Phases of the Moon

Every month, the Moon appears to change shape in the sky as it goes through phases from new Moon to full Moon and then back to new. Ancient civilizations used the phases of the Moon to track the passage of time. Today's Gregorian calendar no longer depends on the phases of the Moon but the Islamic, Hebrew and Chinese cultures still base festivals and holy days on the cycles of the Moon.

The more you understand the nature of the Moon's phases, the more you can appreciate how astronomy influences our culture and the better you'll be able to predict when important events like Ramadan, Hannukah, Easter and Lunar New Year will occur.

In this tutorial, you will explore the changing geometry of the Sun-Earth-Moon system that produces each phase of the Moon, and then the connection between the geometry and the time of day the Moon rises and sets.

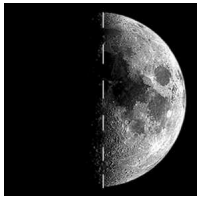
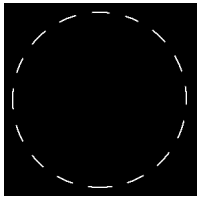
Materials Each group of 3 partners needs a (small) Moon ball and a (big) Earth ball.

Phases of the Moon (Copyright Antonio Cidadao)

Part 1: Phases of the Moon

Imagine your head is the Earth. When it's your turn, stand in the "sunlight" and hold the Moon straight out at arm's length. Be sure the NEAR side is always facing towards you. Spin around slowly to your left and watch the Moon go through phases.

Take turns holding the Moon in the sunlight to find the geometry of the Sun, Earth and Moon that create these phases. Below each picture, **sketch the geometry of the Sun, Earth and Moon** as seen from above. Try to indicate the illuminated halves of the Earth and Moon.

Partner 1	**Partner 2**	**Partner 3**
first quarter Moon 	third quarter Moon 	waning gibbous Moon 
full Moon 	waxing crescent Moon 	new Moon 

Part 2: Local Time on Earth

Unlike the Sun which rises in the morning and sets in the evening, the Moon rises and sets at different times during the day and night depending on its phase.

First we'll review how your local time is determined by the location of the Sun in the sky. Imagine the observer is standing on the Earth at the location of the sticker, watching the sky.

1. Hold the Earth in the "sunlight" with the axis (the pencil) straight up and down. Rotate the Earth until the Sun is directly over the observer. Complete this table:

Local Time	**Location of Sun**
	directly overhead

2. Rotate the Earth, carrying the observer towards the East, by one-quarter of a rotation. The observer will now be on the boundary between light and dark (day and night).

Local Time	**Location of Sun**
	on Western horizon

3. Rotate the Earth another $\frac{1}{4}$-turn.

Local Time	**Location of Sun**

4. Rotate the Earth another $\frac{1}{4}$-turn.

Local Time	**Location of Sun**

5. Finally, rotate the Earth another $\frac{1}{4}$-turn. It's noon again.

Part 3: Moonrise and Moonset

	Earth Partner 1	**Moon** Partner 2	**Recorder** Partner 3
1	Hold the Earth straight up-and-down in the "sunlight". When you rotate the Earth later, remember it always rotates to the East.	Hold the Moon about an arm's length from Earth and make one slow orbit around Earth. Be sure the NEAR side of the Moon is always facing towards the Earth.	Watch the Moon and help your partner keep the NEAR side facing towards the Earth. Then record the times below.
2		Move to the **first quarter** Moon.	
3	Rotate the Earth until **moonrise**, the moment when the Moon appears on the observer's Eastern horizon. Rotate the Earth until **moonset**, the moment when the Moon disappears behind the observer's Western horizon.	Help find the observer's local time.	**First quarter** Moon rises at _____ **First quarter** Moon sets at _____
4		Move to **full** Moon.	
5	Rotate the Earth until **moonrise**. Rotate the Earth until **moonset**.	Help find the observer's local time.	**Full** Moon rises at _____ **Full** Moon sets at _____

