

## Electric Potential

### I. Work By The Electric Field

An electric field can do work on a charge and thereby change its kinetic energy.

Work =

or

Work =

**Example:**

As proton moves from  $x = 0$  m to  $x = 2.4$  m it experiences an

electric field of  $\vec{E} = 5000 \frac{N}{C} \hat{i}$ .

**A.** Calculate the work done by the electric field upon the charge.

**B.** If the proton is initially at rest what will be its speed at  $x = 2.4$  m?

**Example 2:**

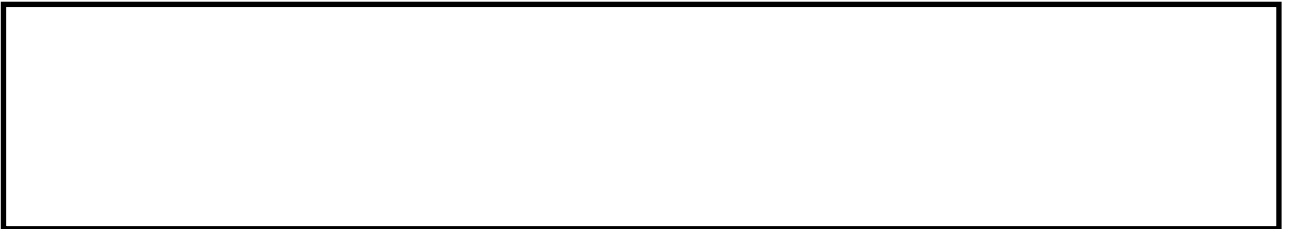
A 1 nC charge moves from  $x = 0$  m to 4 m under the influence of a varying electric field as shown in the graph below:



What is the work done by the electric field on the charge?

## II. Electric Potential Energy – $U_E$

- A.** For non-time varying electric fields, the electric force on a test charge  $q$  is a conservative force.
- B.** Using the definition of potential energy from Chapter 6, we have that the change in electric potential energy for a test object of charge  $q$  as it is moved from point A to point B is given by the equation:



**Note:** The electric potential energy is not a scalar field as it depends on the charge of the test object. The electrical potential energy is a property of a system of charges (those charges that set up the electric field and the test charge).

### III. Electric Potential Difference (Voltage) - $\Delta V$

**A. Definition** – The electric potential difference between two points in space is defined as the change in the electric potential energy that a test object would experience as it was moved between the two points divided by the charge on the test object.



**B. Units – Volts  $\equiv$**

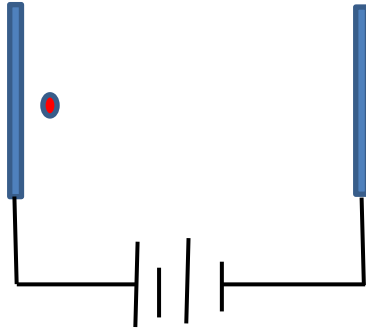
**C.** Electric potential difference depends only on the points in space and not on the test object. Thus, it is a scalar field created by the charges that created the electric field.

**Electric Potential Difference:** (Scalar)

**Electric Field :** (Vector)

**Example:**

A particle with a charge of  $5.0 \text{ uC}$  moves through a potential difference of  $20,000 \text{ V}$  as shown below:



**A.** What is the change in the potential energy of the particle?

**B.** What is the change in the kinetic energy of the particle?

**D.** Since electric potential is defined in terms of electrical potential energy, only changes in electrical potential energy have meaning. Thus, electric potential can be uniquely defined at a point in space only after defining a reference point of zero electric potential.

**Question:** A person touching a Van de Graaff accelerator is at a potential of 50,000 Volts with respect to their friend standing on the ground next to them. The person touching the Van de Graaff doesn't get shocked as long as they don't touch their friend. Why?

## Electric Potential Difference and Electric Field

- A. The electric potential difference between two points is the **negative of the area** under an Electric Field-Position graph.

