Intro to Quantum Physics F3241

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Week 2, Lecture 2

An example problem - part 1: dimensional analysis

We accelerate a mixed beam of electrons and protons to 3×10^7 ms^{-1}, and allow them to enter a region with a uniform magnetic field perpendicular to their direction with a strength of 8T. What happens to the particles?

An example problem - part 2: physics

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A Quick Recap

A Volt is a measure of "energy per charge"

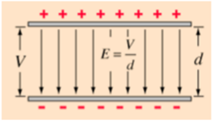
So, energy is "charge times voltage"

Often this is written "Joules = Coulombs times Volts"

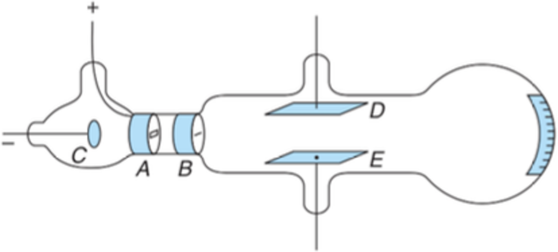
When dealing with electrons, we can use " electronVolts = elementary charge times Volts"

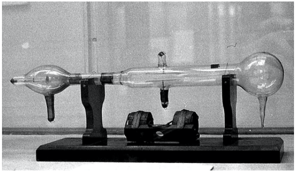
Electric field strength is "voltage per distance"

Electric force is "charge times Field strength " or " charge times voltage per distance" or "energy per distance"

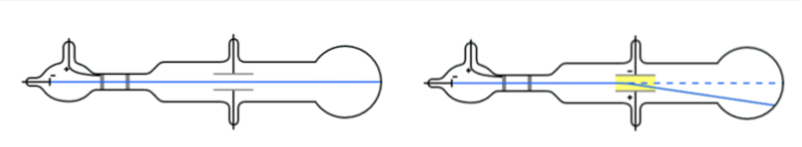


Thomson's Cathode Ray Experiment





Thomson's Cathode Ray Experiment



The cathode ray bends towards the + plate when the electric (or magnetic) field is turned on:

Cathode rays are negatively charged.
If cathode rays are made of particles, we can write:

What can we control in this experiment?

What can we measure directly?

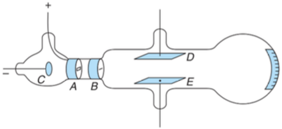
What can we measure indirectly?

Thomson's Cathode Ray Experiment

What variations of this experiment could tell us more?

An example problem

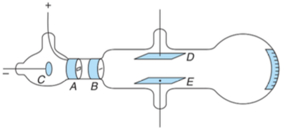
Electrons have kinetic energy of 2000 eV, and are travelling in a CRT with a region of electric field $E = 3.33 \times 10^{3}$ Vm^{-1}. The mass of an electron is 511 keV.



a) What is their speed?

An example problem

Electrons have kinetic energy of 2000 eV, and are travelling in a CRT with a region of electric field $E = 3.33 \times 10^3$ Vm^{-1}. $m_e = 511$ keV.



b) What is the time needed to traverse 5 cm in the region of electric field?

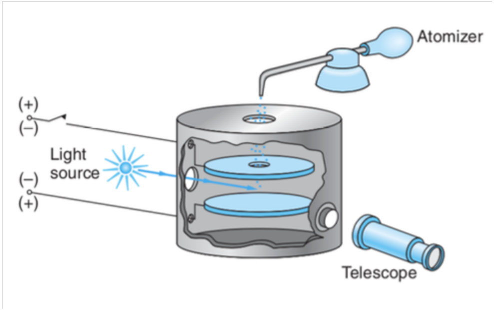
Millikan's oil drop experiment

From Thomson's experiment we know $\frac{q}{m}$, but we don't know q or m

Thomson balanced the electric and magnetic forces to extract this ratio.

Millikan had the idea to balance the electric force against the gravitational force.

Millikan's oil drop experiment



Millikan's oil drop experiment

What important things did we ignore when going through Millikan's experiment?

Millikan's oil drop experiment

3-8. On drop #16, Millikan measured the following total charges, among others, at different times:

$$\begin{array}{lll} 25.41 \times 10^{-19}\,\mathrm{C} & 17.47 \times 10^{-19}\,\mathrm{C} & 12.70 \times 10^{-19}\,\mathrm{C} \\ 20.64 \times 10^{-19}\,\mathrm{C} & 19.06 \times 10^{-19}\,\mathrm{C} & 14.29 \times 10^{-19}\,\mathrm{C} \end{array}$$

What value of the fundamental quantized charge e do these numbers imply?

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Where we are

- We know from electrolysis experiments that the change in mass is proportional to the electrical current
- We know from Thomson et al that q/m for cathode rays is around 1/2000 the value of e/m for H ions
- We know from Millikan et al that q is always a multiple of a specific value : 1.6×10^{-19} C

Electricity is made up of particles, and they are tiny compared to 'atoms'.