Stars and Cells 2007
Astronomy Challenge Solutions

Here I present the solutions as I find them easiest to understand, but you may have your own “mental model” of how to visualize the solutions. Figures are not drawn to scale.

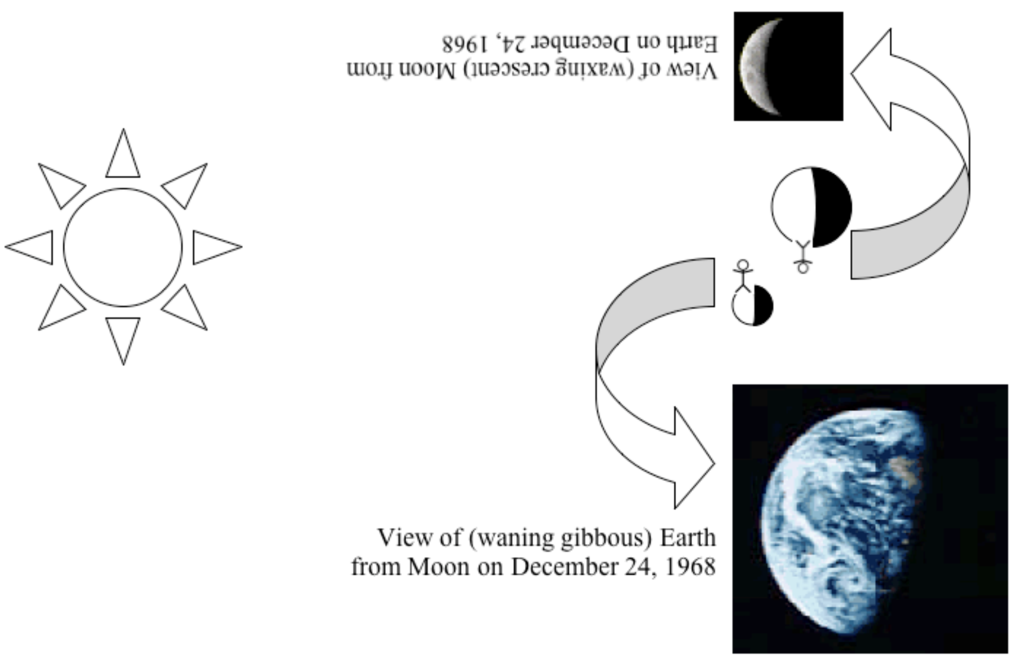
What I want you to remember most is how objects move in the solar system and to observe what you see and not what you think you see.

1. Figure 1 is commonly called “Earthrise.” It was one of the first images of the Earth from space. From the perspective of the moon, the Earth looks to go through phases like the moon does when viewed from Earth.
   What is the phase of the Earth in Figure 1?

   The phase of Earth is the *third quarter*. More precisely, it appears to be slightly more than a half disk, so it is a *waning gibbous*. [This answer is northern-hemisphere biased.]

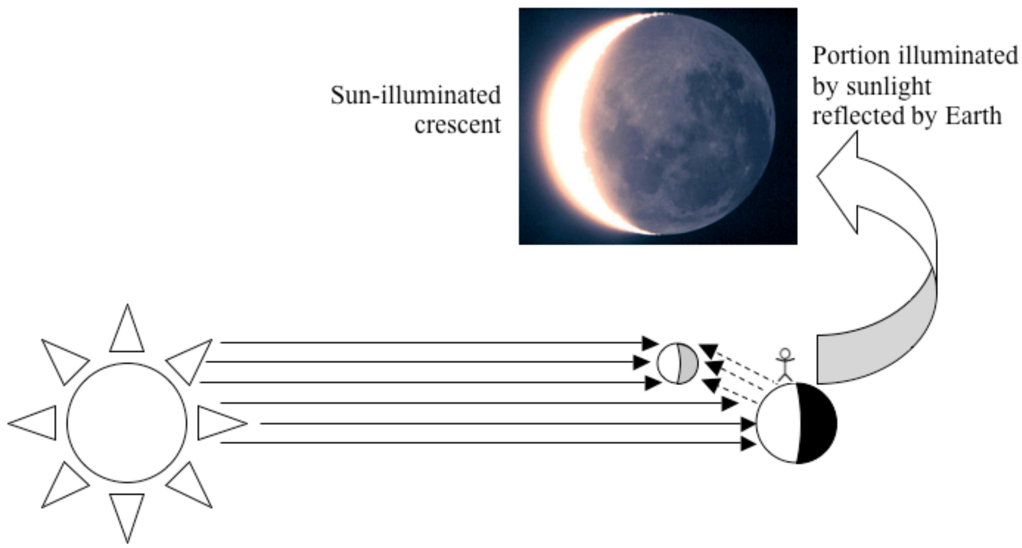
   What is the phase of the moon as viewed from Earth?

