Space is enormous!

A classroom activity to mark the Angolan solar eclipse of February 26th 2017

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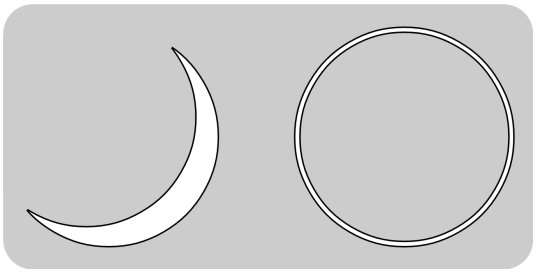
PART 1: BACKGROUND

The Angolan solar eclipse: a teachable moment

Bybee (2015) describes a "teachable moment" as the occasion when students are "caught by phenomena, events or situations" that create "a need to know and increased motivation to learn". On February 26th 2017 there will be an exciting teachable moment for students in Angola: a solar eclipse.

In Luanda it will be an 82% partial eclipse. This means that 82% of the sun will be covered by the moon, and the sun will appear as a narrow crescent (below left). In Cabinda it will be a 70% partial eclipse; in Lubango it will be 94%.



Between Lubango and Lobito — along a narrow corridor that includes Bentiaba, the southern part of the city of Huambo, and the Parque Nacional da Cameia — the eclipse will become annular. This means that the sun will appear as a thin "ring of fire" around the moon (above right).

Information for your town or city

An interactive Google map for the eclipse is available from NASA:
https://eclipse.gsfc.nasa.gov/SEgoogle/SEgoogle2001/SE2017Feb26Agoogle.html

You can zoom in and click on the map to obtain the details for the eclipse at your location. The times shown are Universal Time (UT) — add one hour to get the local time in Angola. For example, 16:32 UT is 17:32 Angolan time.

The annular phase of the eclipse is only visible along the narrow corridor marked by the two blue lines (the northern and southern path limits).

Important safety message

NEVER observe a partial or annular eclipse with the naked eye. Even if the sun is 99% covered by the moon, the remaining sunlight is extremely bright and can cause permanent damage to the eye.

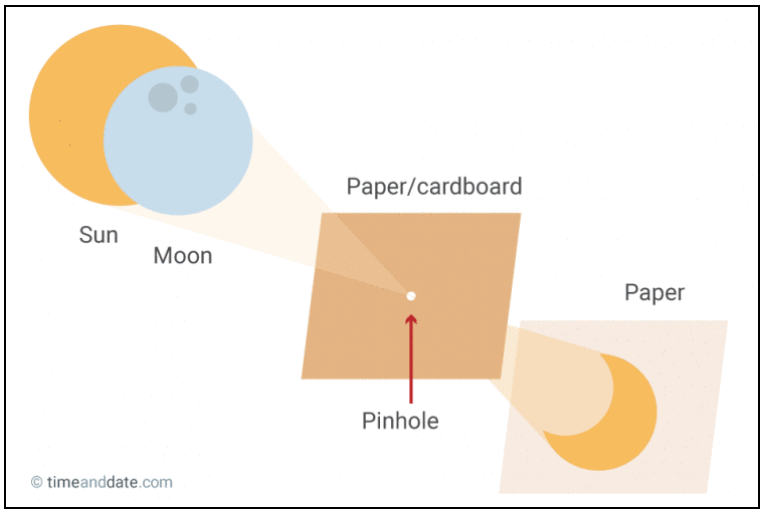
Please make sure your students understand this important safety message before the solar eclipse occurs on February 26th (which is a Sunday).

Observing a solar eclipse safely

Annular and partial eclipses can be safely observed with a specially designed solar filter, such as eclipse glasses or an eclipse viewer. Even when using solar filters, however, NEVER stare at the sun for long periods.

NEVER use normal sunglasses, film or smoked glass, and NEVER use solar filters with binoculars or telescopes (unless it is a specialist telescope filter, and is placed on the front, sun-facing end of the instrument).

Another way to safely observe a partial eclipse is by projection, which can be done very simply with two pieces of card: make a small hole in one card, and use it to project an upside-down image of the sun onto the other. You can experiment by changing the size of the hole, and the distance between the two pieces of card. NEVER look at the sun directly through the hole.



https://www.timeanddate.com/eclipse/make-pinhole-projector.html

PART 2: ABOUT THIS ACTIVITY

Summary and objectives

"Space is enormous!" is a 45-minute classroom activity that can be done either before or after the solar eclipse occurs. It is ideal for students in years 7, 8 and 9.

