Lesson 46: Cloud & Bubble Chambers

Imagine you're on a really stupid game show where they put a whole bunch of ping pong balls on the floor, turn off the lights, and then send you in to count them. How would you do it?

- I'm thinking that your only chance is to get down on your hands and knees and try to touch them around you.
- One of the problems is that in the very act of counting them (by reaching out), you change them by pushing them around, maybe even missing some of them.

This is kind of the same problem that subatomic physicists have. They have to reach around "in the dark" to measure something that they can't see.

- The amazing part is that methods have been developed to do this, and actually do it accurately.
- This is the beginning of our journey into the modern subatomic realm of physics.

Cloud Chambers

In 1894 the Scottish physicist ***Charles Wilson*** was interested in the odd shadows that can sometimes be formed on cloud tops by mountain climbers (called Brocken Spectre).

- To be able to study this further, he came up with a way to build a device called a **cloud chamber** that would allow him to make his own mini-clouds inside a glass chamber.
  - To be able to do this he made his device so that he could keep the air inside **supersaturated** with water.
    - Air can usually only hold a certain amount of vapour. Supersaturated means the air was holding more vapour than it would normally be able to at that pressure and temperature. It is in a very delicate state that can easily be disturbed to cause condensation of the vapour into liquid droplets.
  - He quickly realized that as charged particles passed through his cloud chamber they were able to ionize some of the molecules. This resulted in ions that caused water vapour to condense.
- Over the next few years Wilson was able to "see" the path the charged particles had passed through by looking for the little vapour trails forming in the chamber.
  - This is sort of like knowing where a 747 jet has flown by looking for its vapour trail streaking across the sky.

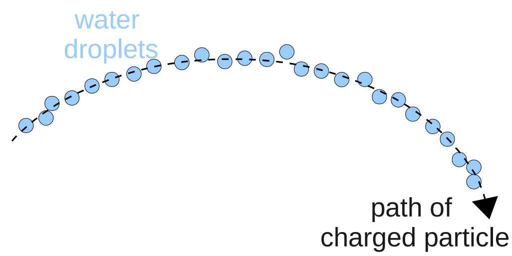


Illustration 1: Water droplets condense along the path of the charged particle.

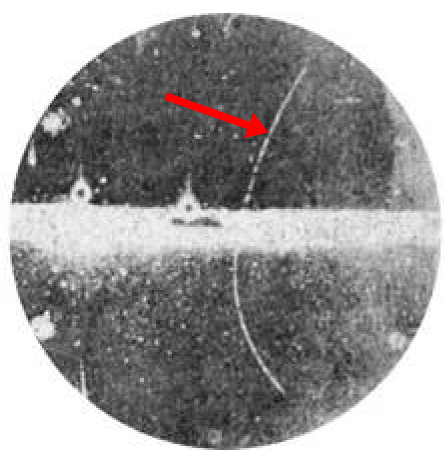


Illustration 2: A particle's path as seen in a cloud chamber.

Bubble Chamber

Illustration 3: A hydrogen bubble chamber image.

A bubble chamber is the exact opposite of a cloud chamber.

- Instead of a supersaturated vapour that can condense into a liquid, a bubble chamber uses a **liquefied gas** that is at such a low pressure that it is on the edge of "boiling" back into a gas.
- As a particle passes through this liquid, it causes it to boil into a gas, leaving a trail of bubbles along its path.
- A bubble chamber is otherwise quite similar to a cloud chamber.

Cloud and bubble chambers are usually operated with a constant magnetic field perpendicular to the path of the particles.

- This way we can observe the particles as they spin through a spiral pattern.
  - This happens because the magnetic force acting on the charged particles causes a centripetal pattern.
  - By simply measuring the radius of their path we can figure out quantities such as charge to mass ratio, just like in Lesson 18.

Both cloud and bubble chambers suffer from the drawback that they can not detect neutral particles, since only ions (and ionizing photons) can cause any change in the chambers.

- Instead, we have to look for the interactions of *other* particles with neutral particles.
  - For example, if we see a charged particle interact with something we can't "see" we can guess it was a neutral particle.