   The phases of the moon run opposite the phases of Earth. The moon is in its *first quarter* if Earth is in its third quarter. The moon is a *waxing crescent* if Earth is a waning gibbous. You can check the moon phase at http://stardate.org/nightsky/moon/.



2. Figures 2 and 3 are curious pictures of the moon doing the same thing (note the pattern of light and less light on the disk of the moon). You may have seen this at night occasionally. It's not that rare, and it's not some special adaptive optics image.
What is the configuration of the Earth, moon, and Sun to make this happen? (Diagram with labels is probably more useful than a description. Please include the path of the light.)

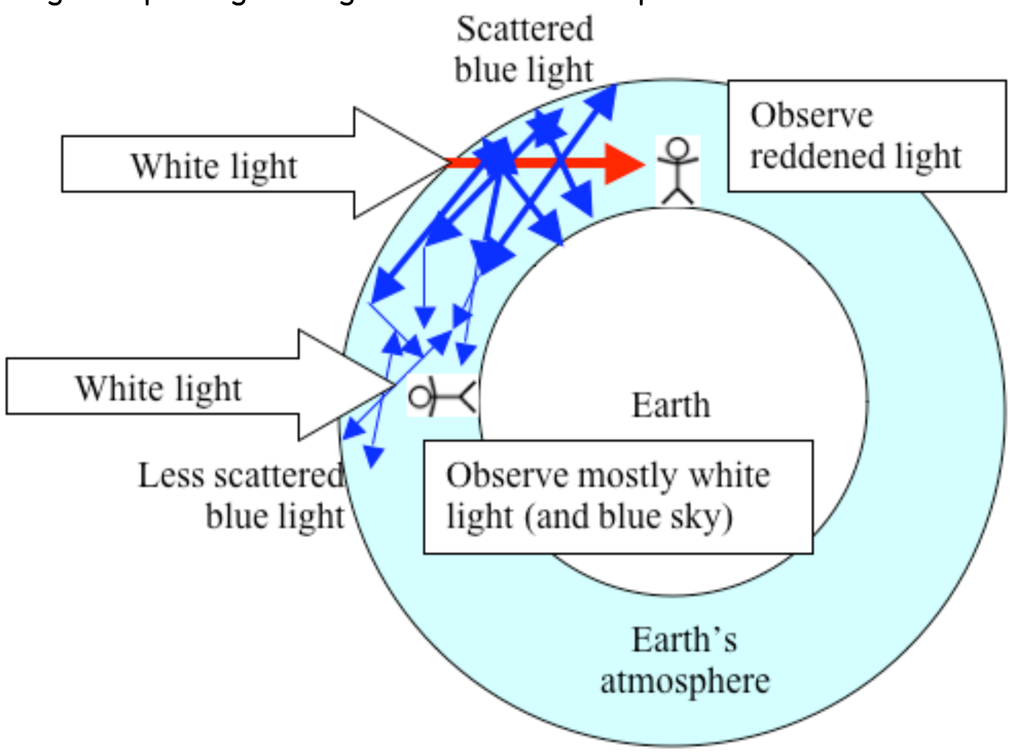
This effect is called "earthshine," when the full disk of the moon is faintly illuminated by sunlight reflected from Earth. This occurs when the moon is almost new so that the moon is in a position to receive reflected light and so that the part of the moon directly illuminated by the Sun does not overpower the faint light from Earth.