The class creates a scale model of the earth-moon-sun system, and uses it to achieve a scientifically accurate understanding of:

- The relative sizes and distances of the earth, moon and sun;
- Why the sun and moon appear to be the same size in the sky;
- Why solar eclipses are rare events;
- Why some eclipses are annular, and some are total.

Links to the Angolan school curriculum

This activity supports the following "general objectives" of physics in years 7, 8 and 9 (Editora Moderna 2013):

- Provide the acquisition of concepts, laws, theories and models necessary to understand the phenomena that surround us;
- Contribute to helping young people to progress in the construction of knowledge, based on their own knowledge;
- Encourage young people to question knowledge in order to reveal the need to alter or even eliminate existing theories.

It can also be used to support the following "specific objectives" of "Theme A: the universe" in the year 7 programme:

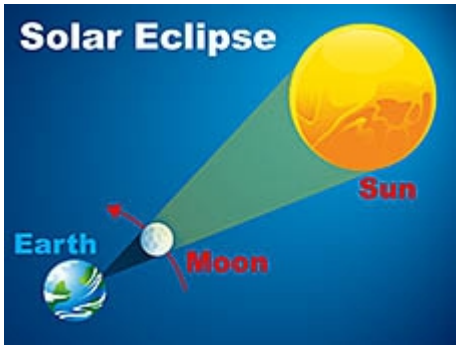
- Place the earth and the solar system in the universe;
- Identify several celestial bodies existing in our solar system;
- Distinguish luminous bodies from illuminated bodies;
- Identify the sun as the star that governs our planet;
- Interpret the apparent movement of the sun and the stars in general;
- Explain the succession of days and nights;
- Explain the phases of the moon;
- Relate the phases of the moon with the movement and rotation of the earth;
- Interpret eclipses of the sun and the moon.

One of the suggested methodologies for the above objectives is the "exploration of models and simulations of the earth's movement around the sun, the phases of the moon and eclipses of the sun and moon."

A popular misconception

According to Allen (2010), "humans routinely construct mental models in order to make sense of the world". However, "if these constructions conflict with accepted scientific ideas they are misconceptions, and act as a barrier, preventing successful learning in science."

A solar eclipse can reinforce a widely held misconception: diagrams in the media — as well as in science textbooks and on science websites — show the earth, moon and sun as being approximately similar in size, and close together in space. Here is an example from NASA's website:



https://www.nasa.gov/content/eclipses-and-transits-overview

As we will see, this is a rather misleading image. In fact, the true sizes and distances are difficult to comprehend. As the popular science author Bill Bryson (2003) has written: "Space, you see, is just enormous — just enormous."

Further information

More information about the sun, the moon, eclipses — and much more — is available at https://www.timeanddate.com/astronomy/

timeanddate.com

Any questions or comments?

If you have any questions or comments about this activity, please send an e-mail to hello@tensentences.com.

Acknowledgements

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References

Allen, M., 2010. *Misconceptions in primary science*. Maidenhead: Open University Press.

Bryson, B., 2003. *A short history of nearly everything*. London: Black Swan Books.

Bybee, R. W., 2015. *The BSCS 5E instructional model: creating teachable moments*. Arlington: NSTA Press.

Editora Moderna, S.A., 2013. *Programa de física: 7ª, 8ª e 9ª classes*. 2ª edição, 1ª tiragem. GestGráfica, S.A.

