Moon Unit – Introduction

Have you ever seen a total solar eclipse? a total lunar eclipse? a partial eclipse of the Sun? In this unit you will learn about eclipses and also about the phases of the Moon. By the end of the unit, if someone tells you the Moon's phase for a certain day you will be able to tell them approximately what time the Moon rose and set on that day.

An eclipse occurs when one celestial body is between the Sun and another celestial body. The type of eclipse then depends on where the observer is located and also on the relative sizes of the various bodies.

If you haven't already done so, you might want to pause here and look at the activity for this unit. It provides you with some hands-on experience that is very relevant to this unit on the Moon.

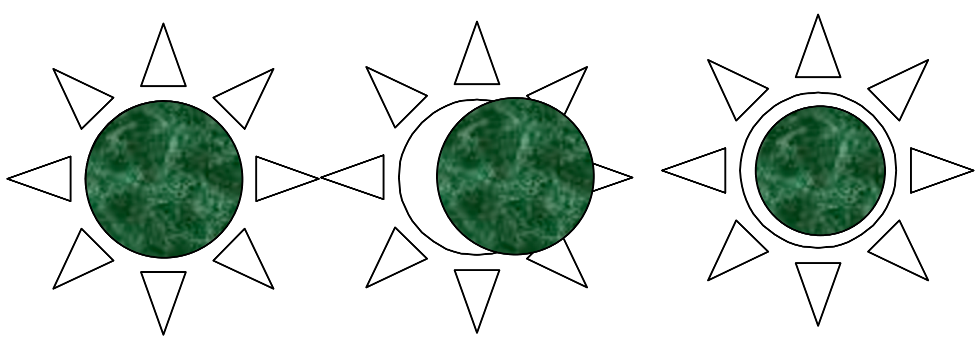
Subunit 1: Eclipses of the Sun.

The Sun and the Moon appear to be about the same size when observed from Earth. The Sun is much larger than Earth; its diameter is about 100 Earth-diameters. The Moon is smaller than Earth; its diameter is about 1/3 of the Earth's diameter. Because the Moon is much closer to us (384,000 miles, on average) than the Sun (93 million miles, on average) they both appear the same size on the sky. In more technical language we say that both the Moon and the Sun subtend about _ degree in the sky – or, if we placed 720 moons edge to edge around its orbit we'd have a chain all the way around the Earth.

Pause for thought: Why 720 moons?

Answer: Each Moon subtends _ degree, so we need 2 moons for each 1 degree and there are 360 degrees = 720 moons to a full circle.

When the Moon comes between us and the Sun we have a Solar eclipse. What you might see (taking appropriate safety precautions in observing the phenomenon[1]) is illustrated below:



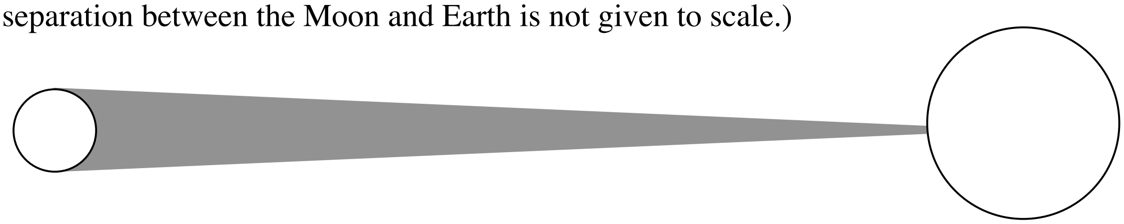
total solar eclipse | partial solar eclipse | annular solar eclipse

[1] Never look directly at the Sun without appropriate eye protection. This is true every day as well as during an eclipse. The only reason people worry during an eclipse is that one is more tempted to look at the Sun then.

Pause for thought: How can we have both a total solar eclipse (where the Moon blocks all of the Sun) and an annular eclipse (where it fails to block all of the Sun) when the Moon and the Sun subtend about the same angle?
Answer: We are sometimes slightly closer to the Sun than the average distance (making it appear slightly bigger) and the Moon is sometimes farther from the Earth than its average distance (making it appear slightly smaller). Thus, although usually they are about the same size, sometimes the Moon appears enough smaller to give the third picture, the annular eclipse.