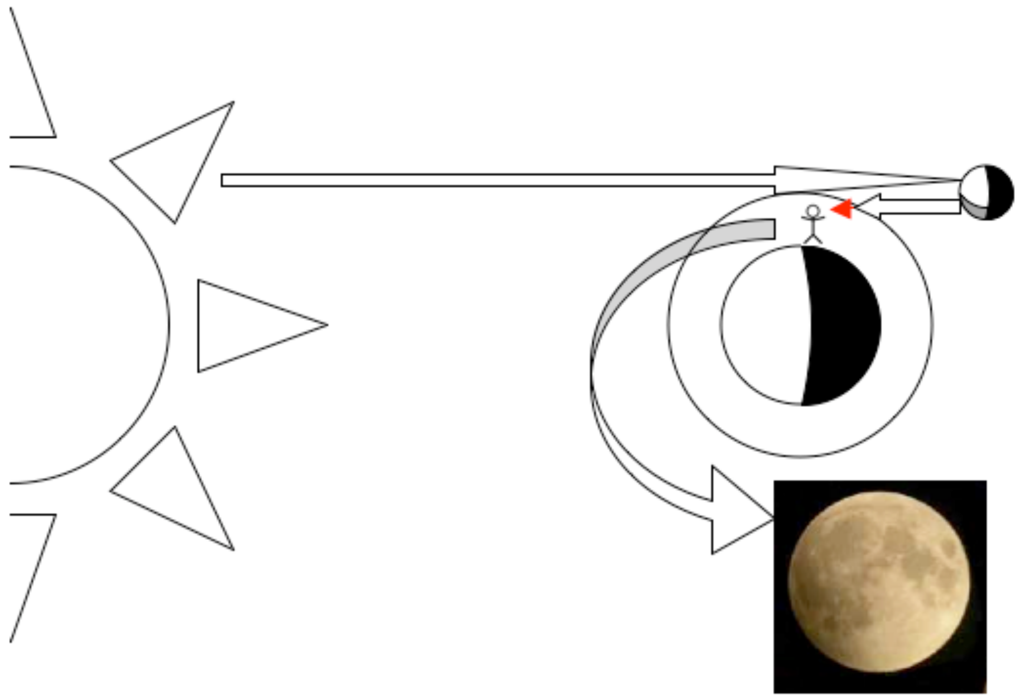
The only source of light in our solar system is the Sun. Our ability to see any object in the solar system is because the object is reflecting sunlight. In this case, Earth reflects enough sunlight to illuminate the face of the moon to the human eye.

3. Figure 4 combines many pictures of the moon taken at various intervals of a total lunar eclipse. The positions of the moons in the image do NOT correspond to physical locations on the sky during the actual eclipse.
Why does the moon change color during the eclipse? There are two subtly different but related reasons why the moon changes color early in the eclipse and late in the eclipse. To start, familiarize yourself with what the configuration of the Earth, moon, and sun are during a lunar eclipse.

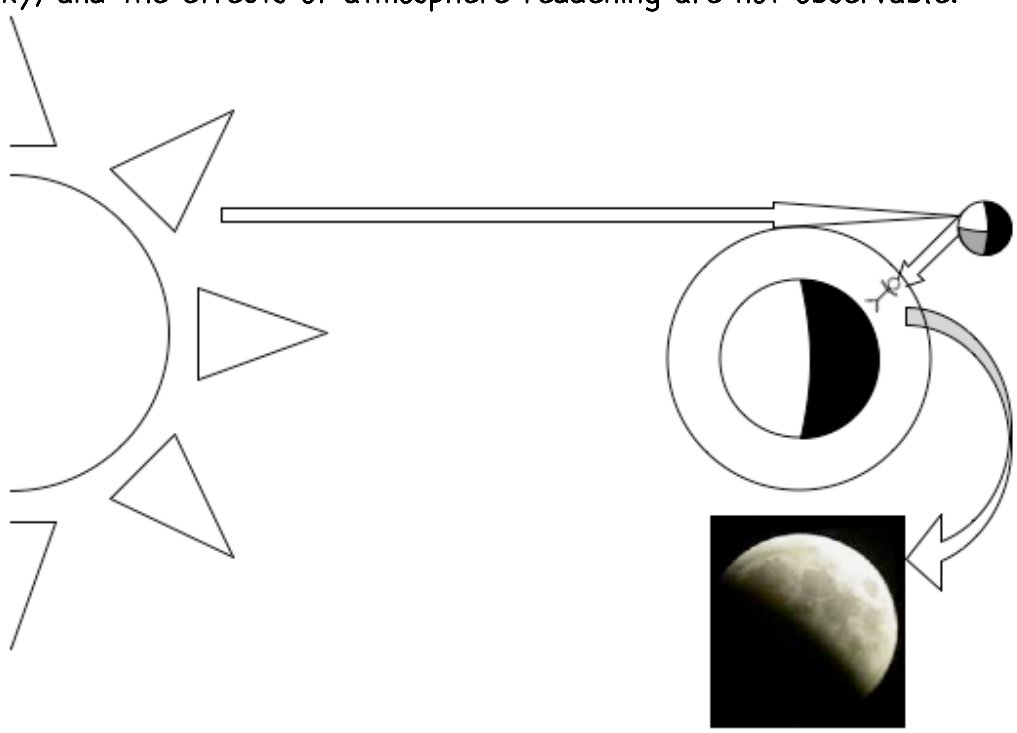
Earth's atmosphere causes light to become redder because the blue light is scattered away. The more atmosphere that light travels through, the more this effect is noticeable. The sky is typically blue because the atmosphere scatters some of the Sun's blue light all over. When the Sun is low to the horizon, it appears red because the sunlight is passing through a lot more atmosphere.



