Reconstructing Cosmic Ray Showers from Directional Information

When a cosmic ray interacts with the Earth's atmosphere it creates secondary particles. These particles then interact in the atmosphere and create even more particles, which then create more particles and on and on. This process, called a *cosmic ray shower*, propagates through the atmosphere until eventually, some of the particles reach the ground.

Some cosmic ray detectors measure the direction of the incoming particles, and from that information are able to reconstruct the direction of the original cosmic ray. This activity will explore that type of reconstruction in two dimensions.

Other cosmic ray detectors record the time the incoming particles arrive, and are able to reconstruct the direction of the original cosmic ray from the timing information. The CHICOS detectors work in this way. A second activity available on the CHICOS classroom webpage will explore that type of reconstruction.

In this activity students will work backwards from ground particle directions to reconstruct a two dimensional cosmic ray shower using the method of angle bisection.

1 Materials

To complete this activity each student will need the following materials:

- Cosmic Ray Shower Activity Sheet (attached)

- Drawing Compass

- Pencil

- Ruler

- Eraser

2 Cosmic Ray Shower Reconstruction

- Notice the short black lines at the bottom edge of the Cosmic Ray Shower Activity Sheet. Using a ruler, extend the two right-most lines until they intersect.

- Use a compass to bisect the angle that is formed when the two lines meet following the steps below.

- To bisect the angel, place the point of the compass at the intersection of the two lines so that it opens into the angle. Sweep an arc across the two lines.

- Reposition the point of the compass at the intersection of the arc and one of the lines. Sweep an arc through the center of the angle you are trying to bisect.

- Reposition the point of the compass at the intersection of the arc and the other line. Again sweep an arc through the center of the angle you are trying to bisect, this second arc should cross the one you just drew.

- Use a ruler to draw a line from the intersection of these two recent arcs and the intersection of the two lines which form the angle. This line bisects the angle.

- You will no longer work with the original two lines, you will only work with the bisection line. Extend the bisection line a few centimeters up the page from where the original lines intersected.

- Move on to the third and fourth right-most black lines at the bottom edge of the page. Using a ruler, extend these lines until they intersect.

- Use a compass to bisect the angle that is formed when these two lines meet, using the method described above.

- Extend the bisection line a few centimeters up the page from where the original lines intersected.

- Move on to the fifth and sixth right-most black lines at the bottom edge of the page. Using a ruler, extend these lines until the intersect.

- Just as before, bisect the angle that is formed when these two lines meet and extend the bisection line a few centimeters up the page.

- Next, extend the bisection lines until they cross and repeat the angle bisection process to find the direction of the resulting line. Whenever two lines cross, bisect their angle to find the direction of the resulting line. Extend only the bisection line once you have found it. In this manner, work your way up the page.

- Repeat this process with the lines on the left hand side of the page. **However, use caution.** The left hand side is more complicated. Some of the lines will not cross another line right away. Extend all six black lines on the left hand side in small increments, a few centimeters at a time, until two lines cross. Whenever two lines cross, bisect their angle and extend the bisection line up the page also a few centimeters at a time, as you increase the length of all lines.

- Every time two lines cross, bisect the angle and extend the bisection line up the page.

- In the end, you should have only one line which goes off the top of the page. This line represents the single incoming cosmic ray.

- To clean up the shower, you may want to erase all the angle bisection arcs and the portions of the lines which extend past the intersection point.

You have reconstructed a cosmic ray shower from the ground up. Looking at the completed shower, you'll see that a single cosmic ray comes in from the top of the page. It interacts with the atmosphere and produces two particles. The particle on the left quickly interacts again and produces two more particles, while the particle on the right travels further before interacting again. In this manner the cosmic ray generated a particle shower which eventually reaches the ground and is measurable in a detector.

Cosmic Ray Shower Reconstruction Activity

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