**Example:** For the electric field shown below:

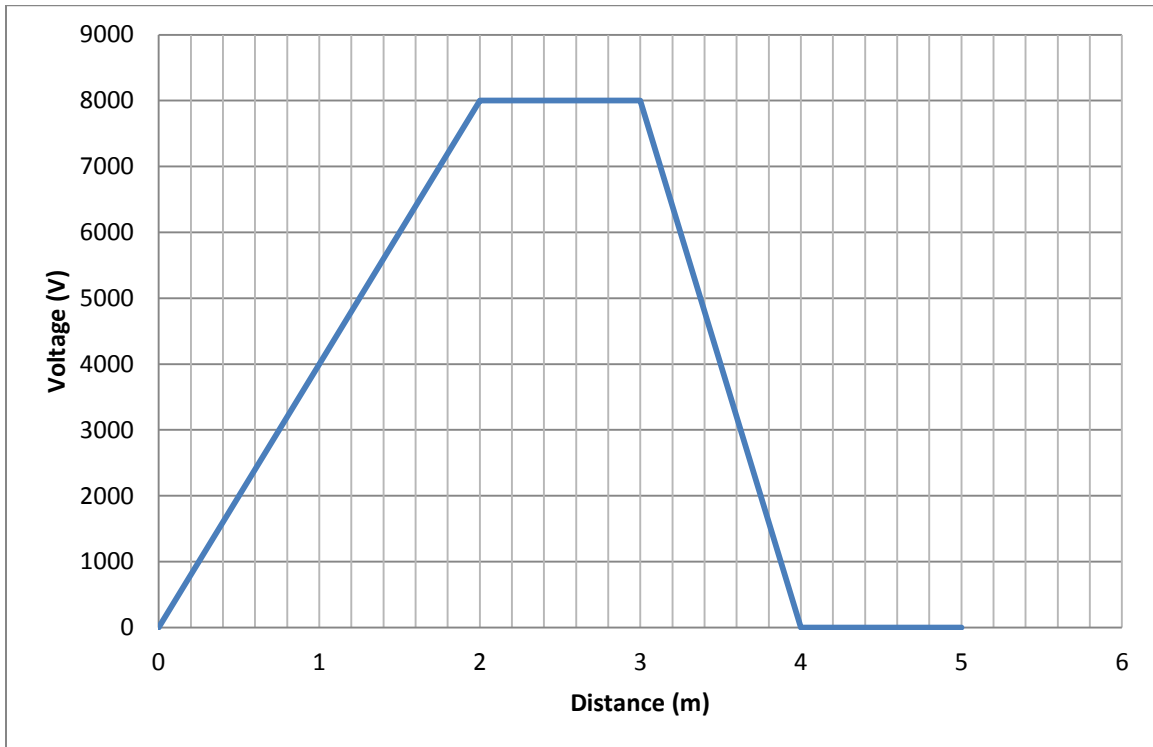


What is the voltage difference between  $x = 3$  m and  $x = 2$  m?



**B.** The electric field is the *slope of the tangent line* on a Voltage-Position graph.

**Example:** What is the electric field for  $x = 1$  m and  $x = 2.2$  m?



#### **IV. Electric Potential For a Point Charge**

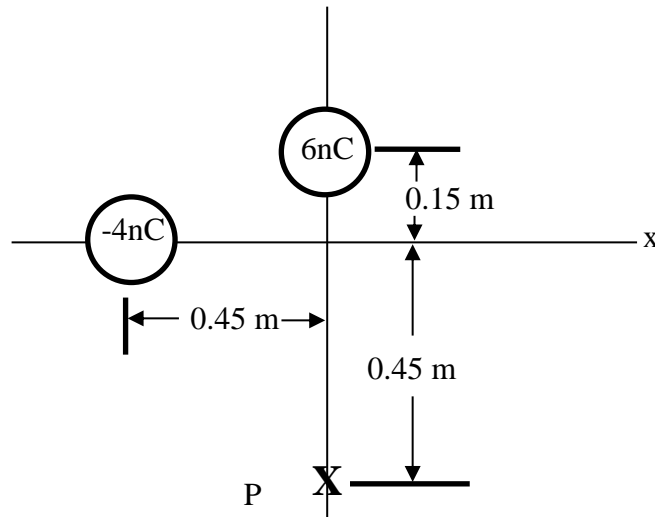
- A.** The electric potential due to a point charge of charge  $Q$  at a distance  $r$  from the point charge is given by



where we have chosen  $r = \infty$  as our zero electric potential reference point.

