Harvard Misconceptions/Lunar Phases

I would like to show you a couple of demonstrations before I begin the main lesson. That is why I have all this "stuff" right here in front of me. The first thing I want to show you is a concept regarding electromagnetic radiation. Electromagnetic radiation represents all the different wavelengths of light—all of the different energy wavelengths that travel at the speed of light. The electromagnetic spectrum is composed of gamma rays, X-rays, ultraviolet radiation, visible light, infrared, microwaves, and radio waves. All wavelengths, all of the different types of radiation in the electromagnetic spectrum travel at the speed of light. What the first demonstration reveals to us is that electromagnetic radiation can penetrate or pass through objects.

What I have in front of you is called a Plasma Ball. There is a high voltage potential in the center of the unit releasing radio waves. The glass ball is evacuated so that it is under a slight negative pressure, certainly not under the pressure of one atmosphere like we are in this room. There are other gases such as argon, krypton, and neon which are infused within the glass ball which are more conducive to conducting the electromagnetic radiation along with electrons through the medium and causing excitation of the gases which form the plasma.   You are seeing the ionization or excitation occurring along the strands of light moving towards the glass boundary.

But the other concept about the radiation permeating through the medium is that it is continuing through the glass and carrying electrons with it beyond the glass into the room. I can prove that with this fluorescent bulb that I am going to bring close to the plasma ball. I will however not touch the glass sphere.

Watch the light fluoresce (glow) in the tube. Can you see that it is beginning to glow? Magic, right? And if I get closer, the fluorescent bulb glows even brighter. The older fluorescent lamps had mercury vapor in them. Ultraviolet light was being produced inside the bulb or tube. An electric current fluoresced/excited the mercury gas inside the tube producing invisible ultraviolet radiation. This UV radiation impacted into the phosphorus material which was on the inside of the bulb or tube causing the phosphorus coating to glow. That is what you're seeing right here, however, I don't know if the gas inside of this tube is Mercury anymore, but I can tell you without any doubt, and you can see this for yourself that the radiation being produced along with the electron stream exciting the gas is traveling beyond the boundary of the plasma ball. Some types of electromagnetic radiation can pass from one medium through another medium carrying, in this case, electron with them. In its extreme, if you ever had the misfortune of seeing a thermonuclear device explode from several miles away, I would simply go out and enjoy the blast. Gamma rays would zap right through your body destroying the inner workings of your cells and causing a rapid death in perhaps as short a period as a few days.

I think this next demonstration is one of the most interesting demonstrations that I have ever seen. The professor that I replaced here at Moravian, Dr. Joseph Gerencher, performed this experiment when I was auditing his class during his last teaching semester at the University. I remember saying to him after class that I needed this devise so I could demonstrate it to my high school students. Joe graciously allowed me to borrow it. The following day when I performed the experiment in front of my students, they went absolutely nuts. They couldn't believe what was actually happening. I call it the *Fahrenheit 451* demonstration after Ray Bradbury's book by the same title. In the society about which Bradbury writes, firemen set fires rather than put them out. The combustion temperature for paper, wood, etc. was 451 degrees Fahrenheit.

I have a plunger. Before I do anything with it, you may have noticed, that I placed a piece of cotton on the top of this little metal cap. I'm going to put the tube down on top of the cap and place the plunger into the tube. I will then push the plunger down very, very rapidly. The air inside the tube is going to be squeezed. When a solid liquid or a gas is squeezed, its temperature goes…? UP! The air inside the tube gets very hot, very quickly. Most people don't know that fact. An analogy is bouncing a ping-pong ball on a table, then forcing it downward with your hand or a piece of cardboard. The ball bounces faster and faster. As I constrain the air inside of the tube, the ping-pong balls, molecules of air, bounce faster and faster, raising the temperature inside of the cylinder.

If I squeeze the gas by depressing the plunger, I am imputing energy into the system causing the molecules of air to vibrate much faster. The kinetic energy of motion of the particles ($1/2mv^2$) is actually what we are measuring when the temperature is taken. "M" is for the mass of the air molecules and the “v” is for the velocity of the particles. The mass does not change, but the velocity does. Squaring the velocity causes the energy of the system to ramp up very rapidly when the plunger is rapidly depressed. Believe it or not, the temperature rises to the point where the energy is great enough to cause the combustion of the cotton on the metal stand.