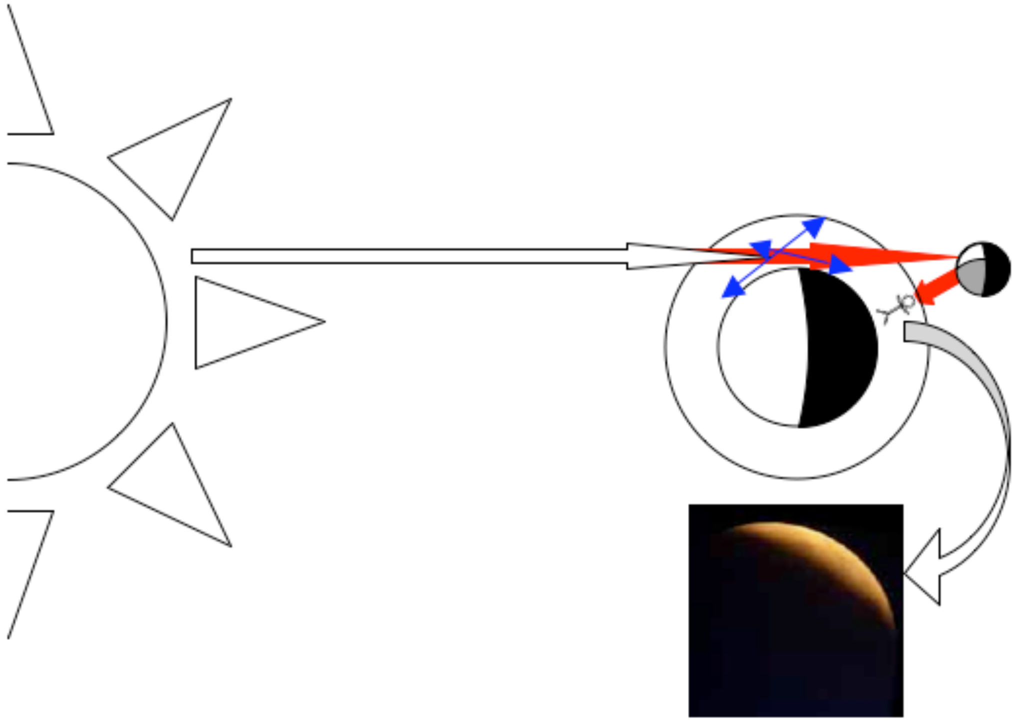
Early in the lunar eclipse shown in the given image, the moon is low on the horizon and passing through a lot of atmosphere, so its light is reddened (like the Sun at sunset or sunrise). This is a fortunate lunar eclipse to start just as the moon rises; the full moon typically is reddened as it rises from the horizon. [Please note that I cannot draw in three dimensions so the effect of Earth progressively blocking sunlight from hitting the moon is not quite diagramed. I do try to show Earth's shadow on the moon with the light grey shading.]



