8.15
Moon and its shape

8.15. Moon and its shape

Overview

Changes in the shape and size of the Moon, over the period of a month, has always been an intriguing topic for children. Even many adults have difficulty in understanding the cause of these phases. One of the common alternate mental models which many learners sometime struggle with is that the phases of the Moon occur due to changing shadow of Earth on the Moon. Many of the difficulties in understanding the phases can be addressed by bringing students' attention to:

i. a full month data about the shape and orientation of the Moon in the sky,
ii. the Moon's rising and setting times on different dates, and
iii. the observations of sun and moon simultaneously in the sky on certain days (during day time).

We eventually learn that it is not the Moon or the shadow of Earth on it that changes. This is an effect seen from Earth which happens due to the changes in the relative positions of the Sun, Earth and the Moon, as the Moon rotates around Earth with sunlight illuminating a different region of the Moon everyday.

In this Learning Unit, students will try to draw conclusions on their own by analysing real data about the Moon and also learn about different terminologies related to the phases of the Moon. The unit consists of two tasks. In task 1, students will do a role play activity to depict (and thus

Minimum time required

3 sessions of 40 minutes each

Type of Learning Unit

Classroom and (if possible) field

visualise) the motion of the Moon around Earth, and in task 2, each student will fill up a table, and answer questions, based on the information given in the data table.

If possible, students may also observe the Moon in the sky for a month and collect their own data and analyse it.

Unit-specific objectives

- To study the phases of the Moon as seen from Earth
- To visualise the motion and the orbit of the Moon around Earth

Links to curriculum

NCERT Class 8 Science textbook: Chapter 16: Light (Concept of light path and shadows)

NCERT Class 8 Science textbook: Chapter 17: Stars and the Solar System

Introduction

We have observed that the Moon changes shape gradually every day, from full Moon to new moon and back to full Moon again over a period of about one month. The changing shapes of the Moon are referred to as the "phases of the Moon". In this unit, we will understand some ideas related to the phases of the Moon, by doing some tasks and exploring answers to some related questions. After we finish writing the answers, we will discuss all the answers together and try to arrive at well-reasoned answers.

Task 1: Role playing activity

Figure 1 shows the orbit of the Earth around the Sun, and the orbit of the Moon around Earth.

"Orbits" are the paths taken by Earth and the Moon as they move around the Sun and Earth, respectively. Note that the figure is not to scale. (The sun is shown

Materials

Paper, pencil, eraser, etc.

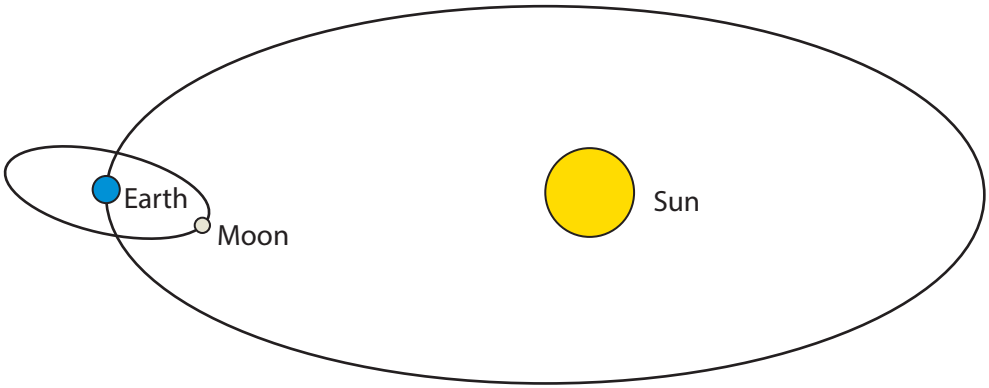

Figure 1 *Illustration of the Sun-Earth-Moon orbit*

much smaller than its proportionate scaled-down size. It is also shown much closer to Earth than its proportionate scaled-down distance.)

The orbit of Earth makes a plane in which both Earth and the Sun lie. Similarly the orbit of the Moon makes a plane in which both Earth and the Moon lie. These two planes are actually different planes. The plane of orbit of the Moon is tilted with reference to the plane of Earth's orbit around the Sun, at an approximate angle of 5°.

