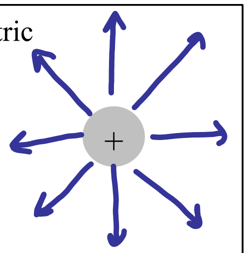
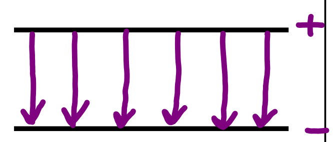
Electrostatics Notes

6 – Electric Potential in Uniform Electric Fields

We have seen that the electric field surrounding a point charge is not uniform – that it…varying strength and direction



If we examine the electric field between charged plates we will find that it is..uniform in strength and direction



Notice that the density of the lines is also… uniform

In a uniform electric field we cannot use our previous formula:

$$\vec{E} = \frac{kq}{r^2}$$

q ← individual charge

r^2 ← distance from charge

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

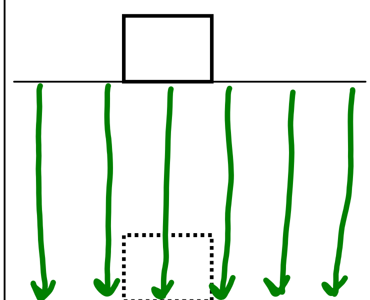
To find an equation for uniform fields, we will once again draw a parallel with gravitational potential energy.

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

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

As it does it… potential energy is converted into kinetic

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



A charged object in an electric field will behave in the same way, accelerating from an area of…high potential to low potential

As it does it..potential energy is converted into 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:

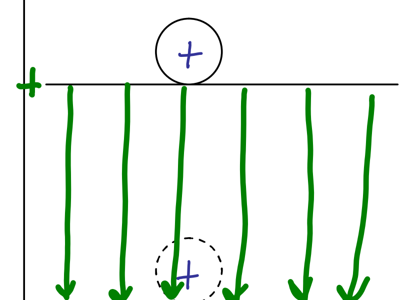
$$W = \Delta E_p = Fd$$

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

Recall that potential difference:

$$\Delta V = \frac{\Delta E_p}{q}$$

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



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

$$\boxed{\vec{E} = \frac{\Delta V}{d}}$$

Where:
E = electric field (N/c)
ΔV = potential difference (V)
d = distance between plates (m)

Example:
Calculate the electric field strength between two parallel plates that are $6.00\text{x}10^{-2}$ m apart. The potential of the top plate is 6.0 V and the bottom plate is -6.0 V.

6.0V
$d = 6.00\times10^{-2}\,m$
-6.0V

$$\vec{E} = \frac{\Delta V}{d} = \frac{12.0\,V}{6.00\times10^{-2}\,m} = 200\ N/c$$

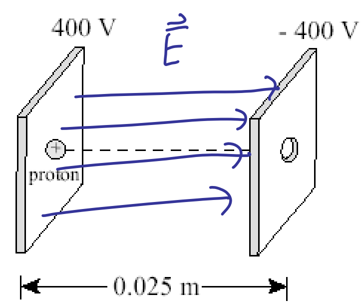
Example:
An electron is accelerated from rest through a potential difference of $3.00\text{x}10^{4}$ V. What is the kinetic energy gained by the electron?

0V 30 000 V

$\Delta E_p = \Delta V q$
$= (30\,000\,V)(-1.6\times10^{-19}\,C)$
$= -4.8\times10^{-15}$

$\Delta E_k = -\Delta E_p$
$= -(-4.8\times10^{-15})$
$= \boxed{4.8\times10^{-15}\ J}$

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?

• Field is + to − ∴ right

$$\vec{E} = \frac{\Delta V}{d} = \frac{800\,V}{0.025\,m} = 32\,000\ N/c$$

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

$$F_E = \vec{E}q = (32\,000\ N/c)(1.6\times10^{-19}\ c)$$
$$= 5.12\times10^{-15}\ N$$

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

$\Delta E_p = \Delta V q$
$= (-800\,V)(1.6\times10^{-19}\,C)$
$= -1.28\times10^{-16}\ J$

$\Delta E_k = -\Delta E_p$
$\Delta E_k = 1.28\times10^{-16}\ J$

$\Delta E_k = E_{k_f} - \cancel{E_{k_i}}^{\,0}$

$E_{k_f} = \frac{1}{2}mv^2 \quad v = \sqrt{\frac{2E_k}{m}} = \sqrt{\frac{2(1.28\times10^{-16})}{1.67\times10^{-27}}}$

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