PHASES OF THE MOON (Materials: 8 small styrofoam balls, black marker, cardboard, play dough)

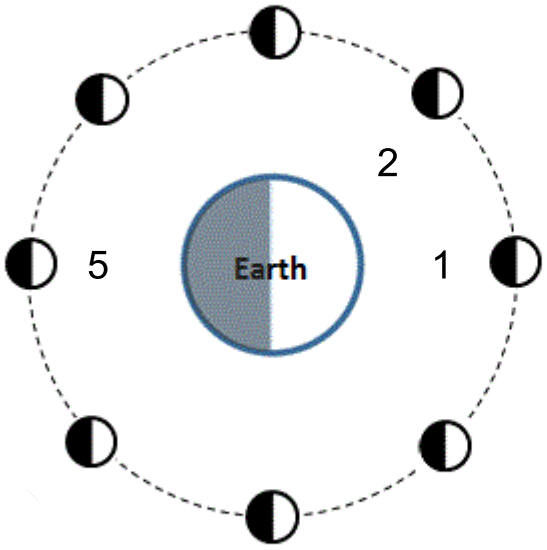
Realize a model of the phases of the Moon:

- color in black half of each ball, they represent the Moon illuminated by the Sun
- place the balls around the hole in the cardboard representing the orbit
- be sure the illuminated face is always in the same direction as in the figure below
- now put your head in the hole and… look at the Moon from the Earth!

a) how does the Moon appear when seen from the Earth in different positions?
b) take a picture of each phase (as seen from the Earth) then:
   - order the pictures and name each phase
   - identify the East and West in each phase

When you look at the Moon during a quarter, do you see a quarter or a half of it illuminated? Why?
How can you distinguish the First and Last quarters? First on the west, Last on the east
How can you distinguish waxing and waning phases? Waxing on the west, waning on the east

1 New Moon
2 Waxing crescent
3 First quarter
4 Waxing gibbous
5 Full Moon
6 Waning gibbous
7 Last quarter
8 Waning crescent



1. Let's think about the time, as you know the Moon's revolution takes about 28 days (27 d 7 h 43 min)

a) how much time passes between the four main phases? About 1 week
b) if today is a Full Moon, what will we see next week? Last quarter
c) look at the ephemeris* of the Moon in July 2022, you can see the time of moonrise and moonset. Which phases can you observe during the night and during the day?

New Moon, waxing crescent, and waning gibbous occur during the day. Full Moon, waxing gibbous, and waning gibbous occur during the night.

2. The Moon's apparent motion replicates the Sun's. Moon rises in the east and sets in the west. Both the Sun and the Moon show a similar apparent motion because of the Earth's rotation. However, if the Moon's apparent motion depends on the Earth's rotation, we should see moonrise approximately at the same time… look at the ephemeris and answer

a) does moonrise happen in advance or is it late each day? why?

Moonrise is late because of the Moon's revolution combined with Earth's rotation

Ephemeris: a table that gives astronomical information, e.g. data, time of moonrise, and moonset

Extra track

As you know the Moon's orbit is 5° tilted compared to the plane of Earth's orbit. If this were not true, what would happen at any Full Moon?

We would never see a Full Moon but an eclipse

If the Moon's orbit were perpendicular to the plane of Earth's orbit can you predict the observations of the phases from the Earth?

a) Which phases are visible? How can you distinguish using east and west (or north and south)
b) Think about the time: when can we observe the phases?

Depending on the position they choose, the students will describe different situations. Such an open question does not aim for any specific answer but stimulates students' HOTS like reasoning, inquiry, discussion, and hypothesis.

DARK SIDE OF THE MOON (Materials: a small ball with two colors)

It is said that the Moon always turns the same face to Earth. In other words, from Earth, we can only see the same half of the Moon, while we never see the backside. In your opinion, is it true?

Probably, most of the students know this fact (however they can't explain why)

Realize a model of the Moon rotating around the Earth using the two-color ball to simulate the Moon so you can easily distinguish the two halves (the two faces of the Moon). Put another ball to represent the Earth and draw the orbit (approximately).

1. Move the Moon around the Earth (revolution) without rotating the Moon on itself:
   a) what happens if the Moon were fixed on its axis while moving along the orbit?
   b) can we see both sides of the Moon from Earth?

We can observe the whole Moon, in different positions along the orbit we see the different sides

2. Now move the Moon around the Earth (Moon's revolution) and simultaneously rotate it (Moon's rotation)
   a) what happens now?

