# 9.2: Aristotle's Flat Moon

There is an ancient theory – sometimes attributed to Aristotle – that accounted for lunar phases in a different way than we do today. This theory held that the Moon was in fact flat (or perhaps bulged out on one side rather like a warrior's shield). One side of the Moon was silvery-white, the other side was black, and it was the orbiting of this half-black, half-white Moon around the Earth that caused the lunar phases.

Why did they say that the Moon was flat? It is very difficult, if not impossible, to actually ***see*** the spherical shape of the Moon. If you look at a ball at arm's length, or even across the room, there are many subtle clues of shading and shadow that allow us to see that the ball is in fact round. This is not true of the Moon! The full Moon looks perfectly flat – just like people in Aristotle's time, we claim to see what we are taught to see!

If this seems silly to you, let me remind you that the most common misconception ***among adults*** about the lunar phases is that they believe that the Earth's shadow falling on the Moon somehow causes or creates the lunar phases! Maybe that Aristotle fellow wasn't as silly as he appears at first glance! In any case, let's test Aristotle's theory as Galileo did and see what happens.

### Academic Standards

#### Science and Engineering Practices

- Developing and using models.
- Planning and carrying out investigations.
- Analyzing and interpreting data.
- Constructing explanations.
- Argument from evidence.

#### Crosscutting Concepts

- Patterns in nature.
- Cause and effect.
- Systems and system models.

#### Next Generation Science Standards

- Space systems (K-5, 6-8, 9-12).
- Structure and function (K-5, 6-8, 9-12).
- Waves and electromagnetic radiation (6-8, 9-12).
- The Earth-Moon system (6-8, 9-12).
- Gravitation and orbits (6-8, 9-12).

## For the Educator

### Facts you need to know

1. The Moon is actually round, not flat. (Okay, you already knew that one!)
2. A model makes predictions – we record these predictions and test them against what we see in Nature. Good models make accurate predictions!

### Teaching and Pedagogy

This activity teaches much more about the process of science as a cultural activity than it does about the Moon. There is no controversy today about how the phases of the Moon work, how far away the Moon is, or what the Moon is shaped like – but this was not always true!

We have areas of science today which have powerful controversies swirling about them. Theories about global climate change, how (and if!) vaccines work, the evolution of species, and life on other planets are just a few of these that students may have seen in the news.

When students see one group of adults shouting that "the science is settled!", or "96% of scientists agree with our theory!" on one side of the issue. On the other hand, there are those who insist just as vehemently that the prevailing theory is wrong; the climate never changes, species do not evolve, and vaccines cause autism but do not actually protect people from disease.

Many students (and adults!) find these arguments very disconcerting. I have had hundreds of students and adults approach me as a scientist and ask, “Which one of these is true?”, or even more to the point, “How do we know which one of these ideas is correct?”

Science isn’t about votes or polls of course, and ***people do not decide*** which theory is valid. Real scientists use experiments and data to decide these things, and Nature cannot be argued with! Even so, sometimes the experimental results are not clear to us; more often, we simply do not know how to interpret and understand what the experiment is telling us.

Never the less, sometimes we do get definitive results; powerful experiments can show us that a theory is clearly wrong. At this point, no matter how fond we are of a particular idea or theory, it is time to discard it in favor of more accurate and powerful ideas. Teaching students how we decide between theories, keeping one and casting the other aside, is a powerful lesson about science that armors children against future misconceptions and manipulation.

### Student Outcomes

What will your students discover?

- Data from an experiment does not always support our hypothesis! This is an important idea. Teachers almost always have students ***perform experiments that work***. Why would you waste precious class time doing an experiment that you knew would fail?

  > The reason that we need to do an activity like this occasionally is that ***experiments do fail.*** Not every hypothesis is correct, and many more incorrect hypotheses are tested than correct ones. Every reputable scientist knows this – but very few students do.

- The Moon is not flat. (Seriously – that is what we were testing with this activity!)

What will your students learn about science?

- Your students will learn that theories are fallible, human creations that are subject to error and misinterpretation. We too often see theories held up as gospel-like and infallible in the media and in classrooms. Students need to know that theories are always open to question and inquiry.
- Theories are beneficial only when they make definite, testable predictions. A theory that makes no testable predictions at all is scientifically useless.
- If a theory makes predictions that are demonstrated to be false, then that theory must be revised or discarded. There is no room for sentiment, desire, or political correctness in science – we must be humble before the facts.

## Conducting the Activity

### Materials

1. A ping-pong planet model of the Earth, Sun, and Moon (See Activity #19)
2. Three poker chips, one white, two black. (You can paint these the necessary colors if you don’t have ones of the correct color. Painted coins may also be substituted.)
3. Epoxy, hot glue, or super glue

## Building the Flat Moon Model

1. Glue one black and one white poker chip together face to face. This will serve as Aristotle’s black-and-white Moon.
2. **[Teacher]** Epoxy or glue the double chip from step #1 on edge on the second black chip as shown below. I filed a flat spot on the edge to make the gluing easier. You can use hot glue or epoxy for this, I have found that silicone glue isn’t strong enough for this edge-on application, and superglue needs more surface to grip effectively. Regardless of what glue you use, be sure to hold the edge-on chips in place until the glue is completely hardened.

