

Our Moon is one of the easiest objects in the night sky to observe (when the phase is right). Unfortunately, it is one of the most overlooked objects by amateur skywatchers, who are usually in the market for a spectacular planet, nebula, or galaxy. The Moon's surface is covered with interesting features that reveal much about its history, and indeed about the history of the Earth-Moon system. To the naked eye, some of the more pronounced features visible as light and dark areas have been likened to the face of the "man in the Moon."

In this exercise, you will observe the Moon through binoculars and whatever other telescopes are available. Moon filters may be available for use on some of the eyepieces. You will read about and identify some surface features and estimate their sizes.

Objectives:

- Learn the correct way to keep an observing log
- Identify basic lunar features and estimate their sizes

Equipment:

- This write-up, calculator, lab notebook
- Various binoculars and telescopes, eyepieces, moon filter
- Flashlight with red filter
- Moon globe and/or maps
- Moon worksheet

I. CRASH COURSE IN LUNAR FEATURES

- A. Craters: Craters are generated by the impact of asteroids and meteors on the surface of the Moon. So called "impact craters" are found on the Earth and on all other objects in the solar system with solid surfaces (terrestrial planets, all moons, asteroids, comets). The impact generally carves out a circular hole that is about 10 times wider and as much as 5 times deeper than the diameter of the impacting object. Thus, an asteroid 1 kilometer in diameter could create a 10 km diameter, 5 km deep crater. An impacting asteroid will strike the surface at a speed of 30-70 km per second! This incredibly violent impact will impart a great deal of energy into surface materials. The heat will melt the surface and the molten rock will then flow outwards from the impact site. Just as would happen if you dropped a big rock into a bucket of water or syrup, the liquid flows outwards from the center. At some distance from the center, the material is less molten and even further, the rock is completely unmelted. The unmelted rock doesn't move so the molten rock flows up over the lip, piling up at this edge. The molten rock then starts flowing back down toward the center of the crater again, all the time starting to cool off and solidify. Much of the molten rock solidifies in the jumble created at the crater lip, thus creating a circular mountain of basaltic rock (a typical rock formed from the cooling of molten lava) that marks the crater rim. Some of the rock flows all the way back to the center and, like the dances in an old fashioned circle dance, all the lava piles up at the center, some of it cooling right there at the pile-up. Thus, a central peak, a mountain of basaltic rock, forms at the center of the crater. Really big impacts send waves out through the warmed up rock surrounding the impact site, like water waves in a pond. The rock freezes into place into upraised circular rings around the impact site, making additional circular mountains around the crater.

- B. Crater rays: Much material will be thrown out from the impact site unmelted. These pieces of debris could be as large as the asteroid itself and will generate secondary impact craters where they land. The biggest pieces will land close by, the smaller pieces will tend to travel further. On the Moon, we can often trace the paths of these ejecta trails as rays extending outwards from craters.
- C. The Shape of the Moon: Often, very simple observations reveal very profound results. The shapes of lunar craters as a function of lunar longitude is one such type of observation. You should notice that craters in the middle of the Moon, as viewed by us on Earth, always look very round. In contrast, as you observe craters that lie at larger lunar longitudes (i.e. closer and closer to the curved lunar limb), the craters become more and more elliptical. The craters retain their normal apparent linear size in the north-south direction but become very narrow in the east-west direction. At the extreme, all the way at the lunar limb, craters appear to have almost no width in the east-west direction. We must conclude that either a) craters have different shapes at different places on the Moon or b) our view of round craters is foreshortened as we view toward the limb. The first possibility is hard to defend. Why should craters have different shapes (and thus be made differently) simply because they are at different lunar longitudes? This is not likely. A much better explanation, indeed the correct answer, is that the apparent shape of a lunar crater depends on our viewing angle, not on lunar longitude or position on the Moon's surface. A crater at the sub-terrestrial point looks round. Craters found at large angular distances from the sub-terrestrial point (the geometric center of the full Moon) are foreshortened. Foreshortening would not occur if the Moon were a flat disk. If we observed longer, you would notice that foreshortening also occurs as we move toward the north or south limb, i.e. it is symmetric around the sub-Earth point on the Moon's surface. Only a spherical or near-spherical object could produce these effects.
- D. Terminator: This is the "line" separating sunlight from darkness on the Moon. Sunlight near the terminator is less direct. If you could stand at the terminator, the Sun would appear on your horizon, either as a lunar sunrise or sunset. Thus, with the Sun low toward the horizon, shadows are very long in this region. Thus, the best observations of the relative heights of features (crater walls and peaks) are obtained near the terminator.
- E. Maria: "Mare" is Latin for "sea" and "maria" is the plural form. A mare is formed when lava flows into a formed crater, filling in its bowl shape and leaving only the mountainous rims uncovered.
- F. Highlands: The smooth, dark maria contrast starkly with the light, rough areas known as the highlands. The surface of the Moon is composed mostly of basaltic rock. However, the basaltic rock of the maria contains a lot of iron, giving rise to the dark color. On the other hand, the highland basalts contain much aluminum. Because of this difference in composition, the maria have a greater density than the highlands.
- G. Ages of Craters: We can learn the relative ages of different features on the Moon by looking for the relative placement of craters and lava. If lava has filled in a crater, then clearly the crater event happened first and the lava filling event happened second. If a crater appears in a mare, then the lava had to be there before the crater event occurred. If one crater has crushed the wall of another crater, the crater with the crushed wall must have been there first.
- H. Crater Counting: The highlands have far more craters than do the maria. The number of craters in the highlands is almost uncountable. So clearly, if the cratering rate has been