Let us play a game which helps us understand the different positions of the Moon between the Sun and Earth, during its different phases.

Instructions

- Three students will play the roles of the Sun, Earth, and the Moon. Other students, who are not playing any roles, will observe the activity from a distance.
- Head of the student playing Earth's role represents the planet Earth, and his/her nose is an imaginary person on Earth's surface.
- The student playing the Moon's role will draw a circle around Earth, to represent the Moon's orbit around Earth (This is not absolutely essential, but it will help).
- The student playing the Sun will stand at some distance away from the Earth and the Moon. This student's head

should be at a slightly higher position than the heads of the other two students. (He/She could be taller or stand on a small stool or chair.)

- Here is some information. If you are looking from the side of Earth's north pole down at the plane of Earth's orbit, you will see that the Moon moves around Earth in an anti-clockwise direction, Earth moves around the sun in an anti-clockwise direction, and the Earth rotates around itself also in an anti-clockwise direction. Keep this information in mind as you play the game.
- Fix the position of the person playing the Sun's role to indicate the direction of sunlight.
- The person playing Earth's role need not go around the Sun and can remain stationary at one position, as we want to focus on the phases of the Moon. This person can rotate on his/her position itself as per the need to observe the Moon's phase.
- Now make the Moon go around in its orbit with its face towards the Earth. To begin with, let the Moon be between Earth and the Sun.

  Guess which part of the Moon's head will be illuminated, and which part will be dark due to the absence of sunlight?
- Now let the Moon take a position such that Earth is between the Moon and the Sun, and all the three are aligned.

  Discuss which part of the Moon is illuminated, and which is not.
- Now let the Moon take various positions in its path. Guess which part of the Moon is illuminated and which is not.

When the face of the student playing the Moon is always towards Earth, students have to do mental visualisation for which part of the head is illuminated. The side of "the Moon's" head illuminated by the Sun would keep changing and the observer would have to imagine different part of the Moon's head being illuminated by the Sun. Here, the students may take some time to absorb the information being conveyed through role play.

If the students have difficulty visualising which part of "the illuminated part of moon's surface" is visible to the persons on earth, they can try an alternate model. The person playing the Moon's part while moving to different positions can keep facing the Sun. This may help students consistently visualise this person's face to be the illuminated part of the Moon. Thus, by observing what part of the illuminated Moon's face is being seen by the observer on Earth, one can visualise the phase of the Moon. In reality, this alternate model involves another approximation as it is not the same part of the Moon that faces the Sun all the time. The Moon rotates around itself while it is revolving around the Earth. Rotation period of the Moon is nearly same as its revolution period. Therefore, only one side of the Moon is seen from Earth.

For detailed discussion on this role play, please refer to the booklet on "Basics of astronomy through role play" by Venkateshwaran and Gupta (see Suggested Resources for full reference).

- **Full Moon and new Moon**

At which position in the orbit of the Moon will a person on Earth (who is at the position of the nose of the student playing Earth's role) see full Moon (or new Moon)?

Where should the Moon be, so that it is full Moon (or new Moon) for an imaginary person at a point on the back of the head of the student playing Earth's role? (The orientation of the Moon is important to note here).

It should be clearly noted that irrespective of where the nose is facing, if it is full Moon, it is full Moon! That is, the Moon has to be oriented with respect to the Sun in a particular way. As Earth rotates, each and every part of Earth will experience full Moon (or new Moon).

Someone who knows a little bit more will say that when the Moon is between Earth and the Sun, it is eclipse time. You can point out that the students have been placed at different heights to avoid such a situation. Then you can say that though the Moon is in the same direction as the Sun with respect to Earth, it is not exactly in a straight line. Also, you can use this as point of reference later whenever you explain the phenomena of eclipses in the classroom.

- **Half Moon**

Guess at which position there would be a half Moon, and discuss it in your group.

The angle between the Sun-Earth-Moon is 90 degrees at two positions of the Moon in its orbit around Earth; at these two positions it will be half Moon. Notice that this time, for everyone on the surface of Earth, it is half Moon.