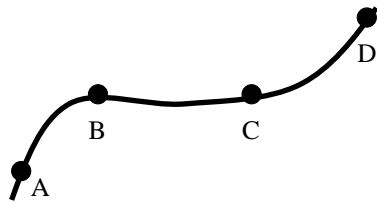
**EXAMPLE:**

Calculate the electric potential at point P : (0.00 , -0.450 m) due to a 6.00 nC point charge at (0.00 m, 0.150 m) and a -4.00 nC point charge at (-0.450 m, 0.00 m).



## Equipotential Surfaces

**A. Definition** – An equipotential surface is defined as a surface consisting of a continuous distribution of points having the same electric potential (voltage).



$$V_{BA} =$$

$$V_{CA} =$$

$$V_{DA} =$$

**B.** From the definition of electric potential, we know that an equipotential surface is also a constant potential energy surface!!!

**C. Electric field is perpendicular to an equipotential surface at every point on the surface.**

**D. Electric field lines point in the direction of DECREASING electric potential.**

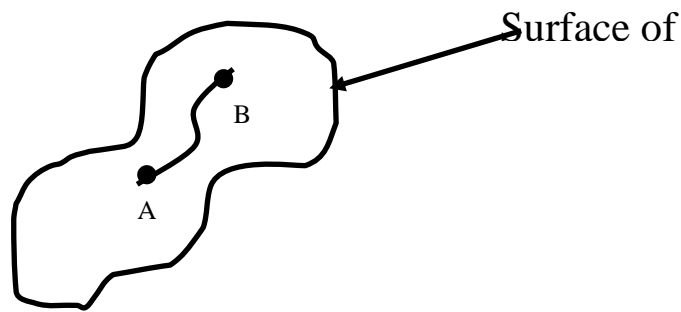
**EXAMPLE:** Draw the electric field lines and equipotential surfaces for the charge distribution shown below:



## V. Conductors and Electric Potential

A. All points on the surface of a conductor are at equipotential!

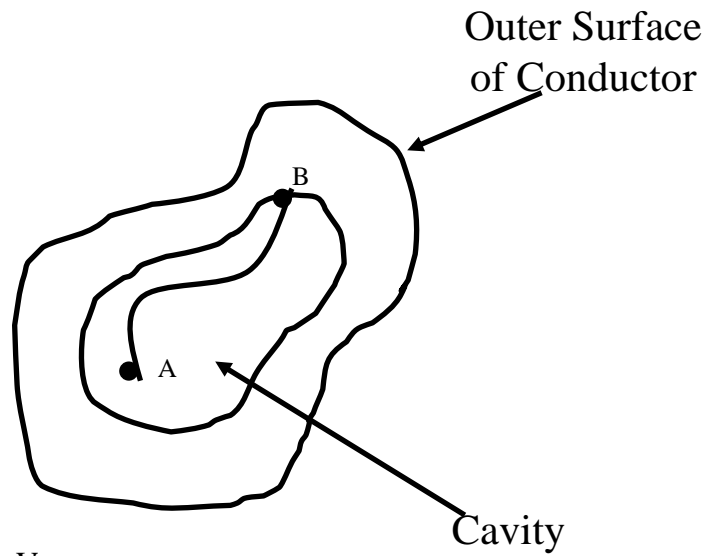
B. All points INSIDE a conductor are at equipotential!



Since the electric field inside a conductor is \_\_\_\_\_,

we have  $V_{BA} = V_B - V_A =$

C. All points in an EMPTY CAVITY inside a conductor are at the SAME electric potential as the CONDUCTOR!!



$$V_{BA} = V_B - V_A =$$