Lecture 6

Mon: Warm Up 3 D2L

Tues: Prob/discussion

Class survey: Q1, Q2 ~~use/learn~~ learn/use knowledge

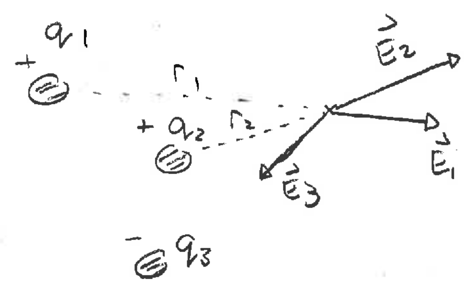
learn
- physics + world
- optics / E+M
- solve HW problems

use knowledge
- career/grad school
- connect to discipline

Also
- analytical thinking
- working from first principles
- technical/math skills

Electric fields for general charge distributions

We have seen that it is possible the electric field for a collection of point charges via



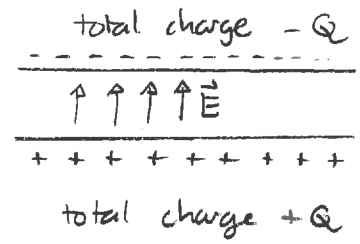
$$\vec{E} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 + \ldots$$

where we have to add vectors and the magnitude of each vector is:

$$E_i = k\frac{q_i}{r_i^2}$$

We can extend this rule to any arrangements of charge but as the numbers of charges increase, the calculations become more intricate. Several special cases are:

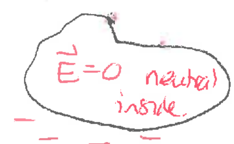
1) <u>field between very closely spaced flat plates</u>



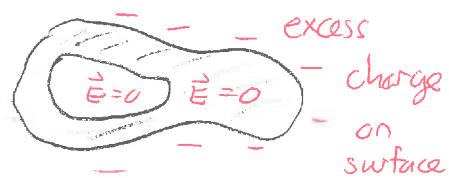
Here the field is uniform inside the plates and this means that it is the same at each point between the plates.

2) <u>field inside a perfect conductor</u>

Suppose that charge is placed on a perfect conductor. Then these charges will rearrange themselves so that the electric field inside the conductor is zero. A general version of E+M then predicts that all excess charge resides on the surface of the conductor. This even includes holes inside the conductor.



This is how electrostatic shielding works. An object is surrounded by a conductor and this protects the object from electrostatic fields



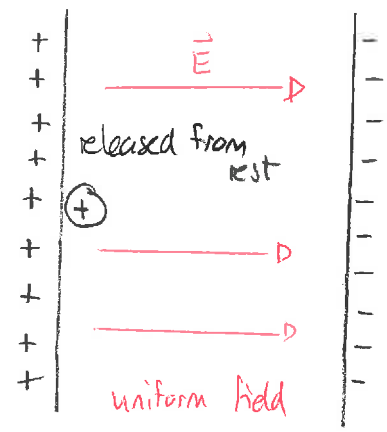
no charge anywhere inside

Forces on charges in electric fields

In general an electric field will exert a force on any charged particle in the field. Consider a particle in a uniform electric field.

