Name: ____________________

Period: ____________________

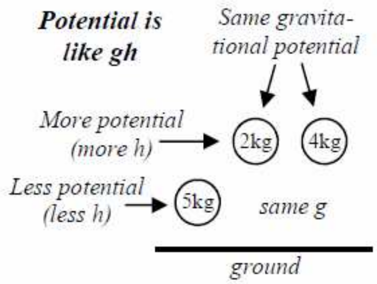
Electric Potential (Voltage)

Electric Potential

The potential for energy.

Electric Potential (voltage) is defined as the amount of electrical potential energy at a point divided by the charge at that point. A volt is a J/C, meaning electric potential tells you how many Joules per Coulomb are possible at a particular point. ***Electric potential is about the position, not what's there.***

Voltage is easiest to imagine thru a gravitational analogy. If PE = mgh (in J), then V = gh (in J/kg). Voltage is the potential for energy: the amount energy possible per kilogram at this point. It is like elevation. A higher place has more potential for energy.



Electric Potential (Voltage) for a Point Charge

$$V = k_c \frac{\pm q}{r}$$

- V: Electric Potential (*in volts* [J/C])
- k_c: Coulomb's Constant $= 9\times10^9\ Nm^2/C^2$
- $\pm q$: Charge that is "r" distance away (*in C*)
- r: Distance from this q (*in m*)

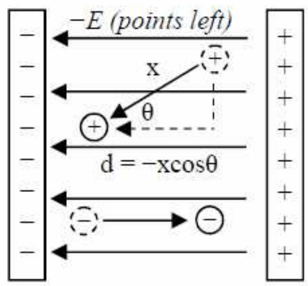
Potential Difference (Voltage) in a Uniform Electric Field

$$\Delta V = -E\Delta d_{\parallel}$$

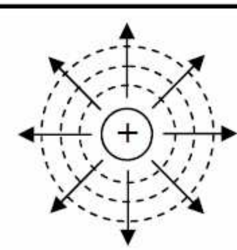
- ΔV: Electric Potential (*in J/C*)
- E: Electric Field (*in N/C or V/m*)
- $\Delta d_{\parallel}$: Distance Moved Parallel to E (*in m*)

Defined by positive charge

Electric potential is defined by a positive charge. Voltage is greater where a positive charge has more potential energy, which is closer to positive charges. Since electric potential is about position only, a negative charge gains potential when it moves toward a positive charge, even though it is losing energy.



Both charges are losing PE by moving closer to unlike charges, but only the negative charge is gaining electric potential since it is moving toward the positive plate.



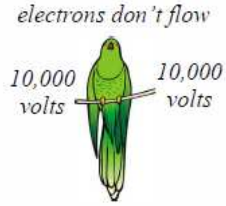
V decreases as you move away from a + charge.

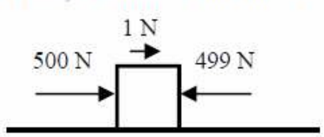
Equipotential lines (where the voltage is equal) are always perpendicular to electric field lines. In this example, the equipotential lines are equal distance from the charge because the electric field decreases evenly. Also, the voltage decreases with each circle.

Only ΔV Matters

In all cases, only the change of voltage matters. A bird perched on a high voltage wire is a perfect example. Because there is no potential difference between its feet, the bird is unharmed.

ΔV = 0 volts electrons don't flow



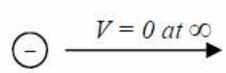


Only 1 N accelerates the object.

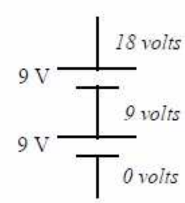
Voltage is like a net force: one of the voltages must be greater for electricity to flow.

Defining 0 Volts

When we calculate PE we don't realize we are calculating a change of energy, because it is assume that PE = 0 J at the ground. With electric potential, a point of 0 volts must be defined.



For point charges, 0 volts is at infinity. Also, the voltage becomes more negative closer to a negative charge.



For constant electric fields (like a battery) ground or the point of lowest voltage is usually 0 volts.