From the Activity for this unit, you may have discovered that when your eye is in the umbra of a shadow, you can see no part of the light casting the shadow, while when your eye is in the penumbra, you can see part but not all of the light. For which of the above three cases is the observer in the umbra of the shadow cast on Earth by the Moon?
Answer: For the total eclipse.

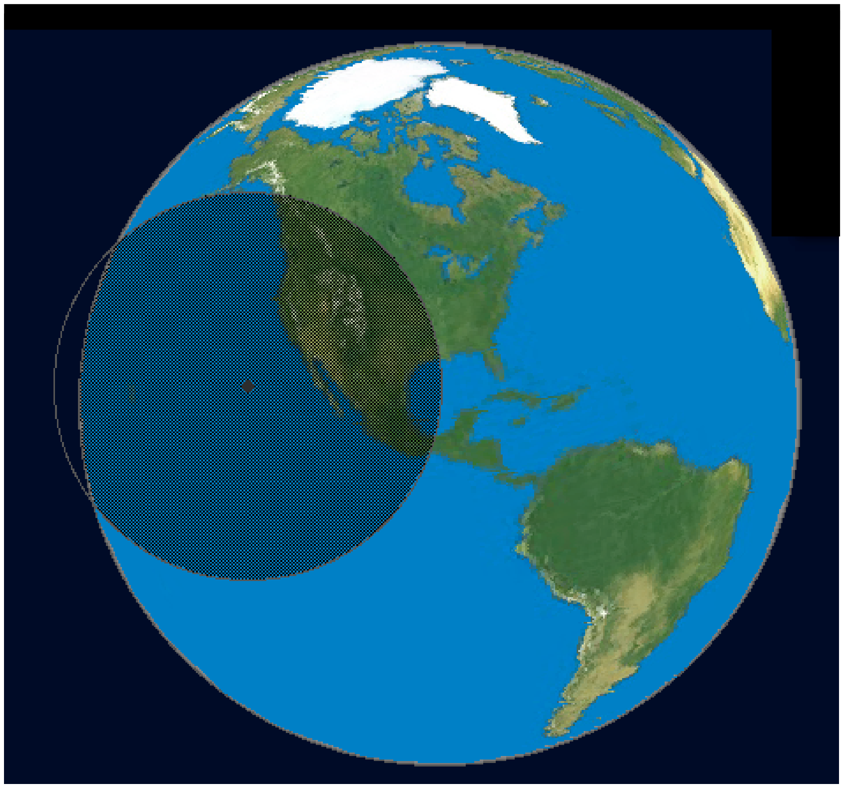
Because the Moon and the Sun subtend almost exactly the same angle in the sky, the umbra of the Moon's shadow on Earth is very small for a total eclipse, and misses Earth altogether for an annular eclipse. Here are illustrations of three cases that are relevant; can you match these to the illustrations above? (The smaller body is the Moon, but the separation between the Moon and Earth is not given to scale.)



Answer: In A the umbra of the shadow reaches Earth, and an observer in the umbra would see a total solar eclipse. In B, the umbra doesn't reach all the way to Earth; an observer on Earth near the point of the shadow would see an annular eclipse. In C, the shadow reaches to but just misses Earth; here, all that would be seen would be a partial eclipse.

If I were to add the penumbra to the above sketches it would make a larger cone that would reach Earth in all three examples.

Here is an illustration of the shadow of the Moon on Earth during a total solar eclipse, taken from the Voyager™ sky simulation software.



The small dark spot is the umbra of the Moon's shadow; the big shaded circle is the extent of the penumbra.

Because the Moon's shadow on Earth is small – just a few km across – and the Earth is spinning while the Moon is orbiting Earth – therefore a solar eclipse viewed from any spot on Earth is a very brief phenomenon. A long eclipse is one where totality lasts three or four minutes as seen from the best possible location. Thus, only a small part of Earth, a strip the width of the umbra and the length perhaps several thousand miles long, is able to see any single solar eclipse. Eclipse enthusiasts often travel far to see this brief event, and are, of course, very disappointed if the weather does not cooperate!

