

We know that the universe is very large; extremely large!

You might wonder what you would see if you could travel to the edge of the universe. The answer may depend upon whether we live in a “flat” or a “curved” universe. This distinction is not readily apparent. The procedure below may help you to understand the difference between a flat universe and a curved universe.

Materials: Paper Tape about 2 Meters long, Scissors, Masking Tape (about 15 cm), Pencil

Procedure: 1. Cut the paper tape into two equal pieces, each about 1 meter long.

For a Flat Universe:

2. Label one of them, “Flat Universe”.

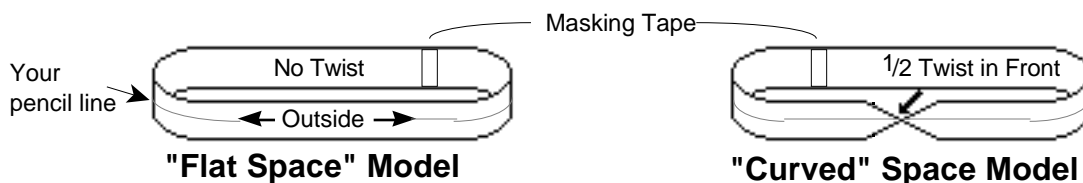
Mark one side in big letters, “**Inside**”, and the other side “**Outside**”.

Use masking tape to make a loop with “**Inside**” on the inside.

3. Draw a pencil line all the way around the outside of loop at the center of the paper (the long way).

4. Carefully punch a very small hole through the paper tape along the line.

Then cut the loop into two loops along that line.



For A Curved Universe:

5. Label the second paper strip, “Curved Universe”

Mark one side, “**Inside**”, and the other side “**Outside**”.

This time, when you make the loop, give the paper a twist so that the inside and outside meet. (See the diagram above.) Tape the loop closed as did in step 2.

6. Draw a pencil or pen line all around the outside of the loop *until it meets itself* to form a closed circle. This is known as a Möbius loop, named after a European mathematician who studied its unusual properties.

Is your line inside or outside the loop? _____

7. Use a point of the scissors to punch a hole along the line and cut the loop in half along the line. How did the “curved universe” come out differently when you cut it?

8. For another surprise, cut the curved universe loop in half the long way again.

What do you get this time? _____

Optional: For an interesting variation, make another Möbius loop, but this time cut it into thirds the long way with your scissors.

Summary: The first (flat) universe, model represents a universe that would have an outer edge. Beyond that edge would be the unknown, outside the universe. The second, (curved) universe model, represents a universe that “curves in” on itself. The curved universe would have no edge, just as the twisted loop has no inside or outside. It’s like the surface of a sphere. A straight line along the curved surface of a sphere loops back on itself.

Wrap-Up:

- A. You may know that light travels in straight lines. What would happen to a ray of light after it comes to the edge of a normal (flat) universe?

- B. The surface of the Earth is a like a curved universe. If you traveled straight west all the way around the Earth, where would you end up? _____
- C. How might that ray of light in question A act differently near the “edge” of a curved universe?

- D. In your own words, what might we mean by a “curved” universe?

- E. This is a very difficult, but an interesting question. What do you think might be outside the universe?

- F. Do *you* think that our universe is flat or curved? Why?

Extensions: What is a “Klein Bottle” as what does it have to do with this activity?
What is the branch of mathematics known as “topology” and how can it be of use to us?

Frank and Ernest

By Bob Thaves



Difficulty: Fairly Easy

Content: High Interest, Not Essential

Mode of Instruction: Lab

Preparations: Assemble materials

Materials: See the lab

Time: 20 - 30 minutes

- Suggestions for the Teacher:**
1. Students enjoy doing this regardless of how much thought they give it
 2. Circulate among students to accentuate the surprises that come in cutting the Möbius loop.

Student Intro: This is a lab to help you understand that the properties of the universe have many surprises.

Post-Lab: Discuss the variety of student answers to the questions in the lab.

Extensions: See the lab.
Also, how has “dark energy” changed our ideas about the future of the universe?

Source: Thomas McGuire, Cave Creek, AZ

Procedure:

6. The line is actually *both* inside and outside. (The loop has just one side!)
7. The sliced loop makes a single larger loop.
8. This time there are two loops, but they are interlocked.
(Looped together.)

Wrap-Up: (Accept a wide range of answers if they seem to represent an honest effort to answer these unusual questions.)

- A. Answers may vary, but one possibility is that light would continue outward, thereby expanding the universe.
- B. Circumnavigating Earth in any direction, you would come back to the place you started.
- C. The ray of light might curve back upon itself returning to where it started.
- D. This is a universe in which the laws of plain geometry do not apply.
- E. Answers will vary. There is no way to say any response is wrong!
- F. Answers will vary.