We can still observe the whole Moon, the dark side fact seems to be false

3. Let's change our investigation. Simulate the "dark side" hypothesis, so move the Moon around the Earth in a way that makes it true that from Earth we always observe the same face.
   a) can you do it? This means the hypothesis can be true
   b) how can you do it? Once the Moon completed the revolution, how many rotations have been done?

Yes, we can simulate the "dark side" hypothesis if the rotation has the same period of the revolution. The Moon completes one rotation at the same time as the revolution.

That's the stuff! The dark side is indeed a true fact because the rotation and the revolution of the Moon take the same amount of time: approximately 28 days.

Take photos and videos to show and tell your discoveries!

Extra track

Consider the duration of the rotation of the Moon…
   a) how long are the days and nights on the Moon?
   b) as a consequence, how do you think the temperature changes on the Moon's surface?

Since the Moon's rotation takes 28 days, on the Moon we have 14 days of sunlight (day) followed by 14 days of darkness (night). This must affect surface temperature with highly increasing temperature during the day and extreme cold during the night

Consider what you have just learned about light and darkness on the Moon…
   a) do you think the expression "dark side of the Moon" is correct?
   b) the "dark side", which is the side we can't observe, is really always in the dark?

No, the "dark side" of the Moon is periodically in the light. The more correct expression is "far side" and "near side" of the Moon.

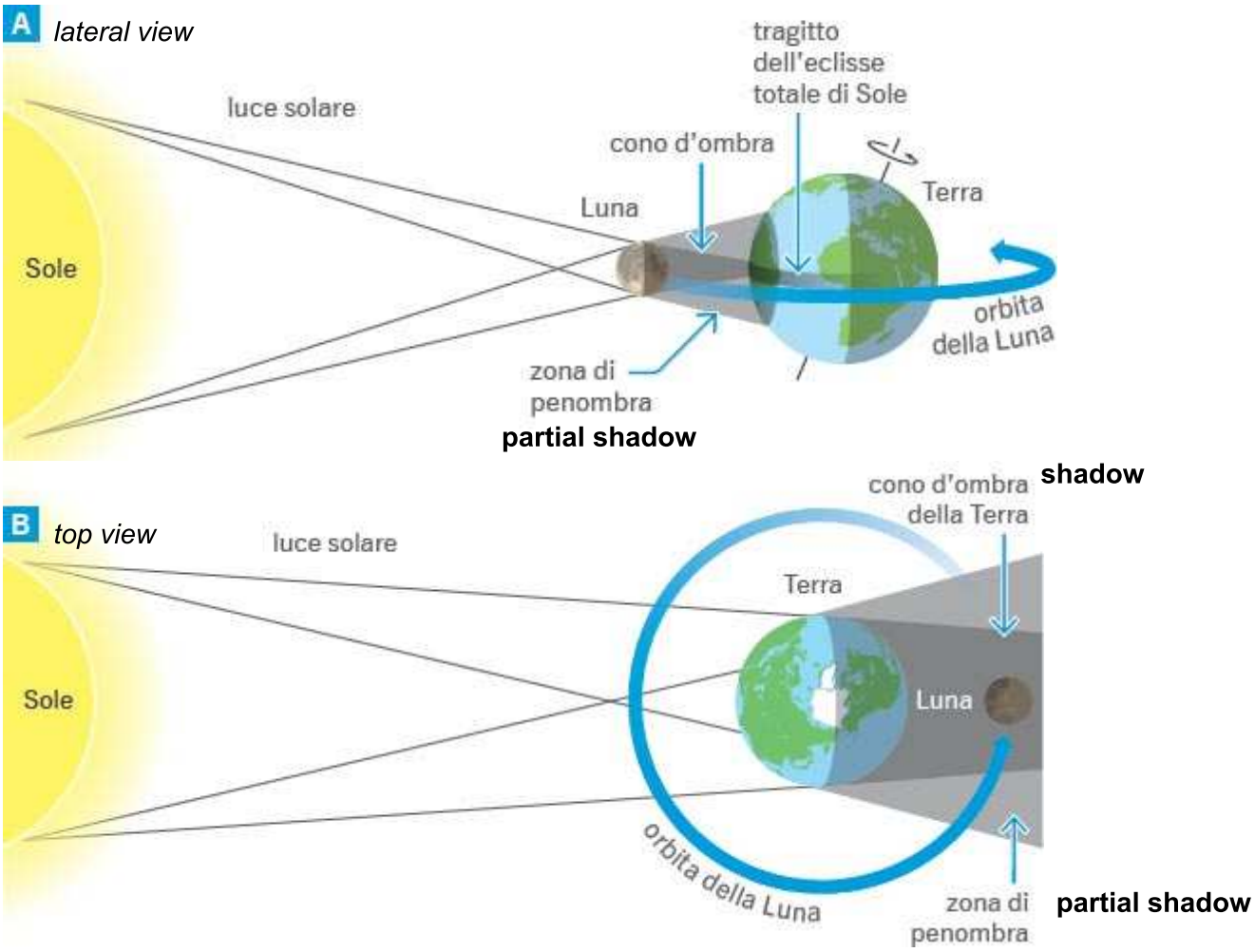
ECLIPSES (Materials: light source, small and large spherical objects, wood ring, play dough)

