Building a Cloud Chamber

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Background

Charles Thomson Rees Wilson is credited with inventing the cloud chamber that he was able to perfect in 1911. His original chamber was cooled adiabatically by expanding the air inside a sealed container until the air molecules cooled and condensed to form a mist. In the following setup, we use isopropyl alcohol instead of water and we cool the chamber with dry ice instead of using adiabatic expansion.

How It Works

As the heating lamp raises the temperature of the top portion of the chamber, the alcohol begins to evaporate and fall away from the felt. The excess of vapor causes the chamber to be saturated with alcohol. The dry ice keeps the bottom of the chamber very cold and as the vapor diffuses towards the bottom, it supercools into an unstable state. This establishes a steep vertical temperature gradient within the chamber. A slight perturbation of this fragile equilibrium state can cause the vapor to easily condense into a liquid. As charged particles pass through the layer of supersaturation near the bottom of the chamber, they ionize the vapor as they strip away electrons from the gas atoms and leave behind positively charged ions. Each ion left behind becomes a primary site for initial condensation of the vapor, and so the settling alcohol droplets outline the trajectories of the passing charged particles.

Theory

As seen in Figure 1, there are many paths the particles can make. By identifying the paths, we can deduce which particles we are looking at in the chamber. The tracks below are results of muons from cosmic rays entering and interacting in the chamber. Tracks that look to have a bend in them are muons decaying into electrons (visible in chamber) and neutrinos (not visible due to zero charge). Tracks starting off as one and duplicating into two are from a muon hitting an electron causing it to fly off in another direction. A very jagged track is a muon bouncing off numerous atoms as it travels through the chamber. If you are using a source, you will see different tracks depending on what particles the radioactive source emits. If you have a strong magnet, you can see particles bend as they near the magnet. This is another way of distinguishing between different types of particles coming from a source.

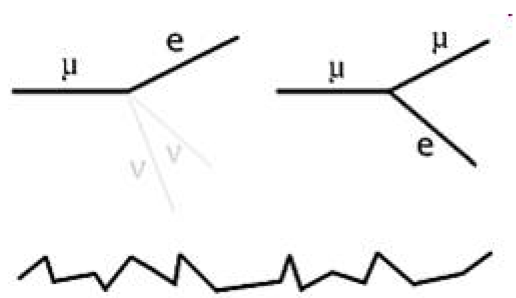

Figure 1: Identifying tracks

Equipment

- A clear, see-through glass container (referred to as chamber) with an open top (fish tank works well) with dimensions near 6" x 12" and 6" tall
- Flashlight that allows light to be focused to a point
- Sheet of metal that is a little larger than 6" x 12"
- Thin cardboard from back of spiral notebook or cereal box
- 3 sheets of felt (from local craft store) for the lining of container
- Plastic container larger than metal sheet / glass container

- Duct tape
- Black gorilla tape
- 91% isopropyl alcohol (may be found at local supermarket)
- 1 lb dry ice (may be found at local supermarket)
- Gloves (to handle dry ice)
- 4 large binder clips
- Super glue / glue gun
- Heat lamp
- Radiation source (provided by professor)

WARNINGS

- Be careful when handling radioactive sources, as they are harmful when handled for long periods of time
- Do not place heat lamp too close to chamber, this may crack the glass
- Use gloves when handling dry ice! Direct contact is dangerous as the temperature of the ice is $-78.5°C(-109.3°F)$

Procedures

Before preparing the chamber, place the dry ice in the plastic container and the metal on top of ice to start cooling process. Also glue the large binder clips to the bottom of glass tank as seen in Figure 2 (Note: Fig 2 is a view of the tank/chamber upside down with the opening facing down). Also line one side of the cardboard with black tape so that the entire surface is black. This will be used as a background to pick up the particle tracks more easily.