Discuss that during the motion of the Moon in its orbit, the bright portion of the Moon (as seen from Earth) increases for some time, and then decreases for some time. When the bright portion of the Moon (as seen from Earth) is increasing it is called as the waxing of the Moon, and when it is decreasing it is called as the waning of the Moon. Now, guess in which half of the Moon's orbit it would be waxing and in which half it would be waning. Explain this by role play. Notice that when the Moon is going from full Moon to new Moon it is waning, and when it is going from new Moon to full Moon, it is waxing (*krishna paksha* and *shukla paksha*, respectively).

Task 2: Analysing a data table

Sr. No.	01	02	03	04
Image of the Moon				
Date	18/02/2018	20/02/2018	23/02/2018	24/02/2018
Rise Time	08:02	10:01	12:15	13:07
Set Time	20:00	22:39	00:31	01:31
Sr. No.	**05**	**06**	**07**	**08**
Image of the Moon				
Date	26/02/2018	28/02/2018	01/03/2018	02/03/2018
Rise Time	15:04	17:10	18:12	19:12
Set Time	03:32	05:27	06:19	07:08

Sr. No.	09	10	11	12
Image of the Moon				
Date	04/03/2018	05/03/2018	07/03/2018	09/03/2018
Rise Time	21:06	22:01	00:13	01:54
Set Time	08:36	09:18	12:06	13:29

Table 1 *Images of the Moon taken on different dates along with rise and setting times. In all pictures, west is top and east is down. Depending on the time and the position of the Moon in the sky, the actual appearance may be different from what is shown above.*

1. In table 2, fill the columns 4 (Moon shape) and 5 (Boundary) using the information given in table 1.

Date	Moon-rise time	Moon-set time	Moon shape (crescent / half / more than half (gibbous) / full / absent)	Boundary of Bright and Dark region of Moon is (convex / concave / straight)
18/02/2018	08:02	20:00		
20/02/2018	10:01	22:39		
23/02/2018	12:15	00:31		
24/02/2018	13:07	01:31		
26/02/2018	15:04	3:32		
28/02/2018	17:10	05:27		
01/03/2018	18:12	06:19		
02/03/2018	19:12	07:08		

04/03/2018	21:06	08:36		
05/03/2018	22:01	09:18		
07/03/2018	00:13	12:06		
09/03/2018	01:54	13:29		

Table 2 *Observation Table (To be completed by the student)*

Date	Moon-rise time	Moon-set time	Moon shape (crescent / half / more than half (gibbous) / full / absent)	Boundary of Bright and Dark region of Moon is (convex / concave / straight)
18/02/2018	08:02	20:00	crescent	concave
20/02/2018	10:01	22:39	crescent	concave
23/02/2018	12:15	00:31	Half Moon	straight
24/02/2018	13:07	01:31	More than half	convex
26/02/2018	15:040	3:32	More than half	convex
28/02/2018	17:10	05:27	More than half	convex
01/03/2018	18:12	06:19	Full Moon	-
02/03/2018	19:12	07:08	More than half	convex
04/03/2018	21:06	08:36	More than half	convex
05/03/2018	22:01	09:18	More than half	convex
07/03/2018	00:13	12:06	More than half	convex
09/03/2018	01:54	13:29	Half Moon	straight

Table T1 *Observation Table*

The Moon's rising time is linked to the phase of the Moon because it is also connected with how far the Moon is from the Sun in the sky (i.e., the angular separation between the Moon and the Sun in the sky).

2. Study the table and state if the following statements are true or false.

c) The bright part of the Moon is always towards the Sun. _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

True

d) The boundary of dark and bright part of the Moon is always concave. _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

False [The inside edge of a crescent Moon is concave, while for a gibbous Moon it is convex. Refer table 1, images 9-11]

e) The Moon does not rise at the same time everyday. _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

True [It rises approximately 50 minutes late every day because of its own motion around Earth.]

f) The Moon does not rise on a new Moon day. _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

False [The Moon does rise, but its side which faces Earth does not receive sunlight. Also, it rises with the Sun and due to sunshine we can not see it.]

g) On the day after full Moon, we expect the Moon to rise around one hour after sunset._ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

True [On a full Moon day, the moonrise happens at sunset, hence one day after full Moon, the moonrise will happen nearly 50 minutes later.]