To find out about the next solar eclipse, check out
http://sunearth.gsfc.nasa.gov/eclipse/SEmono

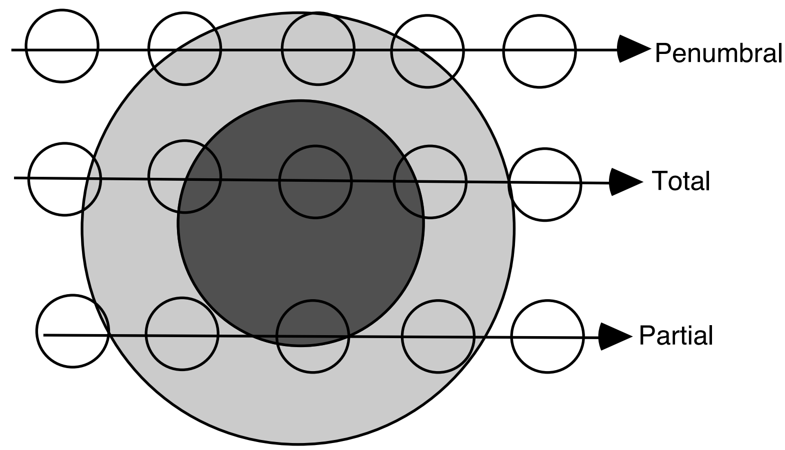
Subunit 2. Lunar eclipses.

If a solar eclipse happens when the shadow of the Moon falls on the Earth, what happens when the shadow of the Earth falls on the Moon? The answer is: A lunar eclipse.

A total lunar eclipse occurs when the Moon passes through the umbra of the Earth's shadow. A partial lunar eclipse happens when only part of the Moon passes through the umbra, and a penumbral eclipse happens when the Moon passes through the penumbra with no part of it reaching the Umbra.

Pause for thought: If the Moon's shadow barely reaches to Earth, is the same true for the Earth's shadow and the Moon? Answer: No, because the Earth is larger than the Moon, so it's shadow is longer.

At the distance of the Moon, the Earth's shadow is still pretty big. This is shown to approximately to scale below.

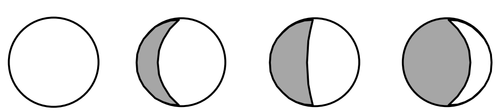


A lunar eclipse is a fairly slow phenomenon, lasting up to a couple of hours. It can also be seen by everyone who can see the Moon, from about half of the surface of the Earth at a given moment.

A Solar eclipse can only be seen when the Moon is new; a lunar eclipse can only be seen when the Moon is full. To see why, continue to the subunit on Phases of the Moon.

Subunit 3: Phases of the Moon.

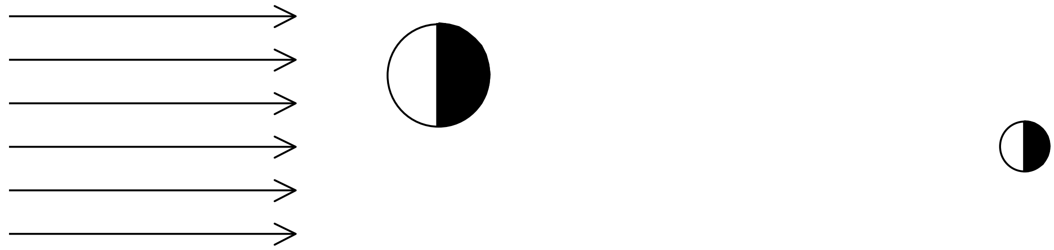
In the activity for this unit you had a chance to sketch what you see when you observe a sphere that is illuminated on one side. What you saw probably looked like these illustrations:



These also look like the full, gibbous, quarter and crescent phases of the Moon, and that is no coincidence!

The Moon is illuminated on one side by the Sun; the other side, the night side, gets no direct sunlight although it may get some light from sunlight reflected by Earth.