PART 3: HOW TO DO THIS ACTIVITY

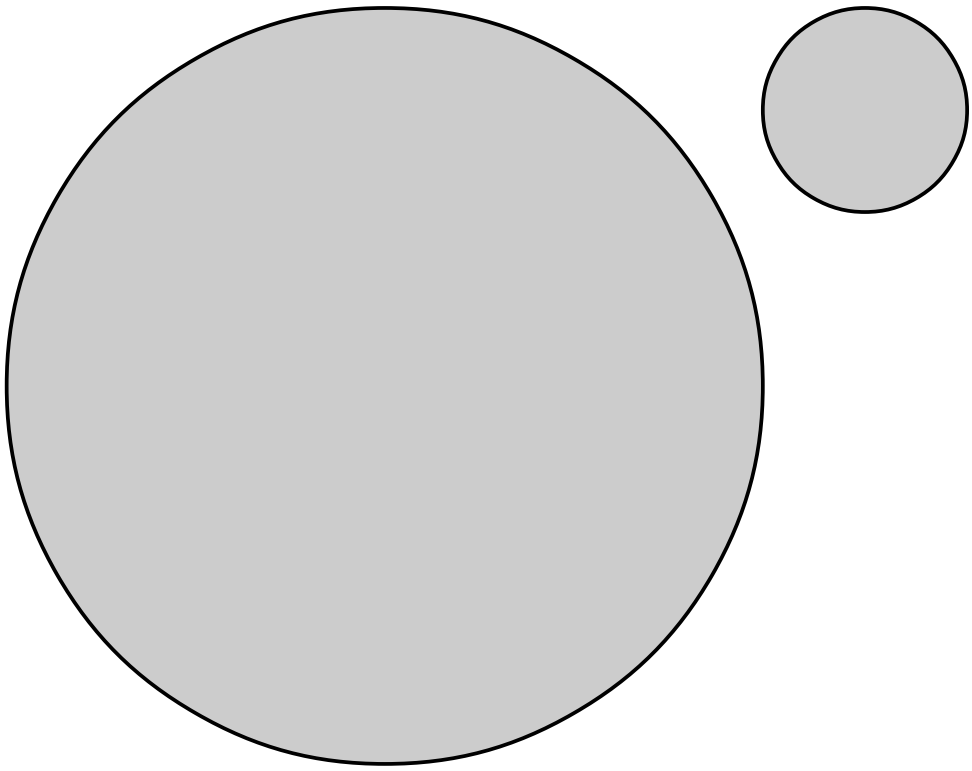
What you will need

You will need the following items.

(A) A ball 10 cm in diameter
This will represent the earth. It doesn't have to be a ball: a piece of fruit, some scrunched up paper, or anything roughly spherical is OK. Also, it doesn't have to be exactly 10 cm: approximately 10 cm is OK.

(B) A ball 2.7 cm in diameter
This will be the moon. A large marble is ideal, so is a ball of plasticine, so is anything roughly spherical. Again, approximately 2.7 cm is OK. Because this is the answer to one of the questions for students, you need to keep the moon hidden somewhere (in a drawer or pocket) at the beginning of the exercise.

If you're completely stuck for items A and B, you can use the following cut-outs. However, if possible, it's better to use solid (3D) objects.



(C) A tape measure or metre ruler
This will be used to measure out the distance between the earth and the moon, plus other measurements. If you don't have a tape measure or metre ruler, you can use your earth as a 10-cm measuring stick.

Two things to think about before you begin

Think of a landmark your students know that is about 11 metres high. As a guide, this is roughly the height of a 3-storey building, or a mid-size baobab tree.

Also, think of a location that is about 1.2 km away from the classroom. As a guide, this is roughly the distance you can walk in 15 minutes.

Using the handouts

Black-and-white handouts have been provided on pages 14 and 15 for photocopying. However, **these handouts are optional**: the activity can be done without them.

There are two separate handouts on each page — these need to be cut up after photocopying. You can either use one copy per student, or one copy per group.

Just to repeat: you don't have to use the handouts! The important thing is to get each group to write down their predictions somewhere: in their books, on a piece of paper or small chalkboard, etc.

Stage 1: "If the earth was 10 cm across..."

Divide the students into groups. Four students per group is ideal, but any number is OK. The following are some suggestions for prompts. (Please note that these are just suggestions — you don't have to follow these exactly!)

> We're going to think about the moon and the sun. We're going to think about how big they are, and how far away they are. To help us, we're going to make everything smaller.
>
> Imagine the size of the earth was 10 cm across, like this.
>
> - *Hold up the 10-cm ball.*
>
> **If this was the size of the earth, how big would the moon be?** In other words, if we make everything smaller so the earth is 10 cm in diameter, what is the diameter of the moon? How many centimetres?
>
> Also, **how far away would the moon be?** In other words, if this was our 10-cm earth right here, what is the distance to the moon as it goes around the earth?
>
> Two more questions: **how big would the sun be, and how far away would the sun be?** Remember, we've made everything smaller, and everything is on the same scale.

- *Draw the following table on the board.*

	Size (diameter)	Distance (from the earth)
Earth	10 cm	X
Moon		
Sun		

- *If you're using handouts, give out "If the earth was 10 cm across...".*
- *Give the groups time to discuss and write down their answer.*

Stage 2: "Space is just enormous!"

You may want to ask each group to share their predictions before giving the actual answers.

- *Hold up the 2.7-cm ball — this is the size of the moon.*
- *Place the earth in the middle of the classroom. Measure out a distance of 3 metres, and place the 2.7-cm moon there — this is the distance from the earth to the moon.*

This is a scale model of the earth and moon. The moon is much further away from the earth than most people think!

How about the sun? Using this same scale model, the size of the sun is 10.9 metres: that's the size of [give the landmark example you thought of earlier]. And the distance to the sun would be 1.2 kilometres: that's the distance from here to [give the location example you thought of earlier, and point in that direction].