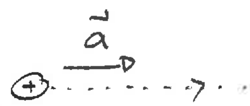
Quiz 1 60-96%

Quiz 2 40%

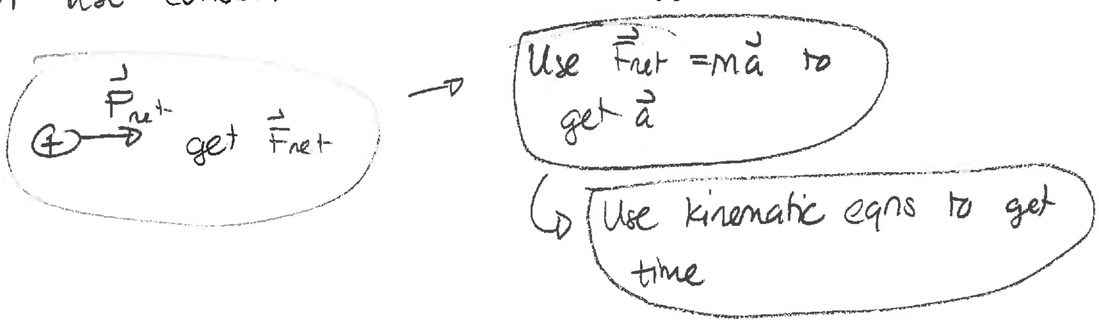


Example: A proton (mass 1.67×10^{-27} kg) is initially at rest on one plate. The distance between the plates is 0.050 m and the field is 4.0×10^4 N/C as illustrated. Determine the time taken to reach the other plate.

Answer: Need acceleration so that we can use constant acceleration kinematics



Scheme



Then FBD $\bullet \longrightarrow \vec{F}_{elec}$ $\Rightarrow$ $\vec{F}_{net} = \vec{F}_{elec} = m\vec{a}$

Now $\vec{F}_{elec} = q_{proton}\vec{E}$ gives $\vec{F}_{elec}$. So

$$F_{elec} = q_{proton} E = 1.6 \times 10^{-19} C \times 4.0 \times 10^4 N/C = 6.4 \times 10^{-15} N$$

So $F_{elec} = ma$ $\Rightarrow$ $6.4 \times 10^{-15} N = 1.67 \times 10^{-27} kg \; a$

$$\Rightarrow a = \frac{6.4 \times 10^{-15} N}{1.67 \times 10^{-27} kg} = 3.8 \times 10^{12} m/s^2$$

This is constant, so we can use constant acceleration kinematics.

Now consider constant accel.

initial — final

$x_i = 0\,m$ $\quad a = 3.8\times10^{12}\,m/s$ $\quad x = 0.050\,m$

$v_i = 0\,m/s$ $\quad v_f = ?$

$t = ?$

$$X = x_i + v_i t + \frac{1}{2} a t^2 \Rightarrow 0.050\,m = 0\,m + 0\,m/s\,t + \frac{1}{2}\,3.8\times10^{12}\,m/s^2\,t^2$$

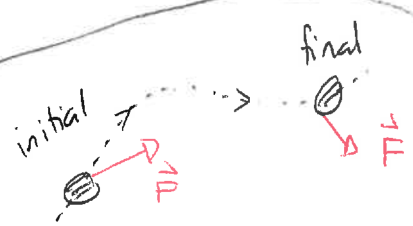
$$\Rightarrow \frac{2 \times 0.05\,m}{3.8\times10^{12}\,m/s^2} = t^2$$

$$\Rightarrow t^2 = 2.63\times10^{-14}\,s^2 \Rightarrow t = \sqrt{2.63\times10^{-14}\,s^2}$$

$$\Rightarrow t = 1.6\times10^{-7}\,s.$$

Work + energy in electrostatics

In the previous example, we could ask for the speed with which the proton hits the right plate. We could use Newton's 2^{nd} law to do this. But we could also attempt to use energy conservation to answer such questions. We then review energy conservation for a particle on which a single conservative force acts. In general we imagine



particle follows trajectory

conservative force acts on particle

→ Kinetic energy of particle at any moment is $K = \frac{1}{2}mv^2$

→ There is a potential energy U associated with the force

→ Particle kinetic energy change

$\Delta K = K_f - K_i$

$= \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$

→ Particle potential energy change $\Delta U = U_f - U_i$

→ CONSERVATION OF ENERGY

$$\Delta K + \Delta U = 0$$

We will show that there is an electrostatic potential energy associated with the electric force - denote this U_{elec}. Then

In any situation that only involves electric forces

$$\Delta K + \Delta U_{elec} = 0$$

throughout the particle motion

Quiz 3

Quiz 4