The key is to really slam the plunger straight down.

Whoosh… bam… light my fire! It worked.

The concept in physics is really simple. If I take a solid, liquid, or gas and I compress it, the temperature goes up or down? Up is correct. If you can remember that one little fact, you'll see so many applications for its use in life. As an example, in meteorology (weather) air descends in a high-pressure system. Highs are always noted for good weather. As the air descends, it is compressed under the descending air above it and the air warms. High pressure systems are not conducive to precipitation where you need to have cooling and the condensation of water to form rain.

Several years ago, I had an older student probably in his 40’s who didn’t believe the experiment was real. He said it was simply “magic.” He asked me if I would use some other material to ignite the material on the metal stand. I said “sure” with a big smile not knowing what would come next. He had a sweater with a few tiny pillows of lint on it. He took a couple of those off and as he was doing that, I said to myself, “Oh thank god.” I thought maybe he would simply give me a small piece of paper, which would have made the demonstration more difficult because of the higher density of the paper. It is better to have the air readily mix with the material that is to be combusted.

So, I joyously put the lint pillows onto the metal stand, set the plunger into the tube, and plunged. A huge, bright flame shot up the tube in a fiery burst of light. It was a really, a wonderful demonstration. I convinced him that it was a principle of physics and not simply magic that made it work. Had he given me paper the demonstration may have remained magic in his eyes, because I don’t believe it would have worked.

In the next demonstration, I will give you a concrete example of the principle of refrigeration or air conditioning. I am going to take a liquid and cause its rapid expansion into a gas. In the process, energy will be removed from the liquid as it rapidly expands into a vapor. The resulting gas will feel very cold. As a solid, liquid, or gas is made to expand, its temperature goes down.

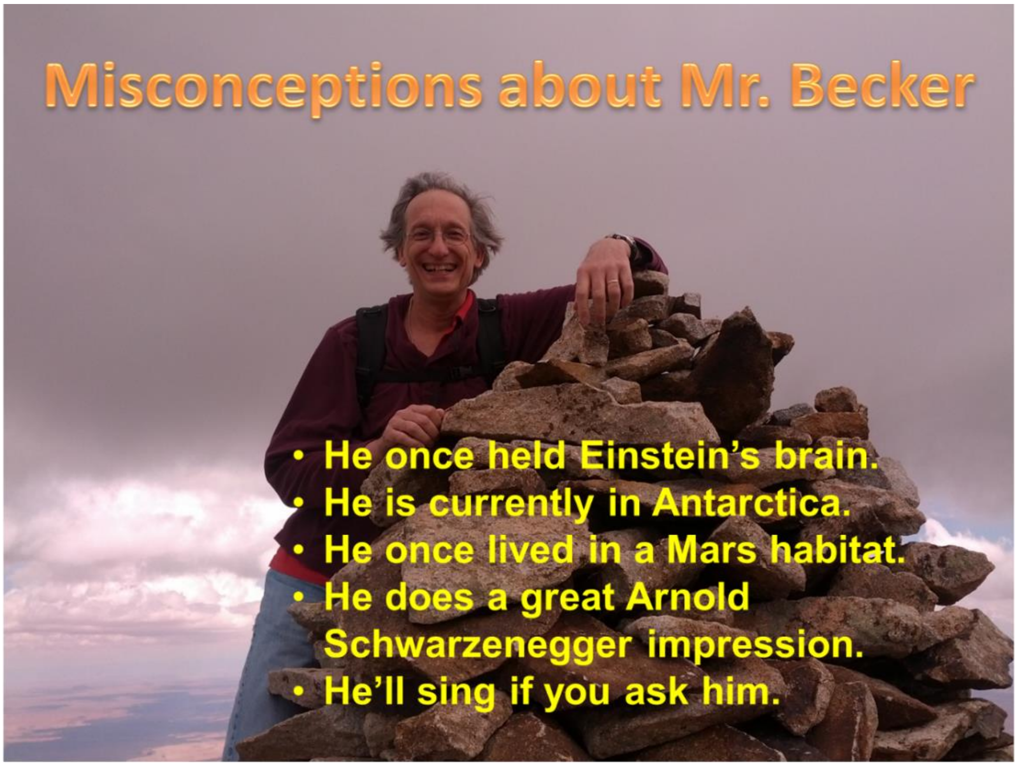
I have a can of air. I'm going to let the liquid propellant escape and expand into a gas by inverting the can. As the propellent escapes, it will rapidly expand changing into a gas. Hopefully the temperature of the gas will be cold enough so when the air hits your hand, a patch of short-lived frost will be produced before you hand falls off.