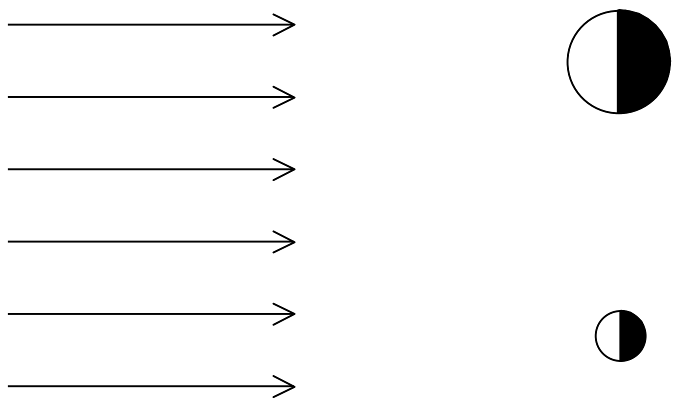
When we see the illuminated side, the full moon, we are looking at the moon from nearly the same direction as the Sunlight comes in:



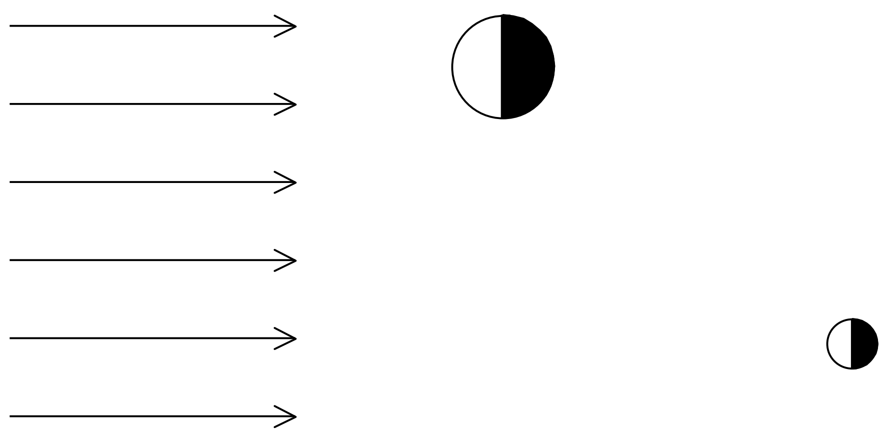
The parallel arrows represent sunlight coming in. The large circle is the Earth, the smaller one is the Moon. One side of each is white to represent the side getting sunlight – the day side. The other side is black for the n ight side.

Pause for thought: Why doesn't the Earth's shadow make the Moon look dark when the arrangement is Sun-Earth-Moon? Answer: This diagram isn't to scale. If we drew it to scale, the Earth-Sun distance would be about 30 times the Earth's diameter. So the shadow of the Earth is very thin and it misses the Moon most of the time.

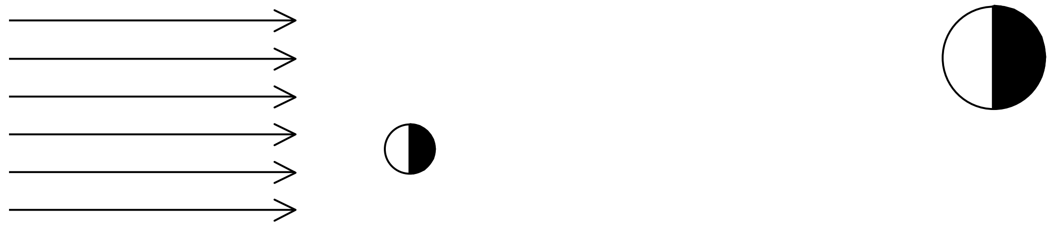
When we see the quarter moon (half bright, half dark) we are observing it along a line that is perpendicular to the incoming Sunlight:



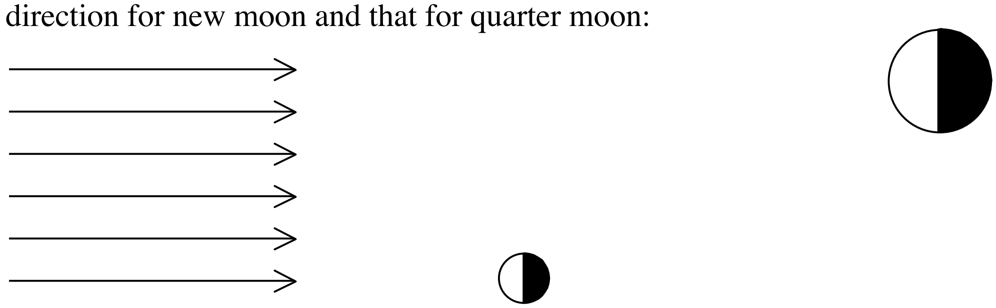
When we see a gibbous (fat) moon, we are between those two positions:



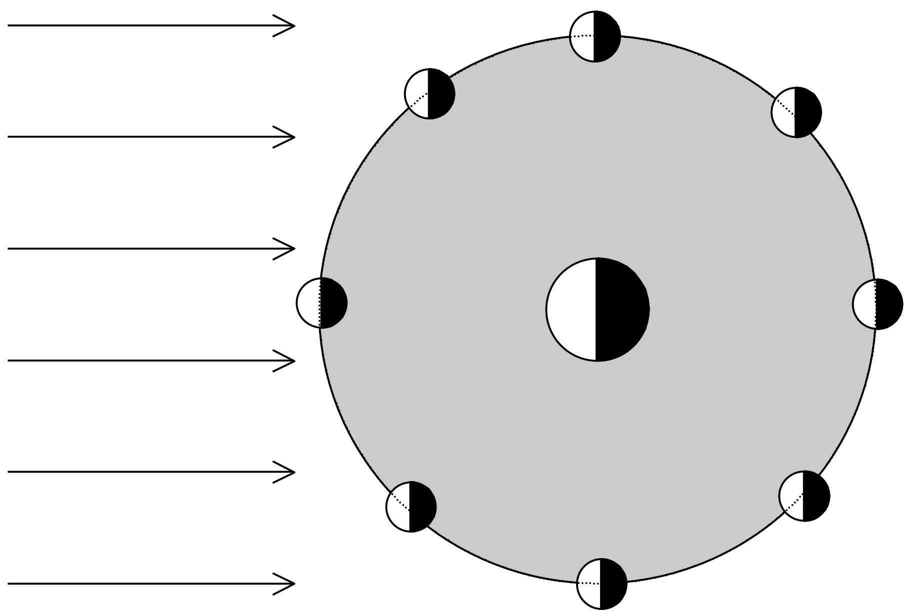
When the night side of the Moon is towards the Earth, then the Moon and the Sun are in nearly the same direction; this is called "new moon".



When we see mostly night side but a small sliver of day-side, then we are between the direction for new moon and that for quarter moon:



We can put all these situations into a single illustration:

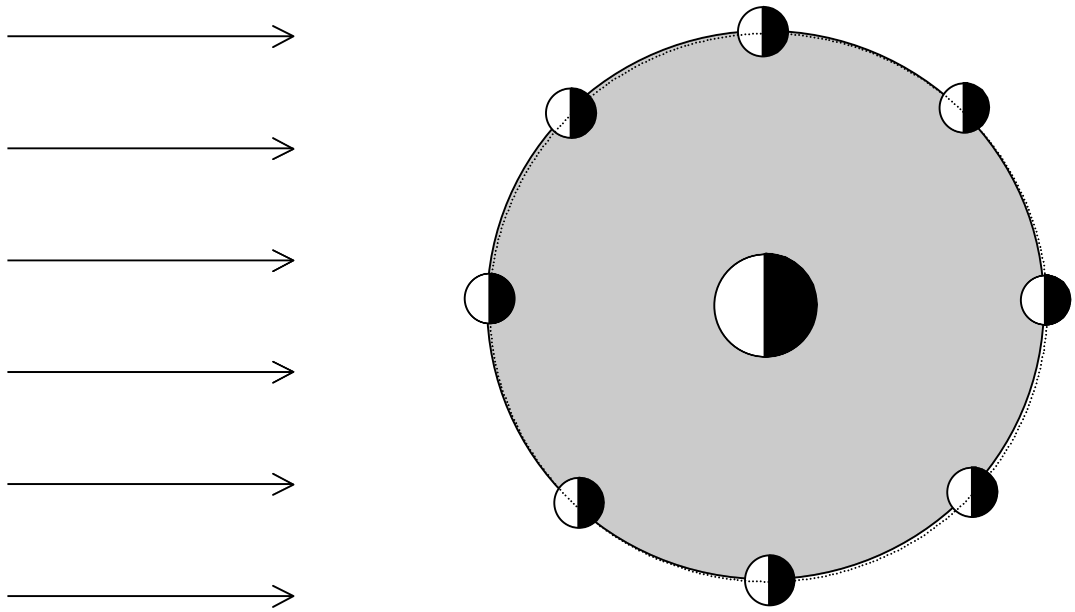


For each position of the Moon, the part within the shaded circle tells us what we will see – mostly dayside, mostly nightside, half and half, and so on.

