How High Up Is Space?

Activity I11

Grade Level: 5–12

What's This Activity About?

How big is the Earth's atmosphere and where does space begin? This is a question that many students have trouble picturing and this activity helps them get a handle on the relative size of the Earth's atmosphere and the various ideas about where space starts.

What Will Students Do?

Students construct a scale model in which the height of Mount Everest is equal to the thickness (diameter) of a regular pencil. They then see where various things (such as airplane flights, the beginning of space, the Hubble Space Telescope, etc.) fit on the model.

Tips and Suggestions

- Depending on the age and math skills of the students, you can either make the calculations a central part of the activity, or just give them the answers and allow the sense of wonder at the results to be the main thing they get out of it.
- We strongly recommend doing Extension 2 at the end of the activity if you can make time. Many students think the Earth's atmosphere is much thicker, relative to our planet's diameter, than it actually is.

What Will Students Learn?

Concepts

- Earth's atmosphere
- Air versus space
- Karman Line

Inquiry Skills

- Calculating
- Measuring
- Predicting
- Comparing
- Visualizing

Big Ideas

- Models and simulations
- Scale and structure

How High Up Is Space?

by Andrew Fraknoi
(Foothill College & ASP)

Introduction

For this generation of students, space flight is a routine part of their cultural experience. Pictures of astronauts in space are commonly seen as posters, screen savers, and textbook illustrations. Despite this, most students are pretty unsure how high above the Earth objects in space really are. This activity is designed to help them get a sense of scale about where outer space begins.

We should also note that scientists, engineers, and policy experts don't always agree on the exact definition of where the Earth's atmosphere ends and space begins. For older students, it's perfectly OK to expose them to this disagreement, as a reminder that not everything in science is as settled as science textbooks sometimes imply.

Procedure

1. First, we want to find out what students own ideas are about the Earth, its atmosphere and outer space. For younger students, you could ask them to draw a picture that shows the Earth (or part of the Earth), its atmosphere, where space begins, and where the Hubble Space Telescope is located. For older students, you might ask them to draw these things and also put in their best estimates in kilometers or miles of where things are.

2. Ask students if they know how tall Mount Everest, the highest mountain on Earth, is. Let them make a series of guesses, before telling them the answer is 8.8 kilometers or 5.5 miles.

3. Now we'll make a scale model. Ask them to draw this mountain at the bottom of a sheet of blank paper and make its height the same size as the diameter of a standard No. 2 pencil (7 mm or 9/32 of an inch). Using that scale, ask them to show how high above the mountain space begins. When they are done making their drawing, they can form small groups, share their ideas, and see if their group can agree on an estimate of how much higher than Mount Everest the beginning of space would be. Each group can produce a final drawing from the group

4. Next ask them to show where they think the Hubble Space Telescope is orbiting on the same drawing. Again, after they do their individual estimate, they should compare within their group and see if they can come up with a group estimate.

Mount Everest from an Airplane

5. You can then ask the groups to report out either verbally, or by posting their group drawing (with group names on it) on the class bulletin board.

6. Then distribute the atmosphere scale model handout and ask them to calculate where the different altitudes are on the Mt. Everest-is-a-pencil-diameter scale. This can be done either individually or in groups. (One issue that always comes up is how to round your answer; how many decimal places should your answer have. You can discuss this with them before hand, or let them struggle with it a bit and then ask *them*

to recommend the right method of rounding.)

Note to teacher: The scale works out to be that 1 km = 0.08 cm, 10 km = 0.8 cm, 100 km = 8 cm. In British and U.S. units, 1 mile = 0.05 in, 10 mi = 0.5 in, 100 mi = 5 in.

7. Once they have done the calculations, they can reclaim their group drawing and measure out where things actually go. Have a discussion of how their estimates compared to reality. Did space begin where they thought it would?

Hubble Space Telescope in Space *(NASA):*

Extension Activities:

1. For older students, hand out the Background Information sheet and then discuss the issue of how to define the beginning of space. Ask them what definition they prefer and to say why.

2. Now let's include the entire planet Earth. First ask the students to guess how big the diameter of planet Earth would be on our scale. After they have made their own estimates, you can ask them to calculate the size of the Earth on the Mt. Everest-pencil scale. Earth is 12,700 km or about 7,918 mi in diameter.