Voltage is a Scalar

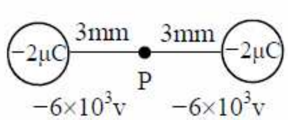
Unlike electric fields and forces you don't need to worry about directions or trigonometry. Just calculate each voltage (keeping track of positives and negatives) and add them together.

$$V = k_c \frac{q}{r}$$

$$= \frac{(9\times10^9)(-2\times10^{-6})}{(3\times10^{-3})}$$

$$= -6\times10^3\ \text{v}$$

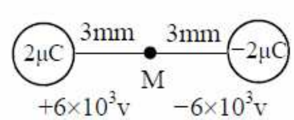
for each charge



$V_{total} = V_1 + V_2 + V_3 \ldots$
$= (-6\times10^3) + (-6\times10^3)$
$= -12\times10^3$ volts

At point P, the electric field and electric force balance and equal zero, since they are vectors. Yet, electric potential is a scalar: the voltages just add together.

At point M (right diagram), however, the electric field and force do not cancel out. As a scalar, though, the magnitudes of the electric potentials do, so V_{net} = 0 volts.



$V_{total} = V_1 + V_2 + V_3 \ldots$
$= (+6\times10^3) + (-6\times10^3)$
$= 0$ volts

1. A point is 3 mm from a $-1.5\mu C$ charge.
   A. Calculate the electric potential at the point.

   B. To increase the magnitude of the potential should the distance be increased or decreased?

2. A 5 C charge is at a point that has a potential of 8V.
   A. A volt breaks down into what units?
   B. Calculate the potential energy of the charge.

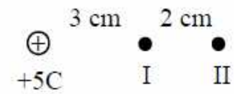
   C. How much work was necessary to move this charge to this point?

3. Where is zero volts defined for point charges?

4. A car battery provides 12V. All electrical components are grounded to the car. How can the car be grounded?

5. 12 J of energy is gained by a charge as it moves thru a potential difference of 24V. Calculate the magnitude of the charge.

6. A 5C charge is in a region of space.
   A. Calculate V at position I.

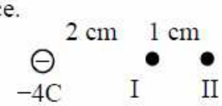


   B. Calculate the electric potential at II.

   C. Where is V greater: near or far from a + charge?

   D. Calculate the potential difference between the two points.

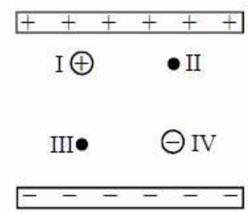
7. A $-4C$ charge is in a region of space.
   A. Calculate V at position I.



   B. Calculate the potential at II.

   C. Where is V greater (more +): near or far from a −?
   D. Draw the direction of E on the right side of the −q.
   E. Does E point toward higher or lower V?

8. A positive charge is within a charged capacitor.
   A. Is V greater at point I or III?

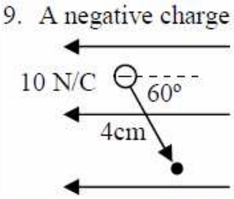


   B. Draw E between the plates?
   C. Does the + want to move to a point of higher or lower V?

   D. Which way will the − move naturally?
   E. Will the − move to a point of higher or lower V?

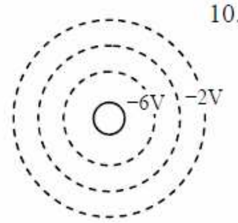
   F. Draw dashed equipotential lines between the plates.

9. A negative charge is moved 4cm at 60° to a constant E.



   A. What is the distance the charge moves parallel to the field?

   B. Calculate the change of potential of the charge.

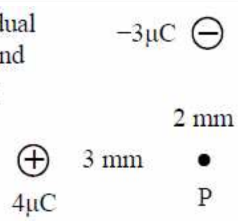


10. The inner dashed circle is $-6V$ and the outer is $-2V$.
    A. Does potential become more positive near a + or − charge?

    B. Label the charge as + or −

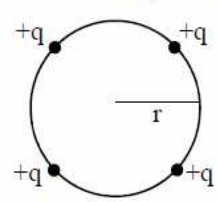
    C. Draw the electric field lines around the charge.

11. A. Calculate the individual voltages at point P and then the net voltage.



    B. If a $2\mu C$ charge is put at P, calculate net PE.

12. Four charges are equidistance from the center of a circle.



    A. By symmetry, what is the electric field at the center of the circle?

    B. Give an expression for V_{net} at the center.

    C. How can the center have energy, but no field?