### Exploring the Flat Moon Model

1. Now it is time to try a version of Activity #23 (Modeling Lunar Phases) using Aristotle’s flat Moon instead of a round one. Let the students play with this model, and ask them to see if they can get anything that looks like the familiar lunar phases out of it.
2. Try as they might, they will not be able to do this successfully. There is no position that works and shows us the familiar gibbous, quarter, and crescent phases. The flat Moon with one white face and one black face conflicts with everything we know about the Sun lighting planets and creating day and night.

3. Because this model of the flat Moon ***does not show us what we see in Nature***, we must reject this model. The model may be interesting, but it becomes clear that Nature does not work this way, so our model is useless to us as scientists.

Discussion Questions

1. What does this activity show about Aristotle's theory?
   - **Answer:** Aristotle's ideas about the lunar phases were incorrect. His theory did not make correct predictions and did not support or explain the facts we already knew.
2. Why do we, as scientists, decide to keep one theory and throw out another?
   - **Answer** When a theory cannot explain new facts, it must be modified to account for the new information. When new information conclusively proves that predictions made by the old theory were wrong – then that theory is incorrect. It must be substantially modified, or discarded all together in favor of a new theory which works better.
3. What happens when we have two different models that make similar predictions? How do we decide between them?
   - **Answer** Sometimes we find out that what we thought were two different models are actually the same when we look at them in another way. Other times, we simply do not know enough about the models to design an experiment that would decide which model is true and which is not. This sort of disagreement often indicates that we do not know enough about the subject and that we need to keep studying and learning more about the Universe before we can decide between our competing theories!

## Supplemental Materials

### Going Deeper

While it may seem strange to set students to trying out an experiment that is quite unworkable and doomed to failure, this activity does serve an important purpose. Aristotle's idea of a flat Moon were simply accepted based upon the thinker's great name and left untested for centuries. These untested (and incorrect!) ideas were taught in colleges, written down in books, and accepted without question for almost ***two thousand years!*** It was Nicholas Copernicus who developed the first modern ***heliocentric model*** of the solar system, but he never promoted his ideas during his lifetime and in fact held back the publication of his work until almost his dying day.

Galileo was cut from a different cloth altogether. He marveled at Copernicus' Sun-centered theory, and set out to test it. Galileo not only invented the modern astronomical telescope, he single-handedly gathered the needed experimental data to prove Copernicus' ideas were correct. Galileo developed many simple activities much like those in this book and wrote about them in simple language so that everyday people could try these experiments for themselves and see that Copernicus' theories of how the solar system worked were superior to those of Aristotle. Galileo fought for the acceptance of these ideas and stood fast, refusing to give up in the face of terrifying opposition.

Galileo's fight for scientific truth cost him his job, his fortune, and even landed him in jail for the rest of his life, but he never relinquished the truth. Galileo's stubbornness freed us from the tyranny of false ideas and launched the modern scientific age. Every time we ask for data, and not blind belief, we too stand fast and support the truth. When the data demands it, Galileo taught us that we must abandon old established ideas in order to move forward. We do not throw out theories because they are unpopular or uncomfortable, we do not accept them because our teachers or civic leaders tell us to do so. We stand fast and support the truth, backed by sound scientific data and successful experiments.

You may have guessed by now that Galileo is something of a hero of mine, I hope he will become one for you and for your students as well. Go ahead and find a picture of the old gent and hang it up in your classroom. Even better, ask the children to draw their own pictures of Galileo and write a bit about what he did and what we owe him for his stubborn stance and determination to protect and promote scientific truth!

### Following Up

Sometimes teachers are uncomfortable about teaching scientifically controversial subjects and choose to avoid them – other times teachers present these subjects as though they are not controversial at all; the phrase "The science is settled" springs to mind here.

I believe that both of these pedagogical models do a disservice to the student. When we avoid controversial topics all together, we teach students to think of controversial issues as unpleasant and to avoid them when possible. There is also an underlying current of disrespect, an implicit claim that the student is not capable of dealing with or understanding the issues at hand.

On the other hand, when we stoutly proclaim that there is no controversy, that ***scientists know the Truth***, we implicitly lie about the nature of science. In the time of Copernicus and Galileo, 99% of the educated populace agreed that the Sun revolved around the Earth which was itself the center of the cosmos. Galileo was dismissed as a dangerous crank – today Galileo is also venerated as one of the greatest heroes in scientific history.

We ***can teach controversial subjects.*** We can teach them, if nothing else, as an example of how science works, how men and women challenge each other's ideas, and struggle to gain a better understanding of Nature. We can teach that science is never 100% certain, and that no idea is above criticism or challenge. Einstein became famous in 1905 because he was the first scientist in 250 years to challenge Newton's ideas about gravity. One hundred years later, scientists are still busily engaged in designing and carrying out experiments to prove (or disprove!) Einstein's ideas and predictions.

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