constant over the lifetime of the Moon, the maria are “younger” surfaces than the highland regions. Younger simply means that lava covered up the old surface, erasing all the geological history of that part of the surface of the Moon. So the maria are younger than the highlands. In fact, the cratering rate has decreased with time so that most of the big craters formed early in the Moon’s history and more small craters formed long ago than recently. Thus, our assumption of a constant cratering rate would have the effect of making the maria younger than they really are since, in reality, the craters in the maria did not accumulate as quickly as did the craters in the highlands.

II. NEAR AND FAR SIDES OF THE MOON

You may have noticed that Earth-based photographs of the Moon always show the same side. Because the Moon’s rotational period is the same as its period of revolution (synchronous rotation) with respect to the stars (the sidereal period), only one side of the Moon ever shows its face to Earth. This side is known as the *near side*. The other side, known as the *far side*, has only been seen directly by a few astronauts during the Apollo missions. The information on Moon maps and globes was obtained through the use of probes and Apollo mission photography. Study the maps and globe for a few minutes to get a “view” of the side that Earthbound observers will never see.

The near side of the Moon has enormous craters filled with mare material, while it is much harder to find evidence of enormous craters on the far side. If you look really closely, though, you will find them but they are almost completely covered by smaller craters. From crater counting, we know that this means the average age of the surface features on the far side is greater than that of the near side. Probably, the lava eruptions that filled in the large impact basins on the near side never took place on the far side. Why? We’re not sure. We do know that the core of the Moon is displaced toward the near side and that tides probably dragged the Moon into this near/far side lock very early in the history of the Earth-Moon system. The near/far side locking and the near side displacement of the lunar core somehow must have made it easier for magma to erupt on the near side than the far side, perhaps because the near side crust was thinner.

III. SKETCHING THE MOON

You will do **two** sketches of the Moon. The first will be a general outline at lower magnification (30-40 mm eyepiece) with the terminator indicated and the maria shaded in. In the second sketch at higher magnification (9-12.5 mm eyepiece) you will locate features such as craters, mountains, etc. For each sketch, you should draw a full circle and then trace the amount of the circle that accurately shows the current lunar phase and indicate the terminator. For example, at first quarter the sketch would look something like Figure 1. ***Do not forget that you must record other important information about your observation such as the date, time, sky conditions, lunar phase, focal lengths of the eyepieces used and what telescopes (aperture size at the very least) they were used in, etc.***

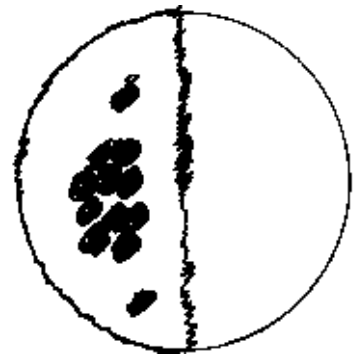


Figure 1. Sample sketch of the first quarter Moon.