After the demonstration, the hands are collected and donated to the anatomy professor for instructional use.

In this next demonstration I would like to exhibit the properties of a field with these two strong elongated ceramic magnets. A field is a force which goes beyond the matter that is creating it. The one magnet is held in the hand of the instructor as it is moved over the magnet on the table. The magnet on the table can be made to move around and twirl indicating some type of field (force) is emanating from it which can influence the other magnet.

These demonstrations of some basic principals in science can be applied astronomically but they also apply to everyday life.

Popular Misconceptions in Astronomy



A number of years ago, in 2013, I was ill for the start of the fall term. A very good friend of mine, Peter Detterline, substituted for me during the first two weeks of classes. He was my student teacher back in 1981, and afterwards, we became very good friends. He's also incredibly interested in astronomy. Pete introduced himself to his students as Gary Becker and taught the first two weeks as Mr. Becker. At the end of his time at Moravian, he projected this slide of me on top of a cairn at the summit of 11,000-foot Mt. Ellen in central, eastern Utah. Pete admitted to the students that he really was not me. There was an older woman taking the class who did not believe him. She was insistent that Pete was really Gary. In fact, she admitted that she had taken the class because of the *StarWatch* articles that she was receiving. At that time, they were distributed to the entire Moravian community. Pete, finally had to get out his wallet and throw his driver's license in front of her to convince her of this fact.

The class during the two weeks that Pete was their instructor was under the misconception that he was really Gary. When they were told that it wasn't so, several students could not believe that they had been duped by their instructor into believing a misconception had occurred right there under their noses. He presented this particular slide to highlight the concept of misconceptions while introducing me to the class.

A misconception is a fact that you unquestionably believe with the whole fabric of your being, but is totally FALSE.

I'm sorry that I have to go back to the last century, but I was born in 1950, so the 60’s and 70’s were the springtime of my existence. I think it was in May of 1994, when a videographer at Harvard University went around to graduating class members and asked 23 individuals (mostly students, and a few professors) this very simple question. What causes the season? They were expecting, because it was Harvard University, to have a majority of students and teachers answer correctly. It came as a shock to them that 21 of the 23 students and professors who were asked that question, got it wrong. That got Harvard thinking about misconceptions and how people actually perceive the world around them. They created this misconceptions test, which hopefully you completed over the past week. When it was published a few years later, some of the answers were so inane that I was forced to change them improve the quiz.
In the original quiz, Harvard students got one or two answers correct out of the 10 questions that were posed. In my high school classes at Allen and Dieruff, my average was three to four answers correct. When I came to Moravian University, I continued teaching these misconceptions as well as others that I thought were important, beefing up the quiz yet again. Most of my college classes have been getting fours and fives which has made me very happy.

Let’s go through the quiz. If you think a certain statement is correct as I read the possibilities, slap your hand on the tabletop. Psychologists say that a misconception takes something like 5000 reinforcements in order to be able to get it completely out of your mind. I am going to posture that we're relatively intelligent people. My thought is by examining the answers and the reasons for these answers, you will see improvements in your comprehension of astronomy information.

So, let's start get started with the first question.

1. One night we looked at the moon and saw:

A few days later, we looked again and saw this:

What do you think best describes the reason for this change?

a. Clouds block the moon.
b. The moon moves into the sun's shadow.
c. The moon moves around the Earth.
d. The moon passes the planets and goes in and out of their shadows.
e. The moon moves into the Earth's shadow.
f. The moon is black and white and rotates.
g. The Earth moves around the moon.