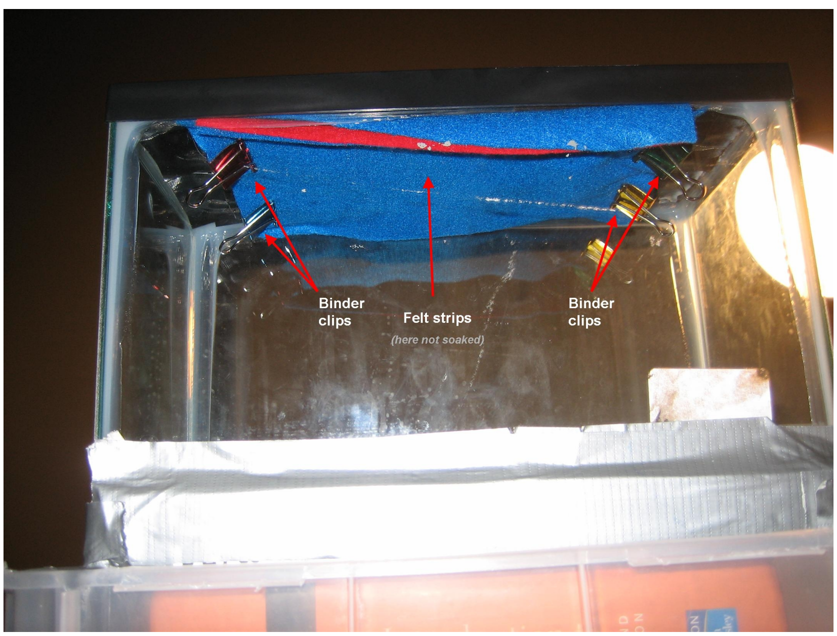

Figure 2: Binder clips attached to top of chamber

Soak felt in alcohol and wring it out if necessary so that there is not excess alcohol dripping down the sides when the chamber is inverted. Attach the felt to the top of the chamber using the binder clips. Make sure that the felt is stretched fairly tight so that it stays in place once upside down.

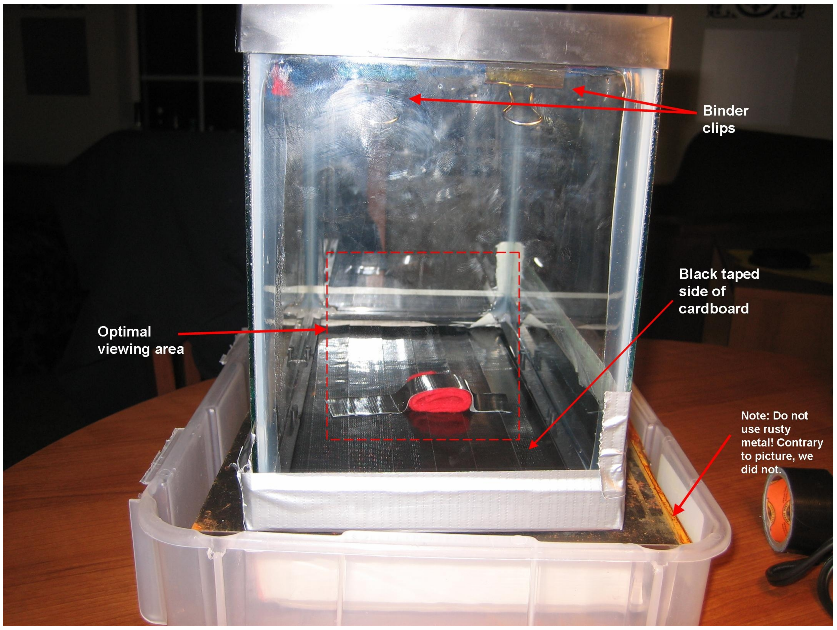

Figure 3: Source and optimal viewing area

If you have a source, attach it to the black side of the cardboard closer to one end with the particles emitting towards the center of the chamber as in Figure 3. Particle tracks resulting from a source are more prominent than cosmic rays.

Place cardboard on the open side of the chamber with the black side facing inward. Fold the edges of the cardboard over if they are wider than the chamber itself. Duct tape the cardboard to the chamber making sure to not cover up too much glass but enough to keep the chamber airtight.

Turn over chamber and place on top of metal sheet as seen in Figure 4. Place the heat lamp over the top of the chamber positioning it to evenly heat the felt layer inside. Wait 10-15 minutes (time may vary).

Turn off the room lights. At this point you should see a layer of rain forming near the bottom of the chamber. This is formed from the temperature difference between the dry ice and the evaporated alcohol. The alcohol evaporates and creates the mist used to see the tracks. Use a flashlight with a concentrated beam to view the particle tracks. If you have a source, there should be more tracks near the particle emitting end.

Notes

- Keeping the chamber airtight is essential for detection of particles
  - If there are large clouds at the edges of the chamber, then air is leaking in
- Make sure dry ice is making even contact with metal sheet so that cooling is uniform
- Bring camera to record events (see Figures 5, 6, and 7)

Useful Links

www-outreach.phy.cam.ac.uk/camphy/cloudchamber/cloudchamber1_1.htm

www.cloudchambers.com/aboutcloudchambers.htm

teachers.web.cern.ch/teachers/document/cloud-final.pdf

Results

Below are some images of the particle tracks resulting from a gamma source (Cs-137) and possible cosmic rays.

