solution:

The electric field does work on the particle, moving it from a position of high electric potential energy to low electric potential energy according to $\Delta V = \frac{\Delta U}{q}$.

$$q = \frac{\Delta U}{\Delta V} = \frac{U_f - U_i}{V_f - V_i} = \frac{-4J}{2V} = -2C$$

The negative sign on the charge can also be deduced by the fact that the field is doing Work on the particle in moving it from a lower potential to a higher potential. If it were a positive charge, the field would be doing Work in going from higher to lower potential.