- *Complete the table on the board:*

	Size (diameter)	Distance (from the earth)
Earth	10 cm	X
Moon	2.7 cm	3.0 m
Sun	10.9 m	1.2 km

These are big numbers — space is just enormous!

There is a strange coincidence hidden is these numbers. **What happens if you divide the size of the moon by the size of the sun, and then divide the distance to the moon by the distance to the sun?**

- *If you're using handouts, give out "Space is just enormous!"*
- *Write the two ratios on the board, and give the groups time to work out an answer:*

$$\frac{\text{Size of moon}}{\text{Size of sun}} \approx$$

$$\frac{\text{Distance to moon}}{\text{Distance to sun}} \approx$$

- *You can help the groups along by writing the numbers in the same units, and by saying that we only want approximate values:*

$$\frac{\text{Size of moon}}{\text{Size of sun}} \approx \frac{2.7\text{ cm}}{1090\text{ cm}} \approx \_\_\_\_$$

$$\frac{\text{Distance to moon}}{\text{Distance to sun}} \approx \frac{3\text{ m}}{1200\text{ m}} \approx \_\_\_\_$$

- *You may want to ask one group to share their results before completing the answer on the board:*

$$\frac{\text{Size of moon}}{\text{Size of sun}} \approx \frac{2.7\text{ cm}}{1090\text{ cm}} \approx \frac{1}{400}$$

$$\frac{\text{Distance to moon}}{\text{Distance to sun}} \approx \frac{3\text{ m}}{1200\text{ m}} \approx \frac{1}{400}$$

This is an amazing coincidence. The sun is about 400 times bigger than the moon. But it is about 400 times further away. So the sun and the moon appear to be the exactly the same size in the sky.

Stage 3: Two more questions

Go back to the scale model. Pick up the moon, and take it on one orbit around the earth. (In other words, walk around the earth in a big circle, keeping the moon 3 metres away from the earth. Of course, you may not have enough room for this — you'll have to do your best!)

The moon goes around the earth — it orbits the earth — like this. Once every 29½ days, the moon passes between the earth and the sun. Remember, on this scale model, the sun is 1.2 km away at [give the location example you thought of earlier, and point in that direction].

So every 29½ days we should have a solar eclipse. But we don't! There are normally only two or three eclipses per year. This year, for example there are just two: February 26th, and August 21st in America.

Why don't solar eclipses happen every month? Can you show this using our model?

- *If you're using handouts, give out "Two more questions".*

And here's one more question. Some eclipses are annular, like the one on February 26th. In an annular eclipse, the moon is a tiny bit smaller than the sun — the sun forms a "ring of fire" around the moon.

But some eclipses are total, like the one on August 21st in America. In a total eclipse, the moon is a tiny bit bigger than the sun — the sun becomes completely hidden.

- *If you're not using handouts, draw a diagram on the board:*

Why does the moon appear to change size? Can you show this using our model?

- *Give the groups time to discuss answers to these two questions.*

Stage 4: Improving the model

Ask if any group would like to show their answers using the model.

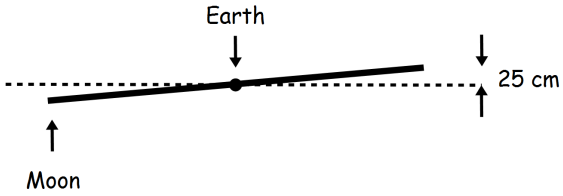
The moon goes round the earth — it orbits the earth — in a circle. But the circle is not flat. The moon's orbit is tilted by about 5 degrees. In our scale model, on one side of the circle, the moon is raised up by 25 cm. On the

opposite side of the circle, the moon is lowered down by 25 cm.

- *Show this on the scale model by moving the moon 25 cm up and 25 cm down.*

- *If you're using handouts, give out "Improving the model".*

- *If you're not using handouts, you can draw a diagram on the board:*



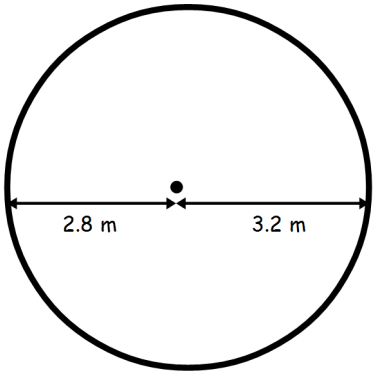
So, most months, the moon does not line up exactly between the earth and the sun. It passes by just above or just below the sun. This is why solar eclipses are rare events.

Next, the moon does not go round the earth in a perfect circle. It is a very slightly 'squashed' circle: an ellipse. So, in our model, the moon is not 3 metres away from the earth. The distance varies between 2.8 and 3.2 metres.