In the Earth-Moon-Sun system, the alignment of three celestial objects is known as syzygy.
There are two alternative configurations:

- Moon in conjunction (configuration S - **M** - E)
- Moon in opposition (configuration S - E - **M**)

Realize a model to represent these configurations and prove that different configurations are not possible.
Different configurations are not syzygial (see Moon's phases)

When the Moon is in conjunction or in opposition, the shadow produced causes the event known as an eclipse. There are Lunar eclipses and Solar Eclipses. Look at the figures, understand the event, and replicate it with your model, then complete the table below.



	Who obscures who?	Where is the Moon?	When can we see the event? During the night or day?
Lunar eclipse	E obscures the M	M in opposition	Night
Solar eclipse - total eclipse - partial eclipse > annular eclipse	M obscures the S	M in conjunction … … and apogee	Day

Take photos and videos to show the events of the eclipses with your model.
What we can see from the Earth?

1. Place the Moon's orbit on the same plane as Earth's orbit and simulate the Moon's revolution. Consider that the Moon takes about 28 days to orbit the Earth and answer the following questions:

a) How many Lunar eclipses should happen in one month?
b) How many Solar eclipses should happen in one month?

If the plane of the Moon's orbit were not tilted, a Lunar and Solar eclipse would happen in a month.

2. Now look at the ephemeris* recording the eclipses that occurred and forecasted from 2016 to 2024.

a) Explain why the frequency of the eclipses is different from your previous hypothesis.
b) What should you change in order to reduce the frequency of eclipses?

From the ephemeris, we can notice that the frequency of eclipses is less than one per month, due to the fact that the planes of the orbits are tilted.

3. The Moon's orbit is 5° tilted compared to the plane of Earth's orbit and what's more it moves like a hula hoop! The position of the Moon's orbit is not fixed, but the inclination is fixed. We call nodes the points at which the Moon's orbit crosses the plane of Earth's orbit. The position of the nodes changes.

a) Consider total and partial eclipses, try to simulate them on your model, and complete:

A total Solar eclipse occurs when the Moon is in opposition/conjunction when crossing a node. Similarly, a total Lunar eclipse requires the Moon to be in a _____ while in _____.

b) What can you say about partial eclipses?

The Moon transits near a node during opposition or conjunction and thus the alignment is not perfect.

4. How often an event occurs also depends on your own point of view! Now that you know the mechanics of eclipses consider what we can observe.

a) Look at the ephemeris and compare the frequency of Solar and Lunar eclipses, how many of them occur in a year? Do the two events have the same frequency?
b) Now consider the eclipses observable from Italy: how many Solar and Lunar eclipses?

Lunar and Solar eclipses have a similar frequency (2-3 events per year)
Despite having a similar frequency, Lunar eclipses are more frequently observed from Italy, while Solar eclipses are a rare observable event. That's why the area of the shadow of the Moon (during Solar eclipses) is small and you can't see the eclipse from any point out of the shadow.

Extra track

If the Moon's orbit were perpendicular to the plane of Earth's orbit, can you predict the observations of the eclipses from the Earth?

a) Can we see Solar or Lunar eclipses?
b) Can we see partial or total eclipses?
c) How often does the event occur?

Depending on the position they choose, the students will describe that the eclipses will never happen or that will occur monthly. If they include the Earth's revolution they could make more deep reasoning. Such an open question does not aim for any specific answer but stimulates students' HOTS like reasoning, inquiry, discussion, and hypothesis.

Ephemeris: a table that gives astronomical information, e.g. data, time, duration, and location of eclipses