IV. OBSERVING THE MOON

Observe the Moon through binoculars and at least one telescope. Keep a good observing log, i.e. don't forget to record date, time, object, type of object, telescope aperture, eyepiece, phase of Moon, sky conditions, etc. Use your naked eyes and then the binoculars to just "tour" the Moon and explore for a few minutes before you jump right in to making sketches and looking through the telescope(s). Take a few minutes to think about what you're seeing and put it in context with the previous reading on lunar geology.

Check the eyepiece of the telescope. To see the entire moon in the eyepiece you will need a long focal length (low magnification) eyepiece: about 30 or 40 mm. In addition, if the Moon is more than a few days past the new phase, you may need to have a Moon filter in the eyepiece to make your eyes more comfortable. If the telescope is not already set up this way, ask your instructor to insert the correct eyepiece and filter.

Make your first sketch and be as detailed as practical. Shade in the maria (refer to Figure 1). Don't worry about leaving out the part you can't see on the dark side of the terminator. If you are at crescent phase you may see very few maria.

Be sure to replace your long focal length eyepiece with a shorter focal length one (about 9 or 12.5 mm) and record the appropriate information. You may no longer need the Moon filter. Look near the terminator of the Moon. Contrast features here with ones closer to the limb (edge). They usually seem more clearly defined because they have more prominent shadows. This is due to the fact that the Sun is at a larger angle as seen from an observer at the terminator. If you were standing at the terminator you would be near sunrise or sunset on the Moon. Just as on Earth, that is when the shadows are the longest.

Table 1. Lunar features near the terminator at a given phase.

Phase (days)	Feature Name	Feature Type
2	Petavius	crater
3	Atlas and Hercules	craters
4	Pyrenees	mountains
4	Jannssen and Fabricus	craters
5	Theophilus	crater
6	Aristoteles	crater
6	Hipparchus	crater
7	Ptolemy	crater
7	Alpine Valley	valley
8	Eratosthenes	crater
8	Copernicus	crater
8	Tycho	crater
9	Sinus Iridum	small maria
10	Kepler	crater

Table 1 contains a list of features and the corresponding lunar phase when they are near the terminator. Phase is noted in days from new Moon. Since a full set of phases takes 29.5 days, first quarter is at $\frac{1}{4} \times 29.5$, or about 7-8 days. Your instructor will tell you approximately what phase the Moon is in for your observations session. **Choose a feature near your phase and indicate it in your second sketch.** This time use the circle to show the edges of what you see in

the eyepiece, that is, the field of view. Also draw a light circle on your first sketch to show what spot on the Moon you are looking at in the detailed sketch.

Now using the longer focal length eyepiece, find a large crater. Identify the crater by marking it on your large-scale map of the Moon. **Estimate how large the diameter of this crater is compared to the entire lunar diameter.** *Be careful to use the lunar diameter and not the distance from the terminator to the lunar edge.*

ANSWER THE FOLLOWING QUESTIONS IN YOUR LAB NOTEBOOK.

1. **Make sure your two sketches illustrate what they are supposed to and that they are labeled and documented properly.**
2. **What is the name of the crater you chose for your second sketch?**
3. **The crater from Question 2 is what percentage of the lunar diameter? What is the angular size of this crater? How many kilometers is this? Recall that the angular size of the full Moon is 0.5° and its radius is 1738 km.**
4. **Using your estimate of the size of the large crater in Questions 2 and 3, you can determine the linear diameter of the crater by using the small angle formula (Equation 1), where d is the diameter of the crater, D is the distance to the Moon (384,000 km),**

$$d = \frac{\alpha D}{206265} \qquad \text{Equation 1}$$

and α is the angular diameter of the crater in *seconds* of arc. You should recognize this equation as the combination of the linear↔angular size equation and the equation for parallax (Equations 1 and 5 from the Angles and Parallax lab, respectively). Use this formula and calculate the linear size of your crater. Does this match what you got in Question 3?

5. **Explain why you did or did not get the same answers for the linear sizes in Questions 3 and 4.**
6. **Using the Moon map and looking at your Moon worksheet, label the features listed. Were you able to see all of these when you observed tonight? Why or why not?**

V. REFERENCES

- Hoff, D.B., Kelsey, L.J., & Neff, J.S. *Activities in Astronomy*, 3rd Edition, Kendall/Hunt Publishing Company, 1992
- Shaw, J.S., Dittman, M., & Magnani, L. *Laboratory Textbook for Elementary Astronomy*, 7th Edition, Contemporary Publishing Company, 1996