The answer is that on our scale model the Earth would be 1016 cm = 10.2 meters or 395 inches = 33 feet wide.

Give students time to react to this calculation. Explain that if the Earth is 10 meters or 10 yards wide, its atmosphere (the Karman line; see the Background Information sheet) is only 8 cm (about 3 inches) wide. Were the students surprised?

Some teachers like to point out that if the Earth were shrunk to the size of an apple, the atmosphere would be the size (thickness) of the skin of the apple.

How High Up is Space?

Worksheet

We want to figure out a scale model for how high up space begins. For our scale, we will make Mt. Everest, the highest mountain on Earth, the size of the width of a pencil (7 mm or 0.7 cm). On that scale, how high would airplanes, meteors, and the beginnings of space be?

Name	Height (km)	Height (mi)	Scaled Height (cm)	Scaled Height (in)
Mt. Everest	8.8	5.5	0.7	9/32 = 0.28
Where commercial jet aircraft fly	8 to 13	5 to 8		
Top of the Stratosphere (below which 99% of the Earth's air is found)	50	30		
Where meteors burn up	75 to 100	47 to 60		
Where NASA says you get astronaut wings	80	50		
Karman Line — the international boundary of space	100	60		
Hubble Space Telescope orbit	560	350		

Figuring Out the Scale:

If 8.8 km is 0.7 cm, then each km is _______________ cm

If 5.5 mi is 0.28 in, then 1 mile is _______________ in

Show How You Calculated Your Scale:

Background Information: How High Up is Space?

by Andrew Fraknoi (Foothill College and the Astronomical Society of the Pacific)

Outer space is fun to think about but hard to pin down. Where exactly does the Earth's atmosphere end and outer space begin? Our atmosphere doesn't end in a neat boundary — it just kind of thins out until its effects go away. So figuring out where to put the beginning of space is not so easy! Experts who have thought about this question disagree.

Some people say we should start thinking of space where humans can't breathe any more, but this is probably too self-centered a definition. Also, people who live at high altitudes all their lives can breathe much thinner air than those who grow up near sea level. That means this definition would be different for different people. Furthermore, people fly in airplanes (whose cabins are pressurized) at much greater heights, and no one thinks that airplanes fly in space. Commercial jets fly at heights of 5 to 8 miles (8 to 13 km). So almost everyone agrees space should start higher than that.

The Earth's Atmosphere and the Moon, Seen from the International Space Station *(NASA)*

Another definition of where space begins has to do with how much of the Earth's air we are above. Scientists divide the atmosphere of our planet into several layers. The lowest layer, which starts at the surface, where we live, is called the *troposphere* and it goes up to an altitude of 4–12 miles (6–20 km). We don't give one height, because at the equator, where it's warm, the troposphere extends higher up than at the poles, where it's cold. About 80% of the Earth's air is in the troposphere.

The next layer up is called the *stratosphere,* and it starts at the top of the troposphere and goes up to an altitude of about 30 miles (50 km). About 19% of our air is in the stratosphere. So by the time you are at the top of the stratosphere, you are above 99% of the Earth's atmosphere. Do you think that could be a good definition for where space begins?

Most experts want to place the beginning even higher. An *astronaut* is someone who has gone into space, and the U.S. government gives astronauts their official designation when they have gone higher than 50 miles (80 km). On the other hand, most other countries demand an even greater height before certifying that a person has been in space. Their requirement is roughly 60 miles (100 km), which is called the *Karman Line.* Theodore von Karman, a Hungarian-American aerospace engineer, first suggested this in the 1950's as the dividing line between the realms of *aeronautics* (the study of how things fly in air) and *astronautics* (the study of how things move in space). Above this line, von Karman calculated, airplanes, which are lifted by the pressure of air under their wings, would have to fly faster than the speed required to orbit the Earth to get enough lift.

Today, the international organization that approves records for flight uses the Karman line to define where space begins. When in 1996, the X Prize Foundation established a prize (eventually called the Ansari X Prize) of $10 million for the first non-government flight into space, they set the height required to win the prize to be the Karman line. The winner, Space Ship One, flew to a height of 112 km in October 2004. This was a case where 10 million dollars hung on the definition of where space began.