MOON DIALS AND PAPER PLATE MODELS

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Abstract: Moon dials allow users to determine when and in which direction the moon can be seen in any particular phase. In this activity, the audience will make their own paper plate models of the moon phases to learn how the moon dial works.

In this activity, participants will create a model of the moon's orbit to learn about the predictive nature of science. With their handmade paper plate Moon Dials, they can determine when and in which direction the moon can be seen during any given phase.

A mainstay of astronomy is predicting the future—not the predicting of astrology, but of science. In science we observe phenomena; build a model to explain the observations; and then make predictions based on the model.

In this activity we will construct a well-known model of the moon orbiting the earth, from which a Moon Dial, or Moon Finder, will emerge. Then we can predict when and in which direction the moon will appear for any given phase.

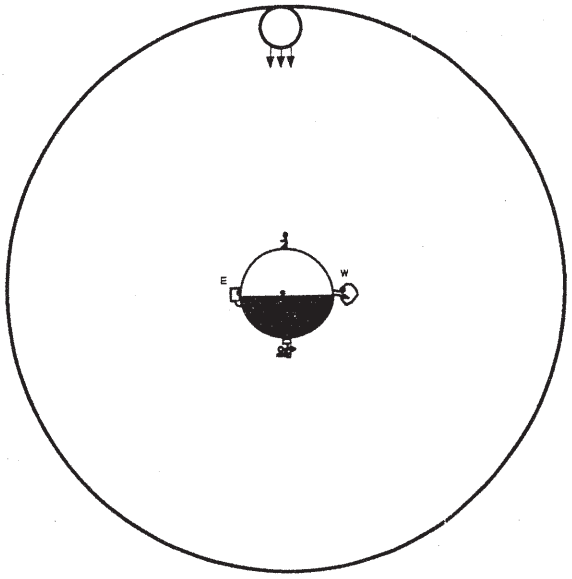
You've probably seen commercial versions of Moon Dials—moon phases and hours labelled on the perimeter of an outer disk rotate around a horizon on an inner disk. Typically you set the current moon phase to your viewing time to determine the moon's azimuth, or direction. They work great—but why?

To meet the time constraints of this paper session, I will rapidly assemble a large scale version of a moon dial as you assemble your paper plate ones. Required materials are a paper plate, a 3x5 card, a pencil, and a paper fastener.

I make the assumption that you have already observed the moon's phases and that you know the accompanying terminology (new moon, waxing crescent, first quarter, etc.). Also, this is written as a northern mid-latitude activity.

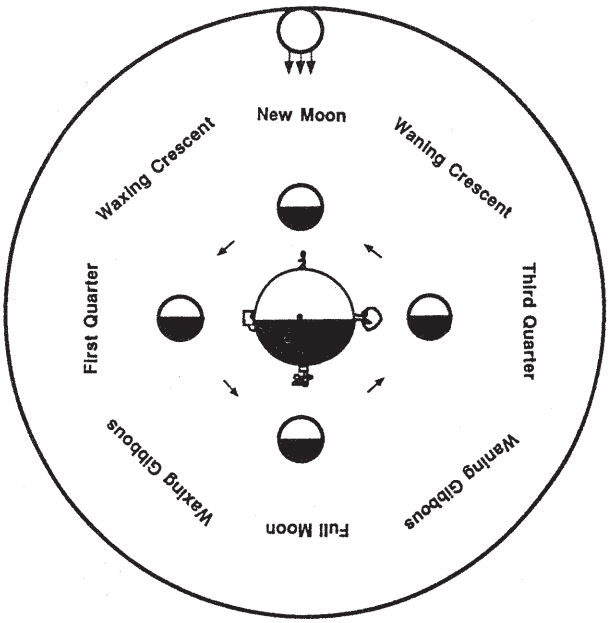
First, you want to draw a model of the moon's orbit that explains the moon's phases. Our chief aim is to depict the angular relationship between the sun, the earth, and the moon in its respective phases. The standard model claims the moon revolves eastward around the earth. On your paper plate, draw a small earth at the center and the sun (with rays) near the edge. Obviously, the sizes and distances in this model will not always be to scale. Shade in the night side of the earth.

This is a "God's eye" view, with the center of the plate being Earth's north pole. To reinforce this perspective, you may draw a person on the noon side of Earth; label east where a car is experiencing sunset and west where a tree is experiencing sunrise; and draw a gizmo on the midnight side of Earth. See Figure 1.



Orbiting the earth (fairly close for this activity), the moon at its four primary phases will be depicted by four circles . For each moon, shade in the half that is opposite the sun. Remember, the sun is so far away the rays can be considered running parallel to the first set of drawn sunlight rays. Begin with the moon between the sun and the earth. Because the moon is nearly in line with the sun, we see only the dark side. Label this New Moon.

Based on previous observations, you know the moon moves eastward against the background sky. Therefore, from New Moon move eastward, or counterclockwise on the paper plate, to the First Quarter Moon and label it so. Next, label the moon opposite the earth from the sun the Full Moon. And further eastward label the Last Quarter Moon. Each month, the model states, the moon orbits through these positions. Additionally, you may label the intermediate waxing and waning phases. See Figure 2.