As Earth’s shadow grows on the moon, the moon rises higher in the sky, and the effects of atmosphere reddening are not observable.



Near the moment of total lunar eclipse, the only sunlight that illuminates the moon has passed through much of Earth’s atmosphere and been significantly reddened. This reddened light reflects off the moon and travels to the observer. [For this diagram, I have moved the moon slightly to show the effect of the sunlight passing through Earth's atmosphere first, then reflecting off the moon.]



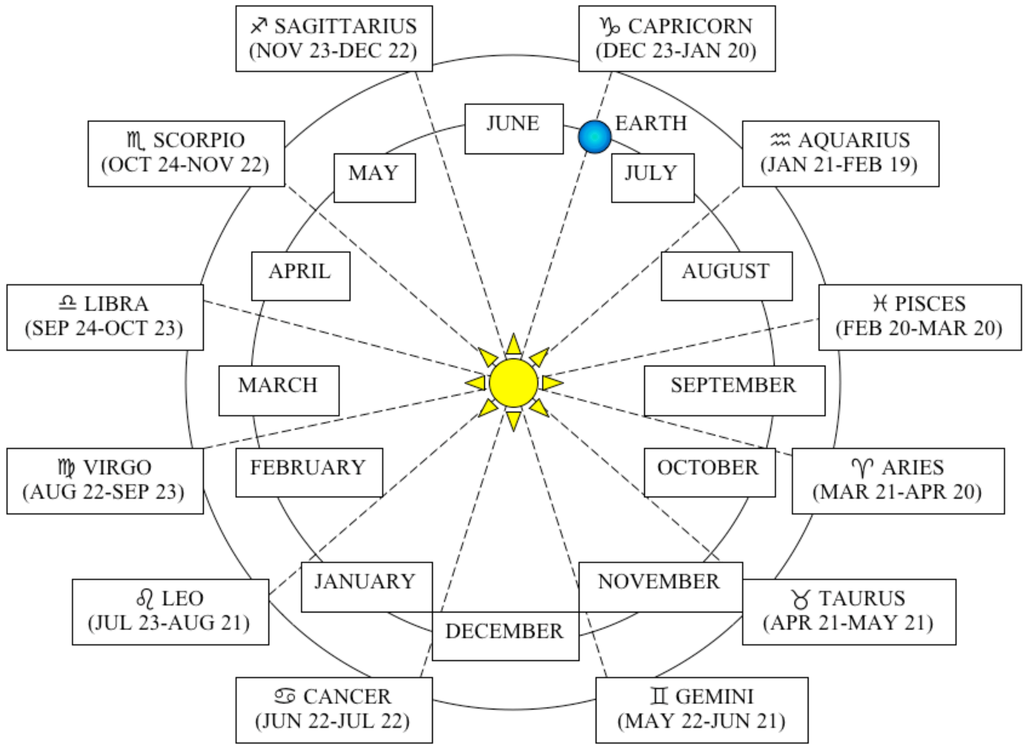
4. Merriam-Webster Online Dictionary has the following definitions:
    a. Astronomy: the study of objects and matter outside the earth's atmosphere and of their physical and chemical properties
    b. Astrology: the divination of the supposed influences of the stars and planets on human affairs and terrestrial events by their positions and aspects

Sign	**Dates**
Aries	March 21-April 20
Taurus	April 21-May 21
Gemini	May 22-June 21
Cancer	June 22-July 22
Leo	July 23-August 21
Virgo	August 22-September 23
Libra	September 24-October 23
Scorpio	October 24-November 22
Sagittarius	November 23-December 22
Capricorn	December 23-January 20
Aquarius	January 21-February 19
Pisces	February 20-March 20

This cluster is about studying *astronomy* but astrology has some foundation in astronomy, and I'm going to use astrology to teach about the *planisphere* and the stars. Given is a chart that will help you identify your astrological sign, which corresponds to a constellation on the ecliptic on your planisphere. A constellation is a region of the sky that bounds the few visible stars that make up the shapes and is typically larger than the visible stars (see Figure 5). The ecliptic is the plane of the solar system on the sky and is labeled on your planisphere (dashed line). **What does your astrological sign mean to an astronomer?** There is an astronomical interpretation to your astrological sign. To start, use the planisphere to view the night sky on your birthday (the exact time does not matter): **where is the constellation corresponding to your sign?**

The astrological sign typically listed in newspapers and magazines is technically your "Sun sign." It indicates the constellation in which the Sun is located on the day of your birth. When you set the planisphere to a *daylight* time on your birthday, your astrological constellation appears in the window (indicating what is in the sky.) If the Sun were not shining, on your birthday, you could see your constellation.

