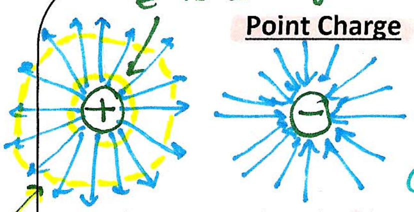
Electrostatics: 4 – Electric Field in Uniform Electric Fields

Name: ______________________________ Period: _______ Date: _______

Point Charge

E is stronger

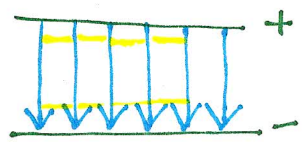


E is weaker

The electric field is NOT constant!

We have seen that the electric field surrounding a point charge is not uniform – That it varies strength and direction.

Charged Plates



The electric field strength is constant!

If we examine the electric field between charged plates we will find that it is: constant in strength and direction. Notice that the density of the lines is also uniform (same separation between field lines)

In a uniform electric field we cannot use our previous formula: $E = \frac{kq}{r^2}$ ← Individual point charge (sphere) ← distance to the charge!

This formula is only valid for describing the strength of non-uniform fields (point charges only!!!)

To find an equation for uniform fields, we will once again draw a parallel with gravitational potential energy.

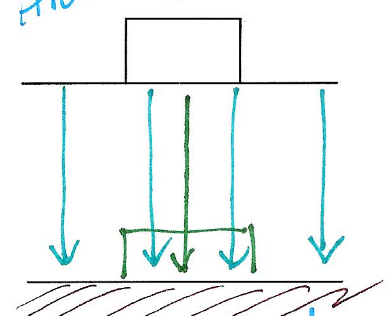
Consider a mass sitting in a uniform gravitational field at some height.

The mass will tend to move from high (height) potential to low potential.

As it does its potential energy is converted to kinetic.

If we allow the mass to fall the work done on it ($W = \Delta U$) is negative. If we want to lift the mass to a certain height we need to do positive work on it.

High Potential (height)



Low Potential (floor)

A charged object in an electric field will behave in the same way, accelerating from an area of high (+V) potential to low potential. (-V)

As it does, its potential energy is converted to kinetic.

In the same way that we would do positive work on an object to lift it against gravity, we need to do work to bring a positive charge near a plate with positive potential.

To calculate the work done in this case we can use the formula:

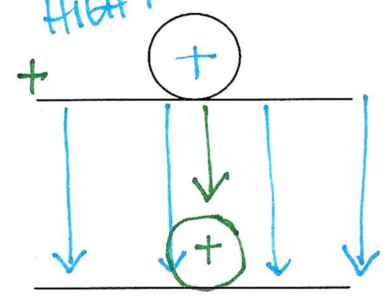
$$W = \Delta U_E = Fd$$

It is often easier, however, to describe the work done in a uniform field using the potential difference between the two plates. Recall the potential difference:

$\Delta U_E = q \cdot \Delta V$ $\Delta V = \frac{\Delta U_E}{q}$

A potential difference is generated any time we have areas of high and low potential energy, just like those generated by gravitational fields.

High Potential



E

Low Potential

In order to determine the electric field between two charged plates we must use the formula:

$$\vec{E}_{AVG} = \frac{-\Delta V}{d}$$

Where:
E: electric field (plates) (N/C)
ΔV: Potential difference (V)
d: distance between plates (m)

Example 1: Calculate the electric field strength between two parallel plates that are 6.00x10^{-2} m apart. The potential of the top plate is 6.0 V and the bottom plate is -6.0 V.

+ $V = 6V$

6×10^{-2} m $E = ?$

− $V = -6V$

$E_{AVG} = \frac{-\Delta V}{d} = \frac{-(-12)}{6\times10^{-2}}$

$E_{AVG} = 200\ N/C$

$\Delta V = -6 - (6)$

$\Delta V = -12\ V$

Example 2: An electron is accelerated from rest through a potential difference of 3.00x10^{4}V. What is the kinetic energy gained by the electron?

$\Delta V = 3\times10^{4}\ V$

The gain in K is the same as the loss in potential (U)

scalar (include SIGNS!)

$\Delta U_E = q \cdot \Delta V$

$\Delta U_E = (-1.6\times10^{-19}\ C)(3\times10^{4})$

$\Delta U_E = -4.8\times10^{-15}\ J$

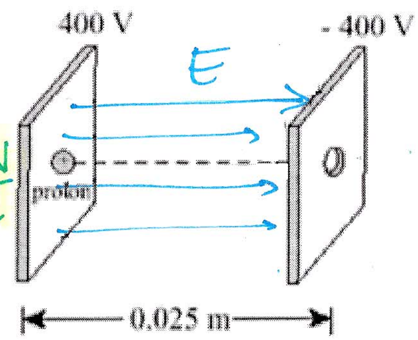
$\Delta K = -\Delta U$

$\Delta K = -(-4.8\times10^{-15}\ J)$

$\boxed{\Delta K = 4.8\times10^{-15}\ J}$

Example:

A proton, initially at rest, is released between two parallel plates as shown.



a) What is the magnitude and direction of the electric field?

$$\vec{E}_{AVG} = \frac{-\Delta V}{d} = \frac{-(-800V)}{.025} = 3.2\times10^{4}\ \frac{N}{C}$$

$\Delta V = -400 - 400 = -800V$

b) What is the magnitude of the electrostatic force acting on the proton?

$$E = \frac{F_E}{q}$$

$F_E = E \cdot q = (3.2\times10^{4}\ \frac{N}{C})(1.6\times10^{-19}\ C)$

$F_E = 5.12\times10^{-15}\ N$

c) What is the velocity of the proton when it exits the - 400 V plate?

$\Delta U_E = q \cdot \Delta V$

$\Delta K = -\Delta U_E$

$\frac{mv^2}{2} = -q \cdot \Delta V$

$$V = \sqrt{\frac{-2q \cdot \Delta V}{m}} = \sqrt{\frac{-2(1.6\times10^{-19})(-800)}{1.67\times10^{-27}}}$$

$V = 3.92\times10^{5}\ m/s$