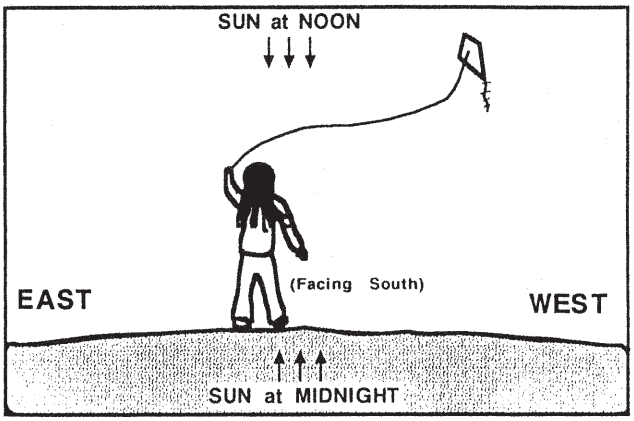


The angular relationship between the sun, the earth, and the moon will always hold, whether you view from high above the earth or from our local site. For example, the full moon will always appear 180 degrees from the sun. The last quarter moon will always appear 90 degrees westward from the sun. However, for the Moon Dial to be practical, you want to view the moon from your specific location on earth, not from above the north pole.

So put the paper plate aside. *It is important that you completely disassociate yourself from the "God's eye" view of the paper plate*. Next you will draw your local horizon on the 3x5 card as if you were facing south (because you won't see the moon far to the north from GLPA latitudes). For the rest of this activity you are back on terra firma.

Draw a line above the bottom of the 3x5 card to represent the local horizon. Midway draw a stick figure who is facing *away* from you. Consider the 3x5 card to be the view the figure and you would have if you were looking out of a bay window that faces south. Label the card's left edge "east"; in the center write "facing south"; and label the right edge "west." In drawing the horizon, you may include local landmarks familiar to you. Under the stick figure, punch a small hole with the paper fastener for later use.

Near the top of the card, draw short sunlight arrows coming down from high in the south and label them "sun at noon." At the bottom center of the card, below the hole, draw parallel arrows coming up from under the earth. This direction is *not* north. Rays from the sun do come from this direction, but they are blocked from reaching the stick figure by the earth itself. Label these bottom arrows "sun at midnight." See Figure 3.



The angular relationships between the sun, the earth, and the moon at its respective phases were established on the paper plate. Now we will use that information. Align the hole on the 3x5 card with Earth's north pole on the paper plate and secure the two pieces with a paper fastener. The Moon Dial is nearly finished.

You may rely on the written designations alone. However, I recommend that, around the perimeter of the plate near the labels, you draw what the moon actually looks like at the respective phases when viewed from your site. In real life, the cusps of the moon always point away from the sun. A shortcoming of the moon dial is that, due to latitudinal differences, it does not accurately depict the angle at which the moon is inclined to your local horizon. Therefore, draw the respective phases as you see them.

Your Moon Dial is now ready. You can now make astronomical predictions based on your model of the moon orbiting the earth. In using the Moon Dial, always keep the 3x5 card level and upright; you will rotate the paper plate.

The sun is the Moon Dial's timepiece. From the perspective of the figure on the 3x5 card, the sun's appearing from specific directions suggests the time. You set the time by placing the sun in the corresponding part of the sky (or behind the 3x5 earth). When the sun is due south, the time is local apparent noon; when the sun is on the opposite side of the earth, the time is midnight. When the sun is at the eastern horizon, the time is sunrise; when the sun is at the western horizon, the time is sunset.

Note that the sunrise and sunset times are not necessarily 6 AM and 6 PM, respectively. Only near the equinoxes does such a relationship hold. If, for example, the sun is between the eastern horizon and due south, you have to interpolate between the sunrise time (consult a newspaper or almanac) and noon.

Use your hand-crafted Moon Dial as you would a commercial version. Given two factors—the time, the moon's phase, and/or the direction of the moon—you can readily determine the third factor.

First, set the outer dial to the correct time by rotating the sun to its proper location on the 3x5 card. From a calendar determine the moon's phase. Locate it's approximate position on the paper plate and mentally ignore the other moons. When you face south, the real moon should appear in the direction, or azimuth, of the corresponding label or drawn moon.

Now you can go about making practical predictions with your Moon Dial. Let's try a few examples.

1. At what time is the Last Quarter Moon due south?

2. The Full Moon nearest the autumnal equinox is called the Harvest Moon. How long into the night is it above the horizon, aiding the farmers as they gather their crops?

3. A romantic young man in Chicago wants to propose marriage to his girlfriend while the First Quarter Moon is rising over Lake Michigan. To win the heart of his girlfriend this way, when does he meet her at the lakefront—during lunch hour, at sunrise, after a sunset dinner, or around midnight?

4. Steve Mitch wants to photograph GLPA conference attendees with a Last Quarter Moon setting in the background behind the Oglebay Resort and Conference Center? For what time should he schedule the photo session, and are GLPA members likely to attend at that hour?

5. "But, Judge," you complain, "I didn't know the speed limit was 30 miles per hour. I was driving east with the brilliant full moon rising in front of me. The moon was so bright I couldn't read the speed limit signs."

The judge reads your ticket. According to the ticket, you were driving east at 2:00 a.m. when the police pulled you over for speeding. After consulting his Moon Dial, does the judge agree with your claim? Why or why not?

The Moon Dial is an analog computer. It works because the relative angles between the sun, earth, and moon—as suggested by our model of the moon's orbit around the earth—are duplicated on the Moon Dial.

•This activity was inspired by the works of Wayne James and Larry Ciupik. I also wish to thank April Whitt for her ideas and support.