The Moon is Earth's natural satellite, and is the only other body in the solar system that humans have landed on. The Moon orbits an average of 384,000 km from Earth, has a radius of about 1738 km (¼ of Earth's Radius), and has 1/80th the mass of the Earth at 7.3x10^22 kg. The most widely accepted explanation for the Moon's formation is that it accreted from the material thrown off of the primordial Earth from a collision with a Mars-sized planetesimal. This idea is supported by the composition and age of the moon, as found from the samples brought back by Apollo astronauts. The Moon orbits with the same side always facing the Earth because the gravitational interaction with Earth has nearly synchronised the orbit of the Moon with it's rotational period. The “nearly” from the previous sentence stems from the fact that the Moon's orbit is slightly elliptical, not perfectly circular. This causes a slight wobble on the face shown to the Earth during a lunar cycle.

As you can see from the above images, the Moon is covered in craters. The craters range in size from massive, visible on Earth, to microscopic visible by microscope on the Moon rocks collected by Apollo Astronauts. The different types of craters arise from the size, mass, speed, and angle of impact from the impacting body. A large object will form a larger crater than a small object. A more massive and faster falling object will create a more violent impact and more complex crater. If an object impacts at a low angle with the Moon's surface, than it will create an extended crater shape, instead of the usual circle. The size and arrangement of craters can tell Astronomers a lot about the Moon's history.

Most craters on the moon with diameters less than 15km are simple craters with bowl-shapes and anatomy like that shown in the above image.
Craters between 20 and 175km are often complex craters with uplifted material at their center like in the above image. Craters of about 175 to 300km can have complex ring structures of uplifted material inside the impact crater. Impact basins are craters over 300km, and they result in massive fracturing of the Moon's surface, with wide debris fields. There are about 40 impact basins on the moon and some are filled with solidified lava.

When an object impacts and forms a crater, the debris that filled that space is thrown out of the crater as ejecta and forms what is known as an ejecta blanket covering the surrounding area. The ejecta can range in size from dust and sand to large rocks and boulders. This raises the question, what happens when the ejecta hits the surface? The answer: not all craters on the moon are from an object originating in space. Many craters are in fact from secondary impacts by ejecta, or tertiary impacts from the ejecta's ejecta. More powerful impacts lead to more ejecta, larger ejecta blankets, and often more secondary and tertiary cratering. Secondary craters are often lined up in rays, because debris can be ejected from craters in arc-form.

The Moon and Earth are constantly being hit by space debris of all kinds, but there was a period of intense bombardment at the end of the Solar System's formation that led to impact scarring on the rocky planets and moons. During the Solar System formation, the planets were molten, and the constant bombardment by comets, asteroids, and planetesimals was adding mass to the larger bodies.
However, as the bodies cooled, they showed the impact craters because molten material was not constantly resurfacing them. The Late Heavy Bombardment was a period of many millions of years, after the large rocky bodies had mostly solidified their surfaces, when a lot of debris impacted the surfaces and caused many of the craters we see on their surfaces.

![Lunar Reconnaisance Orbiter image of a crater in 2D and 3D showing superimposed craters. Image By: http://lunarnetworks.blogspot.com/](image)

The Principle of Superposition is the formal statement that a geological feature can be modified only after it was formed. That is to say, if a crater was broken up by a fault or crack in the surface, then the crater had to be there before the event that caused the surface to crack. Another example would be superimposed craters. The crater on the bottom had to be there before it could be changed by the crater on top of it, as in the picture above. The smaller craters inside the bigger crater had to have come from impacts after the larger crater was formed. If the smaller craters had come first, they would have been erased or modified by the larger crater! So the principle of superposition can be used to give the age of craters relative to the craters they are close to, i.e. the smaller craters on the inside are younger than the larger crater. Radioactive dating is the most accurate method of giving absolute ages of rocks, i.e. 4.23 billion years old.

**Lunar Map Pro Maria and Highlands**

Something previously unmentioned in this lab about the Moon is that the surface apparently has two colors: Light and Dark Grey. The Dark Areas on the Moon are called Maria (singular Mare) which is Latin for Seas. The lighter areas of the Moon are called Highlands.

For Today’s Lab Exercise, you will use Riti’s Lunar Map Pro to compare two squares of equal area on the moon’s surface. Click and drag one square from the light region, another from the dark. You should count the total number of visible craters on this area, give an example of crater superposition for named craters, and count the types of craters in your area. Finally, from counting the craters, your knowledge of the principle of superposition, and your knowledge of the Late Heavy Bombardment, which area of the moon has an older surface: the Maria or Highlands?

**Using Lunar Map Pro**

You will use Lunar Map Pro (LMP) for this exercise. LMP is a straightforward, flexible and
easy to use mapping program for studying lunar features.

1. Open LMP.
2. The opening screen shows a centered fully illuminated lunar disk. In the bottom left of your screen is a Navigator window. You may minimize the Navigator window if you wish and work directly with the main map.
3. The 2 options for controlling the map are a standard drop down menu bar and an icon bar below it. Hover the mouse cursor over each icon to reveal the hint box to explain its function. If LMP was already open on the desktop, select the “show entire map” icon to restore the full image of the moon. If there are any problems or confusion over what is displayed, simply close and reopen the program.
4. Use the magnifier icon to select your square. You can select a point on the map, hold down the left mouse button and drag your mouse in any direction to select the size of the area you wish to work in.
5. Release the left mouse button once you have selected the area. Reducing the size of the program window from ½ to 2/3 the desktop will help you in controlling the area you choose.
6. Select a light area and count the craters in that area. Repeat this step for a dark area. Record your responses.
7. For two superimposed named craters, which one is older? Give a specific example.
8. So, you know how large impacts on the moon form basins that can fill with lava, and you know there is a difference in crater counts for the light and dark areas of the moon. Which surface on the moon is older? The light or dark? What happened to change the surface of the younger area?
Astronomy 153 Lab 5 The Moon Exercise

Using Lunar Map Pro
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Light Area Crater Count:

Dark Area Crater Count:

Superimposed Craters:

Which is older Lunar Maria or Highlands?