4.2: Moonrise and Moonset

This is a fascinating activity for young and old alike. Everyone is aware that the Sun rises early each morning, the time changes a bit from season to season, but sunrise is remarkably consistent. Moonrise is no such thing! Many people know that the Moon is sometimes visible in the early morning sky, but few people take note that the Moon rises about an hour later each day. If the time of sunrise is so consistent, why is the time of moonrise so variable? This activity answers this question with an exciting ballet of planetary and orbital motion that is sure to inspire everyone in your class!

Academic Standards

Science and Engineering Practices

- Asking questions and defining problems.
- 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.
- Stability and change.

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. We all know that the Earth spins on its axis and the Moon orbits the Earth – but most people don't think about these two motions ***occurring at the same time.***
2. Each time the Earth turns once on its axis (one day), the Moon has moved in its orbit.
3. Because of the Moon's motion, the Earth has to turn a bit more than 360 degrees to see the Moon rise over the horizon each day. This change accounts for the changing times of moonrise each day.

Teaching and Pedagogy

This activity is a complex ballet that involves almost everyone in the classroom. With younger students, you may have to practice the different parts of the activity separately before you can pull the whole thing off; doing activity #5 first will be crucial for them!

It is also important to help students understand that what the person in the center in the Earth position sees is what we all see from here on Earth. Both the daily apparent motion (diurnal motion) and the more gradual orbital motion of the Moon should be apparent to them as they participate in the activity.

Don't worry if the very youngest students don't completely catch on to the entire scientific significance of the activity with all its subtlety! Introducing students to a scientifically accurate concept when they are young will help these ideas to 'click!' when they see them again in a year or two when they are older and more sophisticated thinkers!

Student Outcomes

What will the student discover?

1. The Earth spins and the Moon also revolves in orbit – both bodies are moving at the same time.
2. The combination of the spinning Earth and revolving Moon create changes in the way we see the Moon each night.
3. Being able to imagine standing far off in space (instead of being trapped on the Earth's surface!) makes it easier to understand what is happening and how the Earth-Moon system works.

What will your students learn about science?

1. Keeping accurate time, and recording when things happen, can show us many subtle and interesting things that we might not otherwise notice!
2. Sometimes what we think we see (apparent motion) is not what is actually happening (orbital motion). Only careful experiments and accurate time and record keeping can help us sort things out!

Conducting the Activity

Materials

1. Artificial horizon (See activity #7)
2. A set of irrigation flags with clock hours on them (See activity #7)
3. Sidewalk chalk (for pavement), or 30 unmarked irrigation flags (for a lawn) to mark out the Moon's orbit
4. Sun model – a 12-inch yellow vinyl play ball is preferred ($3), but any soccer or basketball will do.
5. Moon model – a 12-inch vinyl play ball – dark blue or black is preferred, but you can paint any color ball half-black, half-white for this.
6. Ten, 12-inch squares of poster board (construction paper or cardboard may be used)
7. A can of flat-black spray paint
8. A can of flat-white spray paint
9. Markers or paints

Building the Moonrise and Moonset Model

1. Take seven, 12-inch squares of poster board and mark then with large numerals 1-7. If you do not have a separate ball for your Sun model, draw and label a large Sun on another piece of poster board.
2. **[Teacher]** Make a Moon model by masking off half of your dark-colored vinyl play ball with masking tape and newspaper. Prop the ball on an empty soup can and spray paint half the ball flat white. Let the ball dry completely before handling it.
   - Note: If the paint on your model does not dry properly, dust it liberally with corn starch and let it sit overnight. Brush off the corn starch with a dry paint brush and your model will be perfectly dry and ready to use!
3. Now take all the pieces of your model outdoors and choose a place on the lawn or playground for the Earth and mark it with chalk or an irrigation flag. Have one student start at the Earth position, and walk two steps away. Stretch a piece of string between the Earth position and this student. Using this string as a compass, mark out the face of the clock, starting with Noon. Remember that this is a 24-hour clock face! Instead of 12, 3, 6, and 9 o'clock, we will have Noon, 6pm, Midnight, and 6am at the cardinal points.
4. Have a student start at the Earth position and walk 4-½ steps away – this is the distance to the Moon's orbit. Stretch a string between the Earth position and this student as a compass. Mark out the path of the Moon's orbit with sidewalk chalk if on pavement, or with a series of irrigation flags about 2 ft. apart if you are on a lawn.
5. Have a student hold the Sun model well outside the Moon's orbit in the Noon position. This will allow the students to see the Moon both in the evening and morning if you continue the Moon's orbit long enough!
6. One student will hold the Moon model, also starting in the Noon position. Remind them to keep the white portion of the Moon pointing in the same direction at all times! With the Moon in this position, the student in the Earth position will see 'new moon' – none of the white portion of your Moon model will be visible.
7. One student will now play the Earth – they get to wear the Time Hat you have prepared! Have this student use the rope loops to hold the artificial horizon against their back (rather like a backpack!) while standing at the center of the circle. Start the student off facing the noon flag – remember to emphasize that ***the student in the Earth position is the hour hand of the clock*** – whichever flag is straight ahead of them – that's what time it is on the ***Earth Clock***!
8. Have a student stand just outside the lunar orbit holding up the "Day 1" poster board to mark the Moon's first position. The stage is now set, time to set Earth and Moon in motion!