Analyzing Particle Tracks

The best way to use either kind of chamber is to place it in a magnetic field and then make measurements of the paths of particles.

- Any charged particle will follow a distinct pathway in the magnetic field because of the magnetic force acting on it. This will cause it to follow a circular path, allowing us to use...

$$F_m = F_c$$

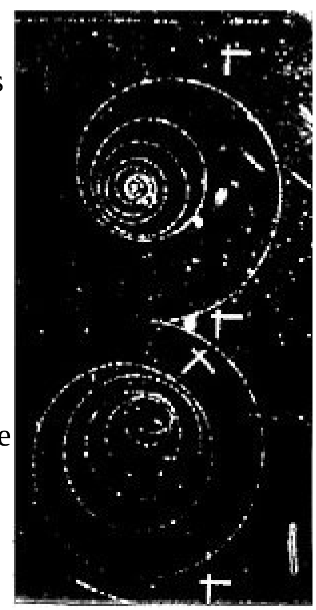


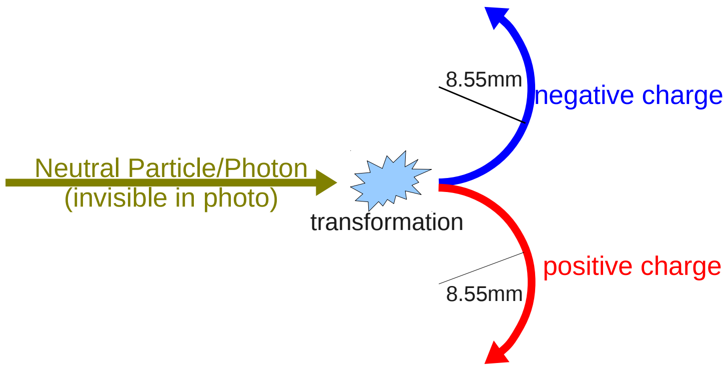
Illustration 4: Photo taken in a bubble chamber.

Example 1: The image shown here was taken using a bubble chamber that was placed in a 4.75e-3 T magnetic field [out of page]. Notice that in the middle, where nothing was before, we suddenly have two tracks appear that spiral in opposite directions. Each of these tracks has an initial radius of 8.55 mm. We know that the particles creating the tracks are initially traveling at 0.0240c (0.0240 times the speed of light). **Explain**, using a **sketch**, what you believe is happening in this image. **Determine** the charge-to-mass ratio of both particles. Finally, **explain** the significance of your calculation.

Since the spiraling particles appear "out of nowhere," we must assume that there was originally an uncharged particle or photon traveling to the right. It then transformed into two charged particles that we can see in the bubble chamber.

According to conservation of charge, since the original particle/photon was neutral the charges of the two particles we see must add up to zero. This means one of them is positive and the other negative. We can use the third hand rule to figure out which is which. Since the particles are

traveling to the right (thumb) and the magnetic field is out of the page (fingers), our **left hand** palm pushes **up** (must be a **negative charge** spiraling **up**), and our **right hand** pushes **down** (must be a **positive charge** spiraling **down**).
A sketch of this would look something like this...



To figure out the charge-to-mass ratio, we know that the the magnetic force is causing centripetal motion. We only need to do this once for both particles, since they are both doing the exact same thing (even though in opposite directions) in the same field.

$$F_m = F_c$$

$$qvB = \frac{mv^2}{r}$$

$$\frac{q}{m} = \frac{v}{Br}$$

$$\frac{q}{m} = \frac{0.0240(3.00e8)}{4.75e\text{-}3(0.00855)}$$

$$\frac{q}{m} = 1.7728531856e11 = 1.77e11\, C/kg$$

This value is significant because it is very close to the charge-to-mass ratio of an electron. What is surprising is that we already figured out the one particle is negative and the other is ***positive***. Both particles have a charge-to-mass ratio that indicates they are both electrons, but one of them *has* to be positive. We'll examine this odd result in the next lesson.

Homework

p834 #1
p835 #7