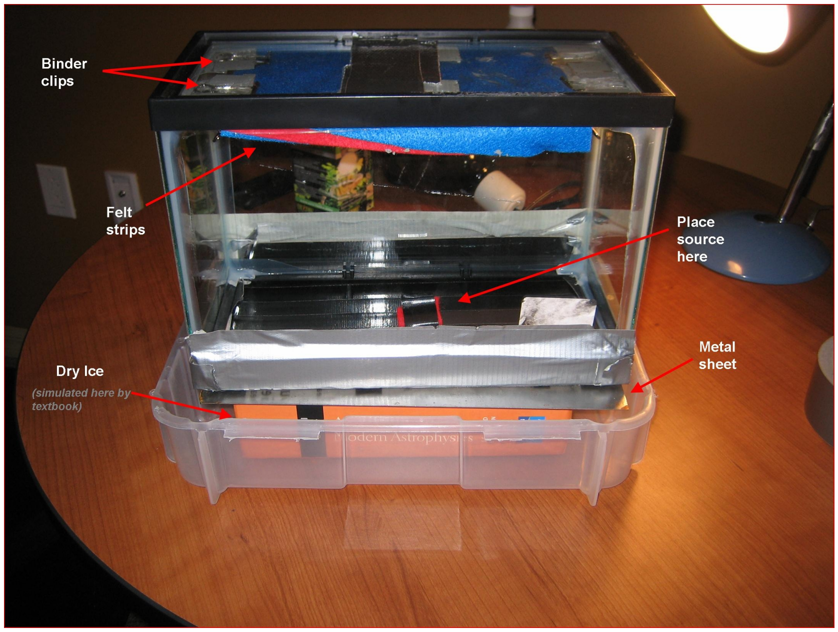

Figure 4: Complete cloud chamber

Figure 5: Single particle track

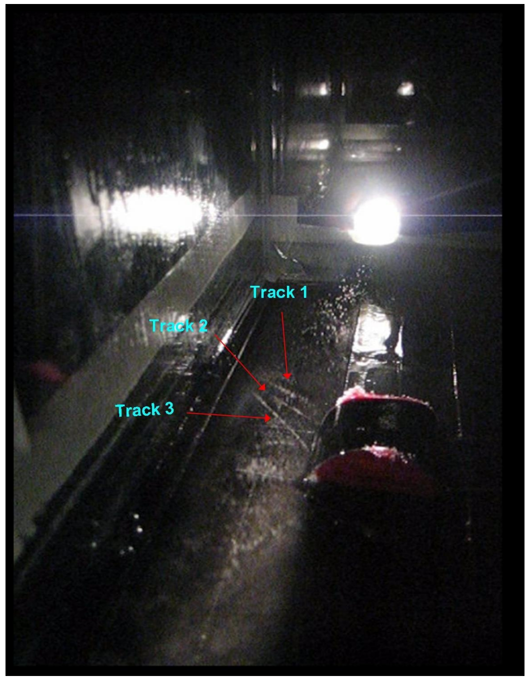

Figure 6: Three tracks

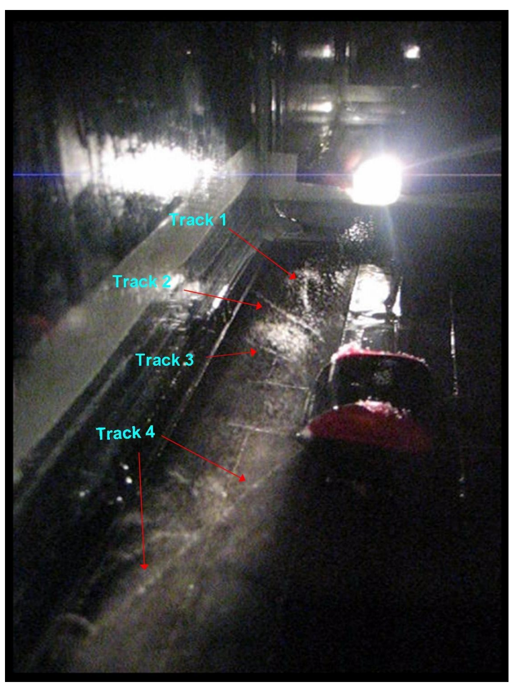

Figure 7: Four tracks