h) On the day before new Moon, we expect the Moon to rise around one hour before sunrise._ _ _ _ _ _ _ _ _ _ _ _ _ _ _

True [On a new Moon day, the moonrise happens at sunrise, hence one day before new Moon, the moonrise will happen nearly 50 minutes earlier. This phase of the Moon is usually very faint and may not be visible easily to naked eye. From some locations if the eastern horizon is clear, it is possible to observe it with naked eyes.]

i) In a waxing fortnight (*shukla paksha*/bright fortnight), the Moon is already in the sky at sunset. _ _ _ _ _ _ _ _ _ _ _ _

True [The fortnight from new Moon to full Moon is called as the waxing fortnight. On a new Moon day, the Moon sets with the Sun, and after that, everyday it sets 50 minutes later. This is why during a waxing fortnight, the Moon will be present in the sky for some time even before sunset.]

j) In a waning fortnight (*krishna paksha*/dark fortnight), the Moon is still in the sky at sunrise. _ _ _ _ _ _ _ _ _ _ _

True [The fortnight from full Moon to new Moon is called as the waning fortnight. On a full Moon day, the Moon sets when the Sun is rising, and after that, everyday it sets 50 minutes later. This is why during a waning fortnight, the Moon will be present in the sky at the time of sunrise.]

3. Imagine that we are astronauts and have gone in space above the plane of our solar system, and we are observing Earth and the Moon from above. Rays of the Sun are falling on Earth and the Moon from the left of the page and are parallel to the bottom edge. In the diagram (figure 2), draw appropriate diameters of Earth and the Moon, to separate the parts receiving sunlight and the parts not receiving sunlight. Shade the dark part with your pencil. Next, assume a tiny observer "O" on the surface of earth, exactly along the line connecting the centres of Earth and the Moon. Draw an appropriate diameter of the Moon to show which part of the Moon will be visible to this observer.

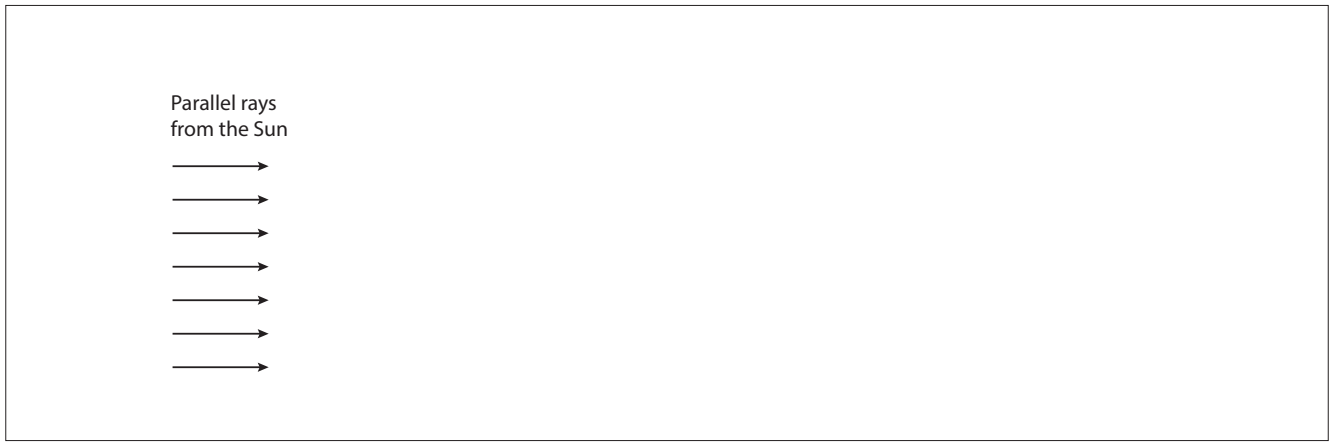

Figure 2 *Moon phase for observer O (To be drawn by the student)*

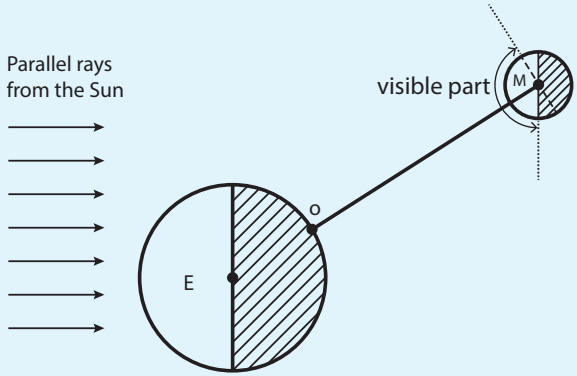

Figure T1 *Moon phase for observer O*

4. Based on your diagram, answer the following:
   a) Is the observer in the bright part or the dark part?

The observer is in dark part.