This illustration explains why we call a half-bright moon a "quarter moon": it is one quarter of the way around the pattern of phases in this diagram.

The Moon goes around the Earth in 27.322 days, as seen by an observer in a fixed location in the solar system. This is the *sidereal period* or orbital period of the Moon. In that same amount of time, the Earth goes 27.322/365.2422 of the way around the Sun.

The result is that the time between one full Moon and the next, or one new moon and the next, is closer to 29.531 days. From full moon to first quarter is _ of this *synodic month* of 29.531 days, or just slightly more than 1 week.

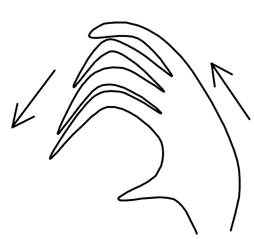


From the above diagram, can you figure out what the phase of the Moon is when there is a total solar eclipse? …when there is a total Lunar eclipse?

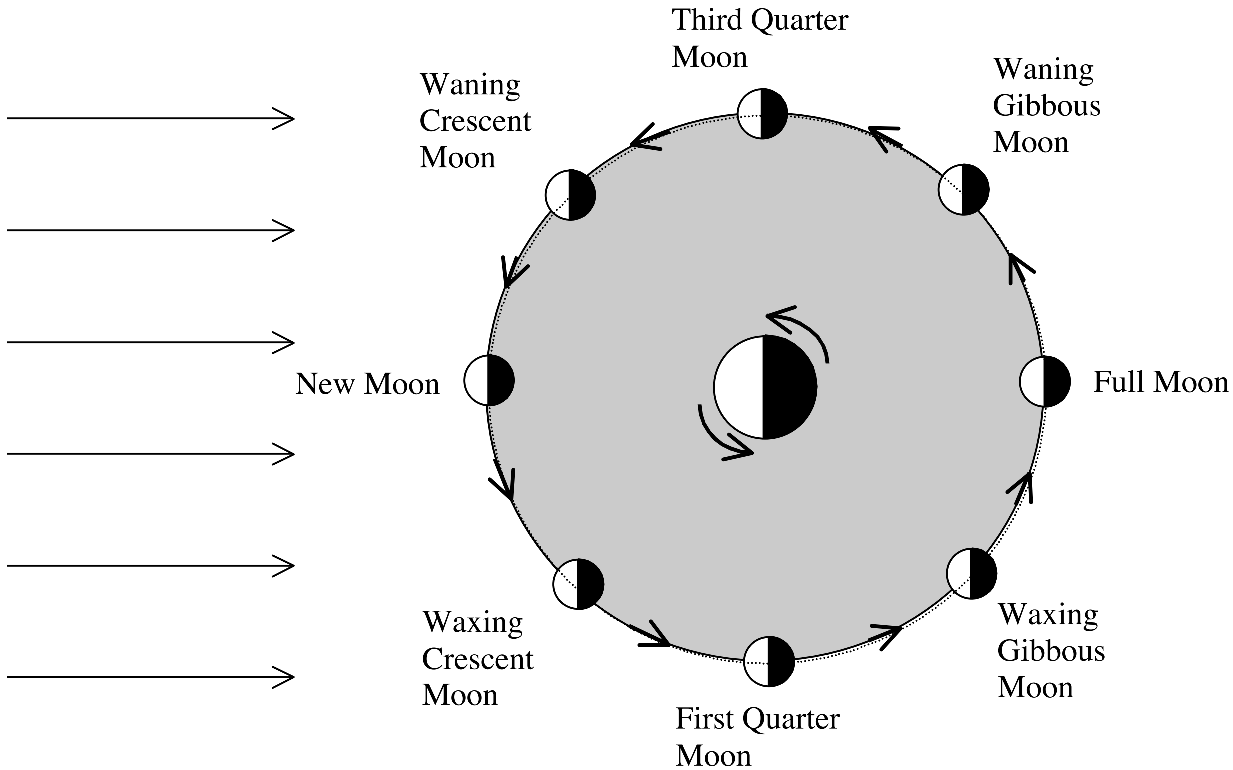
There are two eclipse seasons per year – two months six months apart during which any solar or lunar eclipses will occur. Why don't we get eclipses every month? Answer: Eclipses require the Earth, Moon, and Sun to be lined up very precisely – within _ degree for a solar eclipse and a somewhat wider tolerance for lunar eclipses. The orbit of the Moon is tilted about 5 degrees compared with the plane of Earth's orbit around the Sun, so only twice a year is the Moon near this plane – the "ecliptic", meaning where eclipses occur – at the right phases (full and new).