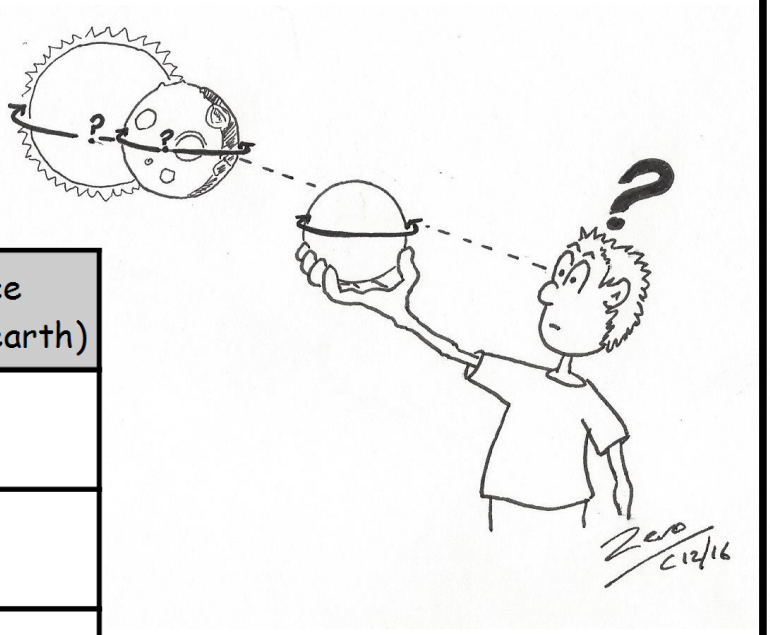
- *Show this on the scale model by moving the moon 20 cm closer or 20cm further away from the sun.*

So sometimes the moon is nearer the earth and appears bigger. And sometimes it is further away and appears smaller.

- *You can also draw a diagram on the board:*



If the earth was 10 cm across...



	Size (diameter)	Distance (from the earth)
Earth	10 cm	X
Moon		
Sun		

Space is just enormous!

	Size (diameter)	Distance (from the earth)
Earth	10 cm	X
Moon	2.7 cm	3.0 m
Sun	10.9 m	1.2 km

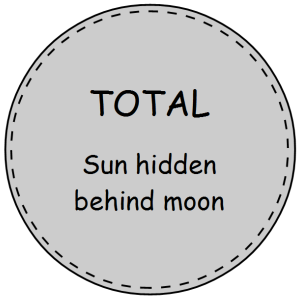
$$\frac{\text{Size of moon}}{\text{Size of sun}} \approx$$

$$\frac{\text{Distance to moon}}{\text{Distance to sun}} \approx$$

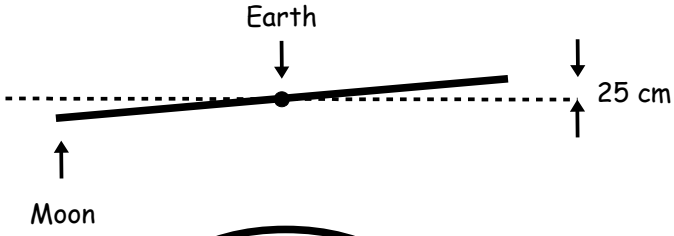
Two more questions

The moon passes between the earth and the sun every $29\frac{1}{2}$ days.
So why don't we have solar eclipses every month?

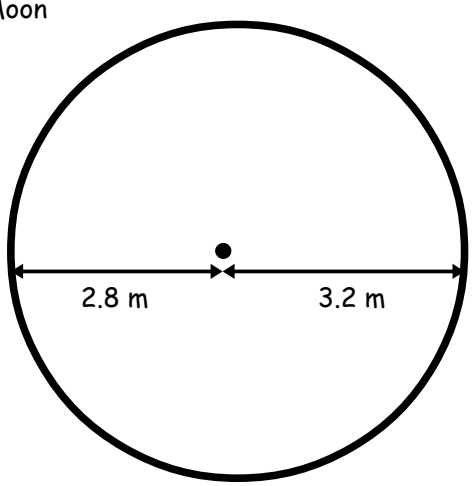
In an annular eclipse, the moon is just smaller then the sun.
In a total eclipse, the moon is just bigger than the sun.
Why does the moon appear to change size?



Improving the model



The orbit of the moon is tilted by 5 degrees. So the moon usually passes either above or below the sun.



The orbit of the moon is an ellipse. Sometimes the moon is nearer the earth (and appears bigger). Sometimes it is further away (and appears smaller).