   b) As seen by this observer, how much of the Moon's disc is bright (less than half/more than half)?

More than half.

   c) Let us assume that the diameter of the Moon is 2 mm. Then the diameter of Earth will be approximately 7 mm. At this scale, the distance between Earth and the Moon will be about 23 cm. Draw a diagram of the relative sizes and the distance between Earth and the Moon. By looking at this diagram (figure 3), it is possible to conclude that observers at any location on Earth will see approximately the same phase of the Moon. Do you agree?

Figure 3

Yes. Due to extremely small sizes of Earth and the Moon, as compared to the distance between them, observers at any location on Earth will see approximately the same phase of the Moon.

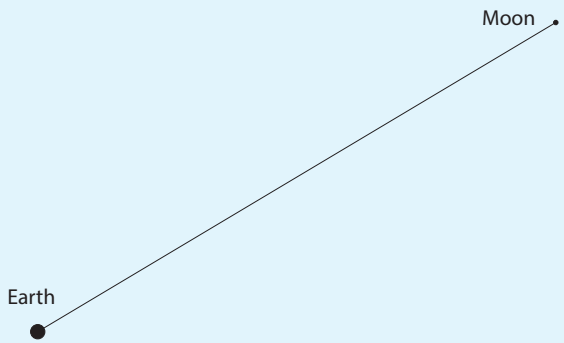

Figure T2 *Diagram indicating the relative sizes of Earth and the Moon and the distance between them.*

d) Where will the Moon be on the full Moon day? In your diagram, mark the position with a circle, and label it as F.

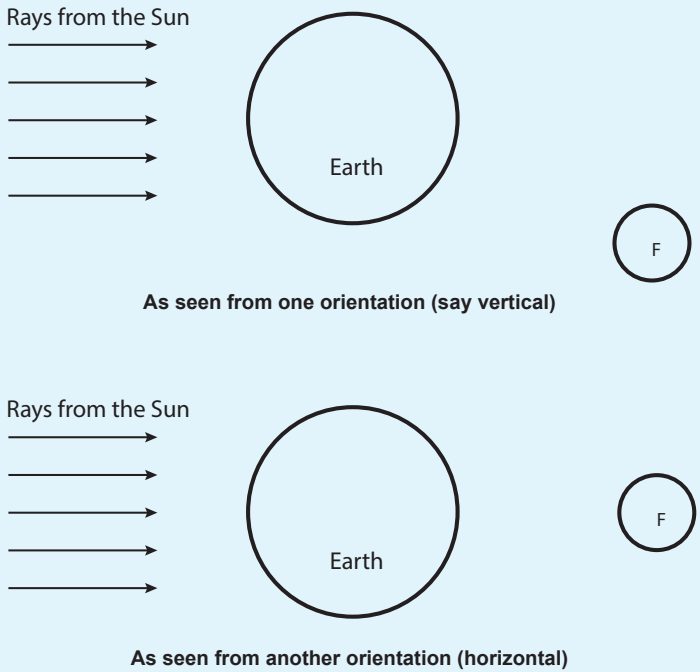

Figure T3 *Full Moon day (Any of the two drawings done by students are fine. Drawing both may help bring more clarity to students.)*

e) Where will the Moon be on the new Moon day? In your diagram, mark the position with a circle, and label it as N.