The correct answer is the one for which most of you slapped the tables. The moon moves around Earth. What is really happening when the moon moves into the Earth's shadow (lunar eclipse)? The moon is black and white and rotates. That is actually a true statement, but it has nothing to do with the question being asked.

As we are watching the moon change its shape, meaning the part of the moon that is reflecting light from the sun, we are simply watching the moon proceeding through a day and night cycle—day and night on the moon. It takes about 29-1/2 days for this to occur which is very close to a month. In fact, month and moon are related. We will demonstrate the lunar phases later in this class as well as lunar and solar eclipses.

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You better get this next statement correct.

2. What causes night and day?
   a. The Earth spins on its axis.
   b. The moon blocks out the sun's light.
   c. The sun goes around the Earth.
   d. The Earth moves around the sun.
   e. The Earth moves into the sun's shadow.

You are correct, it is simply the spinning of the Earth around its axis that causes day and night. If I stand with the light of the projector shining on my face, all I have to do is begin rotating (spinning) to create a day and night sequence.

I used to teach this lesson to first graders? I would normally have two classes, about 50 students in front of me at a time. They would later come to the Allentown School District Planetarium in the same groupings. It would take me about one hour to teach that concept to the excited students in the classroom.

We would have an earth, and I'd give the kids a 2500-watt lamp, actually a 25-watt protected lamp. I wasn't that cruel. I'd ask what causes day and night? The kids would come up and move the sun around the Earth or turn the lamp on and off. We would have a lot of clapping and a lot of cheering. I'd say, "Great idea (everyone would cheer), but I am sorry to say that your answer is incorrect. That is not the way it happens. We need to try it again." The kids would continue to volunteer and cheer even if the answer was incorrect until eventually one student would be holding a lamp and say to me, "I can't do it by myself. I need your help." "What do you mean," I'd say. "Would you hold the lamp," the child would ask, and I would take the lamp. The child would then walk over to the Earth and start turning it. That got the biggest round of applause because it was the correct way to demonstrate day and night. It was a very big breakthrough which the children would remember. After that we would play Simon says day and Simon says night, and the kids were the Earth. The teacher would hold the lamp, and the first-graders would have to rotate, counterclockwise into the correct position.

So how long does it take the earth to complete one rotation, not how long is the day? Twenty-three hours, 56 minutes a student eventually responds.

Twenty-three hours 56 minutes 4 seconds is the exact answer. For some reason, everybody remembers those four seconds. So, you are saying to yourself, that doesn't make any sense because that clock over on the northern wall of this room indicates it takes 24-hours to complete one day. A day and the period of Earth's rotation are two related, but different concepts.

Let's use a planetarium program with the computer. We are pretending that you are standing in a field with the sky all around and above you. We will increment 23 hours, 56 minutes, four seconds, which is the sidereal period (sidereal day) of the Earth and is equivalent to one Earth rotation. Can you see on the screen the yellow dot which represents of the sun?

The sun is here on this dotted line which is the meridian, a great circle that goes from the south point, up through the zenith, and continues to the north point on the horizon. It divides the eastern sky from the western sky. That is a vocabulary word which you had to know for the quiz. Everybody has a meridian when you go outside to observe the sky, because everybody has a north and south point, as well as a zenith position. The only place where that would not happen would be at the North and South Poles, where you only have one true direction. Think about that! I want to let one day—twenty-four hours go by. If I let one day pass, the sun will return to exactly the same location—the meridian.

Okay, the sun remained to the same position. I'm going to now switch to 23 hours 56 minutes. Can you see what's going to happen? Each time I increment that period, the sun is slowly going to start moving eastward by about one degree each sidereal-rotational interval. The sun is going to come up to, but not quite reach the meridian which takes 24 hours to occur. If I want to bring the sun back to the meridian, I have to let the Earth rotate essentially one extra degree. That adds four minutes to the sidereal day giving us the solar day which is equivalent to what happens on a 24-hour wall clock.