One way to visualize the movement of stars from the perspective of Earth is to assume the stars move on a sphere outside of our solar system (known as the celestial sphere). The solar system is a plane, so the movement of the planets and Sun on the celestial sphere is basically a circle (known as the ecliptic, shown on your planisphere).



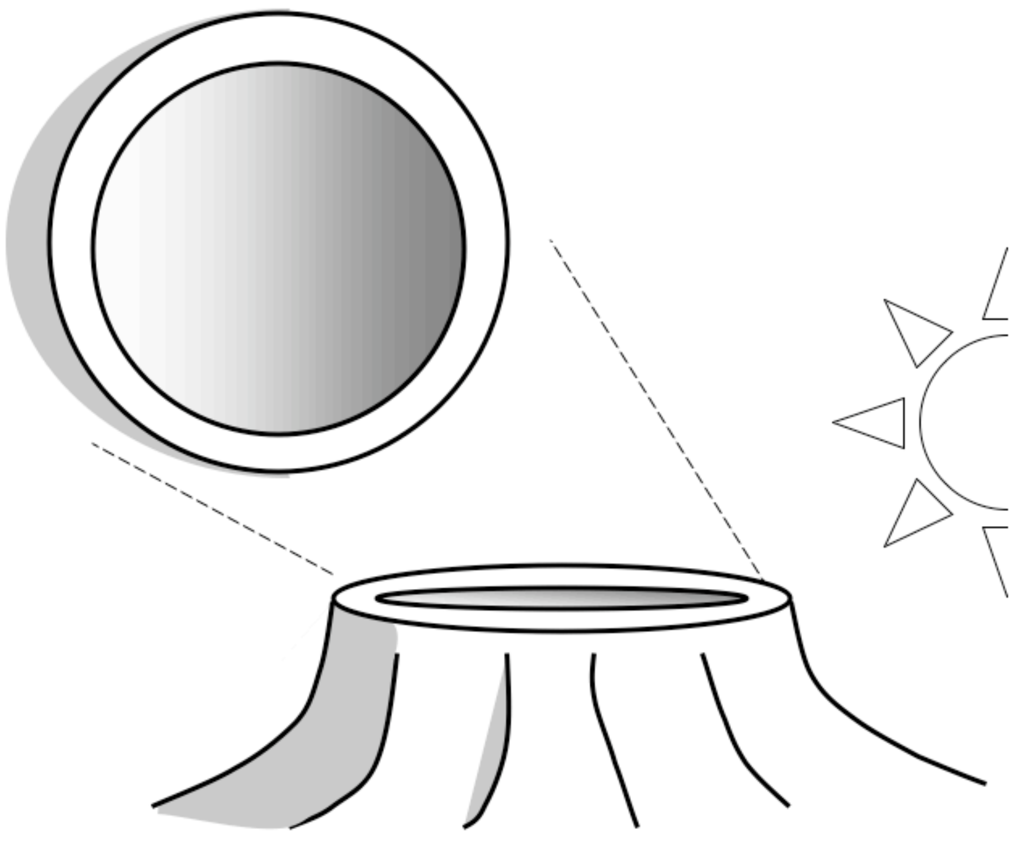
Shown in the above diagram is the Sun at the center of the celestial sphere (the outermost circle) and the path of Earth (the circle with Earth and month labels on it). For example, from June 22 to July 22, the Sun is between Earth and the constellation Cancer (so Cancer cannot be seen at night). This can also be phrased as "the Sun is in the constellation Cancer" from the perspective of Earth. Six months earlier, from roughly December 23 to January 20, the Sun is between Earth and the constellation Capricorn, and the constellation Cancer can be seen at night.