Exploring the Moonrise and Moonset Model

1. As the Earth turns slowly anti-clockwise in place (revolving on its axis!), have the Earth student look to their right (over the western horizon). Tell them to **stop** when they can no longer see the Moon – this is ***moonset***! The 'Earth' can now look straight ahead – the arrow on the Time Hat will now point to the correct time of moonset! (This will be about 6pm.)
2. As the Earth continues to spin, the Moon moves one step anti-clockwise around its orbit[2], and another student will mark the position by holding up the poster board denoting the number of the new day.
3. Point out to your students that the spinning Earth will now have to turn just a bit farther than 360-degrees to see the Moon over the eastern horizon again – this is ***moonrise***. When they reach the point where they can see the Moon again – check the Earth clock – it should show about 7 pm. Moonrise has changed by about an hour!
4. Have the 'Earth' take note of the Moon's phase at moonrise on the second day – if the bright side of the Moon has been held in a steady direction, they will see a thin crescent moon!
5. By continuing to advance the Moon each day, everyone can see that the Moon is moving from ***west to east*** in its orbit, making moonrise and moonset time about an hour later each day. But the student playing Earth will see something else – as they spin slowly to the left (eastward!), the Moon will rise over the eastern horizon, and travel across the sky (their field of vision) and set in the west. Each day will also see the Moon's phase increase, the crescent will gradually increase to quarter phase, and then gibbous and full if you continue the activity long enough.
6. Allow as many students as possible to take the Earth position and try this out. There is nothing like being at the center of things to improve your perspective and understand cognitively and kinesthetically that the Earth's spin creates the ***east to west*** motion we see each day, and the Moon's orbital motion creates the ***west to east*** motion that we see over days and weeks.

Discussion Questions

1. Challenge groups to present what they have learned to the class. Give each group two minutes to explain the daily change in moonrise time and give a small prize to the best group.
   - **Answer** Communicating what we know puts us on the road to true mastery of a subject. It is also an excellent assessment for the effectiveness of the activity. Ask questions of your groups and encourage others to do so as well. By the time you have finished, everyone will have learned a little more about the Moon!
2. It turns out that the Moonrise time advances about 52 minutes each day. Challenge to students to explain why this change is ***less than 1 hour***.
   - **Answer** This question again depends upon ratios; this time we will compare the ratio of the time for Earth to spin once (24 hours) to the time it takes for the moon to orbit the Earth (28 days.)

A day has 24 hours while the Moon orbits in 28 days. 24/28 gives us .857, if we multiply 60 minutes by .857, we get 51.4 minutes change per day.

Supplemental Materials

Going Deeper

1. Aristotle said ***the Earth wasfixed***; he believed that the Earth was immobile, it neither spun on its axis nor orbited around the Sun. In fact, Aristotle believed that the Earth didn't move though space at all, and his models dominated scientific thinking for almost 2000 years! Use the internet to find some the ancient scientific explanations Aristotle used to try and convince people that the Earth did not move or spin, can you explain why these are not true using what you have learned in these activities?
2. Making an accurate clock was an important scientific quest for many centuries! In fact, scientists today are still striving to make ever more accurate clocks! Can you think of a way to make an accurate clock? Can you build one? [Hint: Start your students looking at pendulums and old-fashioned grandfather clocks. They may also want to investigate Galileo and his ***water clock***!]

Being an Astronomer

It is time to be a backyard astronomer again and take another look at the Moon! Start at the new moon phase and watch over a series of nights to see where the Moon appears at sunset. Watching the Moon at the same time each day will be important for the success of this activity!

Students can use irrigation flags, or even just sticks or small rocks to note where the Moon appears over the horizon each night. Place one flag to mark your observing spot, stand in this same place each night. Standing in your chosen spot, point to the position of the Moon at sunset. Take a 6-foot piece of string and stretch it across the ground and use a flag or stone to mark the direction in which you see the Moon. A parent can help with this!

Over the course of several nights, you will note that the position of the Moon in the sky at sunset moves steadily from ***west to east!*** Our scientific model of the Moon's orbit is confirmed! If the student or parent has a smart phone, take a photo of the diagram you've created after a week or so of observations to show what you have discovered!

Being a Scientist

Scientists often gather data to detect patterns in Nature; you can do this with the Moon as well. For this activity, it is important to have a consistent – and safe! – from which to watch the Moon each night. One easy way to do this is if you have a window that looks to the west; this keeps you inside safe and warm! The best time to do this is ***just after new moon.*** This means the Moon will be visible in the western sky just after sunset.

Watch the Moon set into the west and record the time when the Moon is no longer visible. This may be when the Moon drops below the horizon, or when it goes behind a building; as long as you use the same point of reference each night your experiment will work fine.

Keep in mind that the Moon sets ***later each night,*** you will only be able to get three or perhaps four nights before moonset is too late for you to stay up!

Record the time of moonset each night. After you have finished collecting several days of data, do the math to figure out how many minutes of change you observed in moonset each day.

Our activity predicts a change of about 51 minutes change each day. Can your observations confirm this? How close did you get to this figure?

Following Up

Have you been keeping track on your whiteboard of things like the phase of the Moon and hours of daylight along with the date and day of the week? This can be a great time to add a new feature: tracking the Moon's position in orbit around the Earth.

Make a set of 'orbital magnets' by coloring small circles of cardboard – one yellow for the Sun, one blue for the Earth, and a grey one for the Moon. You can move the Moon around the Earth, changing its position 2-3 times each week. Remember that during one entire week (7 days), the Moon must move 90 degrees in orbit.

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1. The Moon and Sun are both ½ degree wide. Since there are 360o in a circle, we divide 360 by 0.5 and get 720; in other words, the complete circle is 720x wider that the angular diameter of the Sun or Moon. We take the time of sunrise and multiply by 720 to get the time for a complete rotation of the Earth. ↵
2. When we set up the radius of the Moon's orbit as 4.5 steps, we created a circumference of 28 steps – the same as the Moon's 28 day orbit around the Earth. Each day – one spin around for the student playing Earth - the student holding the Moon model moves one step in orbit. ↵