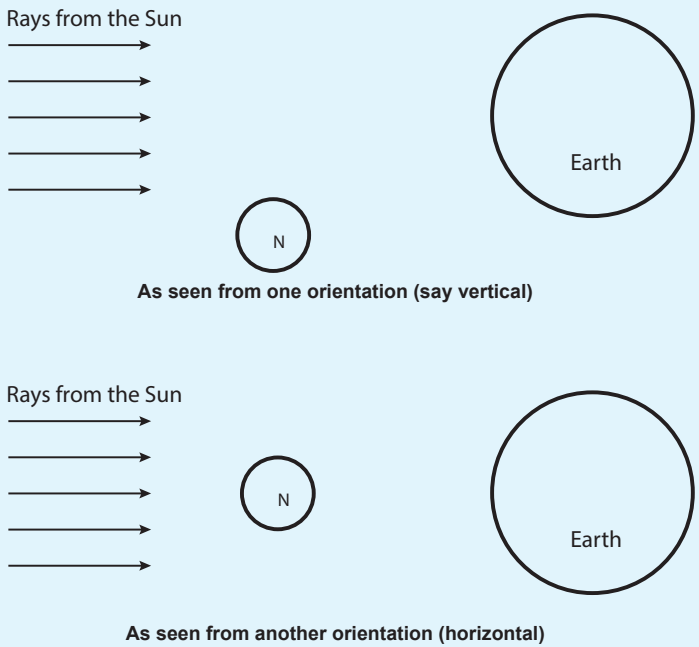

Figure T4 *New Moon day (Any of the two drawings done by students are fine. Drawing both may help bring more clarity to students.)*

f) Will the shadow of Earth fall on the Moon on a new Moon day?

No, on a new Moon day, the Moon is on the same side of Earth as the Sun, therefore Earth's shadow cannot fall on the Moon. A common misinterpretation for this scenario is that the Moon being on the same side of Earth as the Sun will always lead to solar eclipse. Note that the Moon may not be necessarily on the line connecting the Sun and Earth and hence there need not be a solar eclipse.

g) As seen by astronauts, Earth rotates anticlockwise. In question no. 3, now place a second observer on the surface of Earth, on the upper edge of the dark part. Does this second observer see a sunrise or a sunset?

We have assumed that the Sun is on the left side of the diagram, and from this angle, Earth appears to rotate anti-clockwise. Thus, the second observer is moving from the darker region into bright region. Hence the second observer must be watching a sunrise.

h) As seen by astronauts, direction of the Moon's revolution is also anti-clockwise. So, is this a waxing fortnight or a waning fortnight?

Direction of the Moon's revolution is also anticlockwise, hence the Moon is moving towards the same side as that of the Sun in the sky with respect to Earth. Therefore, it is a waning fortnight.

i) Can you guess this?

(*i*) During a lunar eclipse, the Sun, Earth, and the Moon get aligned. But we don't see a lunar eclipse on every full Moon day. What do you think is the reason for this?

(*ii*) Do we see a solar eclipse on every new Moon day? Give reasons.

Suggested Reading / Resources

- An education research paper on the difficulties faced by learners in understanding origin of phases of moon: Subramaniam, K., & Padalkar, S. (2009). Visualisation and reasoning in explaining the phases of the moon. International Journal of Science Education, 31(3), Special Issue on "Visual and Spatial Modes in Science Learning", 395-417.
- A short children's film in Hindi (~25 min) made by NCERT in 1999, including role play activities by children: https://www.youtube.com/watch?v=z1EBuKZ-MHY

- A shorter YouTube video in English (~ 4 minutes) demonstrating phases of the Moon: https://www.youtube.com/watch?v=wz01pTvuMa0&feature=youtu.be
- Timetable of phases of the Moon for the current year: https://www.timeanddate.com/moon/phases/
- Brief introduction to the different terms for phases of the Moon: https://astrosociety.org/edu/publications/tnl/12/12.html
- Venkateshwaran, T. V., & Gupta, A. (2009). Basics of astronomy through role play. New Delhi: Bharat Gyan Vigyan Samiti, New Delhi. http://www.arvindguptatoys.com/arvindgupta/role-play-eng.pdf

Title: Moon and its shape
Main Author: Aniket Sule
Contributing Authors: Pritesh Randive, Pranay Parte, Karishma Dhanmeher
Reviewers: Arnab Bhattacharya, Vandana Nanal
Creative Commons Licence: CC BY-SA 4.0 International

VIGYAN PRATIBHA
विज्ञान प्रतिभा