Everyone switch jobs

	Earth Partner 3	**Moon** Partner 1	**Recorder** Partner 2
6	Hold the Earth straight up-and-down in the "sunlight". When you rotate the Earth later, remember it always rotates to the East.	Hold the Moon about an arm's length from Earth and make one slow orbit around Earth. Be sure the NEAR side of the Moon is always facing towards the Earth.	Watch the Moon and help your partner keep the NEAR side facing towards the Earth. Then record the times below.
7		Move to the **third quarter** Moon.	
8	Rotate the Earth until **moonrise**. Rotate the Earth until **moonset**.	Help find the observer's local time.	**Third quarter** Moon rises at _____ **Third quarter** Moon sets at _____
9		Move to **new** Moon.	
10	Rotate the Earth until **moonrise**. Rotate the Earth until **moonset**.	Help find the observer's local time.	**New** Moon rises at _____ **New** Moon sets at _____
11		Move to the **waxing crescent** Moon.	
12	Rotate the Earth until **moonrise**. Rotate the Earth until **moonset**.	Help find the observer's local time.	**Waxing crescent** Moon rises at _____ **Waxing crescent** Moon sets at _____

Everyone switch jobs

	Earth Partner 2	**Moon** Partner 3	**Recorder** Partner 1
13	Hold the Earth straight up-and-down in the "sunlight". When you rotate the Earth, remember it always rotates to the East.	Hold the Moon about an arm's length from Earth and make one slow orbit around Earth. Be sure the NEAR side of the Moon is always facing towards the Earth.	Watch the Moon and help your partner keep the NEAR side facing towards the Earth. Then record the times below.
14		Move to a **waxing gibbous** Moon.	
15	Rotate the Earth until **moonrise**. Rotate the Earth until **moonset**.	Help find the observer's local time.	**Waxing gibbous** Moon rises at _____ **Waxing gibbous** Moon sets at _____
16		Move to a **waning gibbous** Moon.	
17	Rotate the Earth until **moonrise**. Rotate the Earth until **moonset**.	Help find the observer's local time.	**Waning gibbous** Moon rises at _____ **Waning gibbous** Moon sets at _____
18		Move to the **waning crescent** Moon.	
19	Rotate the Earth until **moonrise**. Rotate the Earth until **moonset**.	Help find the observer's local time.	**Waning crescent** Moon rises at _____ **Waning crescent** Moon sets at _____

When you've completed all the Moon phases, ask your TA for Part 4: Questions

Name _____ ID No. _____ Tutorial Day/Time _____

Part 4: Questions

Please hand in this worksheet when you are finished.

1. The calendar on the back of this page shows the phase of the Moon for every day of the year. Find and highlight today's date. What is the phase of the Moon today? _____

   Draw a diagram showing the geometry of the Sun, Earth and Moon today.

   What time is it right now? _____ Mark your location on the Earth in your diagram.

   If you go outside right now and the sky is clear, can you see the Moon?

   - ☐ You can never see the Moon during the day.
   - ☐ No, the Moon is below the horizon.
   - ☐ Yes, the Moon is up.

2. Let's assume that any time between moonrise and moonset, the Moon is visible. In other words, we won't worry about buildings, trees or clouds that block our view.

   In Part 3 of the tutorial, you found the times when a certain Moon phase is visible. In this question, you find the phases visible at a certain time of day. For each phase of the Moon in this list, check "Yes" if the Moon is **visible at 1 a.m.** or "No" if it's not.

Phase of the Moon	Moon visible at 1 a.m.? Yes	No
new Moon	☐	☐
waxing crescent	☐	☐
first quarter	☐	☐
waxing gibbous	☐	☐
full Moon	☐	☐
waning gibbous	☐	☐
third quarter	☐	☐
waning crescent	☐	☐

3. You and your friends want to paint stars on the big Engineering *E* on the Main Mall. You're planning on doing it next month at 1 a.m. on a night with **no moonlight**. Circle the dates on the calendar on the back of this page that are good for your evil plan. Which do you think is the best? Explain your reasoning.

4. Look back at the geometry of the full Moon, when the Sun, Earth and Moon are lined up. A "lunar eclipse" occurs when the Moon passes through the Earth's shadow. Why don't we have a lunar eclipse every month?

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