Subunit 4. Relating phases of the Moon to times of rising and setting.

One fundamental fact will let us relate the phases of the Moon to the times when we may see it in the sky. That fact is that the orbital motion of the Moon and the Earth's rotation (spin) are both in the same sense. This means: If we picture the Moon going counterclockwise around the Earth, then the Earth is also turning in a counter-clockwise direction. This is what you get from taking your right hand, pointing the thumb at your nose, and seeing where the fingers are pointing; the right thumb is the north pole of Earth, in this illustration.



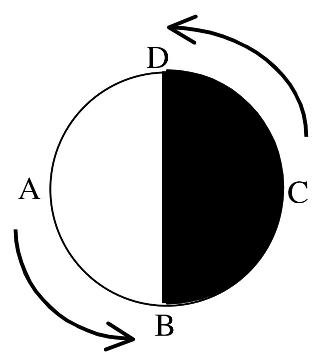
Adding this information to the general moon phase diagram from the last section gives this useful version:



From the above diagram, can you figure out the meaning of waxing, waning, and gibbous?

Answer: Waxing is growing bigger; waning is growing smaller, or shrinking; gibbous is fat but not quite full moon.

Now consider Earth, shown here again:



A person at B is moving from day into night; that would be sunset. A person at D is moving from darkness into light; that would be sunrise.

A person at A is halfway from sunrise to sunset; for A, the time of day is noon. A person at C is halfway from sunset to sunrise; for C it is midnight.

Comparing this picture with the moon phase diagram, can you answer these questions?

1. For an observer at C = midnight, where is the full moon?

Answer: High in the sky.
2. For an observer at A = noon, where is the new moon?

Answer: High in the sky, near the Sun.

3. For a full moon: Which observers can see it?

Answer: B, C, and D.

4. Therefore, what time does it rise and set?

Answer: A full moon rises at sunset and sets at sunrise (approximately – for details, see the Northstar course).

5a. Which observers can see the first quarter moon? So when does it rise and set?

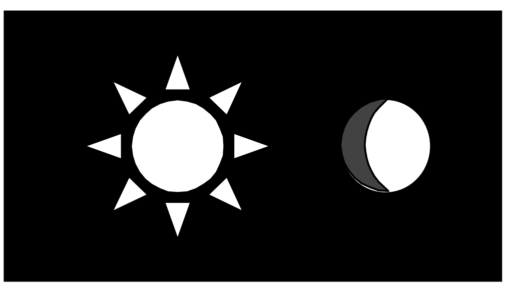
Answer: A, B, and C; it rises at noon and sets at midnight.

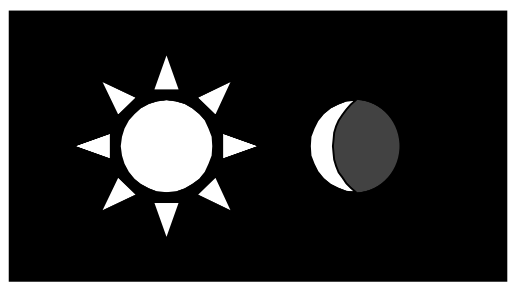
5b. Would you look for a waxing crescent in the evening sky or the morning sky?

Answer: A waxing crescent will set between sunset (when the new moon sets) and midnight when the first quarter moon sets.

Now for a bit of a challenge:

Can you tell me which of these pictures is correct, and what is wrong with the other one?





Answer: The bright part should be the part that is in sunlight, and that is true only for the picture to the right.