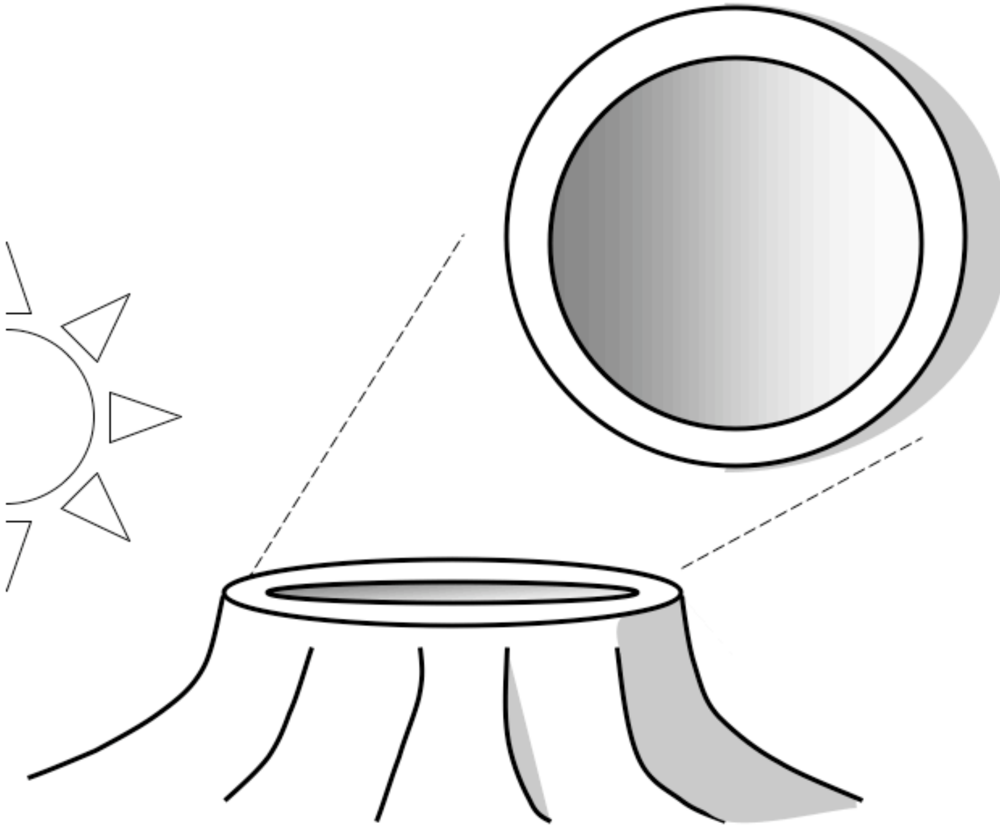
Bonus question: what might be another useful *type* of astrological sign (not another constellation in the sky)? As in the type listed above, this type would be important and fairly unique to your birthday. Hint: the type of sign of which I'm thinking would not be as easy to pinpoint by only the month of one's birth but would require the birth day and hour.

Another type of astrological sign would be the "moon sign," defined to be the constellation in which the moon is located at the exact time of your birth. It is not as easy to know as your Sun sign because the moon is not in the same constellation at every minute year after year. But you can determine your moon sign by looking up the location of the moon at the time of your birth. Then you could draw a diagram similar to the one above (can you envision how?)

5. Figures 6 and 7 are of a full moon (the same side of the moon too). They are quite different. (This is the very tricky question, by the way.) Figure 6 is very unique (though also not an adaptive optics image), and the other is quite common. To start, clearly enumerate how the images are different.
   What is so special about Figure 6?

   It is a composite image where the right half is a first quarter moon and the left half is a third quarter moon. You can tell this by examining how the pattern of illumination and shadow change direction between the right and left sides, especially along the center seam. In the below figures, you can see the top-down and profile views of a crater illuminated from the right (like during the first quarter) and left (like during the third quarter). Note the difference in the shadow patterns.





Craters along the center of the full moon (the real full moon, not a composite of two quarters) are illuminated from directly overhead and do not show any distinctive shadow patter. (Maybe a little ring of shadow around the rim.) Toward the edge of the full moon, the craters are illuminated more from the side and show some definition. (Remember the moon is a sphere.)

The composite "full" moon image has the craters toward the edge illuminated from directly overhead and showing no distinctive shadow pattern.