Why did the sun move to the east in exactly one Earth rotation? It was because the Earth was revolving at the same time. What is a synonym for revolving? Circle…? But better yet, to orbit is to revolve. **<u>Rotation</u> is to <u>spin</u> as <u>revolution</u> is to <u>orbit</u>.**

How many degrees are there in a circle? Three hundred, sixty (360) degrees is correct. How many days are there in a year? Be careful. Three hundred, sixty-five (365) or 366 is exactly correct. Do you think the number of days in a year and the number 360 are related to each other? What's your gut feeling telling you?

The Egyptians had a year with 360 days and five festival days equaling 365 days. The year and the degrees in a circle are intimately related to each other. Since the Earth revolves or orbits the sun in a year's time it must be moving about one degree each day. Yes, some days it's a little more and some days it is a little less, depending upon whether the Earth is closer or farther away from the sun. But, can you get the feeling that in order to get around the sun once during the course of year, the sun has to be moving about one degree per day? Hopefully, that makes sense. The Earth moves one degree in its orbit each day and that shifts the sun by exactly the same amount to the east each day. If we do not correct for this eastward movement of the sun in a sidereal period, 23 hours, 56 minutes, 4 second by adding essentially four minutes to the sidereal day, the sun would eventually move off the screen to the left, or eastward.

What we want to do is bring the sun back to the meridian every day, because we want to have some uniformity in our timekeeping structure. We want to have the sun crossing the meridian every day at the same time. Actually, in reality, it is a fictitious sun moving uniformly on the celestial equator that creates the time interval of a day, but for this exercise the real sun is close enough. We want the real sun to be on the meridian, due south, as high as it can go in the sky for that day, at 12 o'clock noon every day. That varies a little bit during the course of the year because of the Earth changing orbital speed, but nothing that is more than 16 minutes off from where the real sun should be in the sky.   **In conclusion, the day is 24 hours, the**

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Earth's rotational period is 23 hours, 56 minutes, four seconds.

How long does it take the Earth to revolve around the sun? Be careful again. Close to a year is correct, but not accurate enough for this class. Three hundred, sixty-five and a quarter day comes a response. Actually it's 365.24 days to get around the sun, but I will certainly accept 365.25 days. How many days are there in a year? Three hundred sixty-five or 366 days. Can you see that it would get really bitchy if we put a quarter day into the calendar mix? But in all honesty, we really have to input that time increment into the calendar, to keep the Earth’s position with respect to the sun in step, but we only do it only once every four years.

We give the Earth a task to finish, which is to orbit the sun. It takes 365.24 days to complete, but we only give the Earth 365 days to accomplish this task. Does the earth complete a full circuit around the sun in a year? No, it is impossible! The first year Earth is a quarter day behind; the second year it is a half day behind; the third year Earth is three quarters of a day behind; the fourth year, the time interval adds up to one whole day. What do we do to bring the Earth in step with the sun? We add a leap day to the calendar, February 29, and all is well. The last leap year happened in 2020 and will occur again in 2024 and 2028. The year has to be divisible by four, without a remainder attached to it for a leap year to occur.

That almost corrected the calendar, but it was still not good enough. The calendar with 365.25 days in it is known as the

Julian calendar. It overcorrected the time interval of one Earth orbit because that calendar allowed 365.25 days for a complete revolution. What was happening was that Easter and Christmas were coming closer together.

If you're a Christian or you know anything about Christianity, then you understand that Christmas celebrates the birth of Christ and Easter is day of Christ’s resurrection. You really do not want to have them occurring at the same time of the year. This is what became evident to the Catholic Church. Christmas and Easter were getting closer together. You can't have Christ born and then die two weeks later. You have to give the Church liturgy a little chance to go through all of the necessary steps to move from the birth of Christ to his death and resurrection.

How can I prove this? Today there are Christian sects, such as the Russian Orthodox and the Greek Orthodox churches that follow the original Julian calendar formulated in Rome and inaugurated in 45 BC. These churches continue the 365.25-day tradition in calculating one Earth revolution. They use the more modern Gregorian calendar that contains 356.24 days for civil functions—meetings times, governmental business, etc., but fall back to the Julian calendar for religious traditions. The date of Christmas according to the Julian calendar corresponds to January 6 on the more modern Gregorian calendar. You can see how Christmas and Easter are drawing closer together.

Easter is based on a whole variety of astronomical events. It is the first Sunday after the first full moon after the vernal equinox. That is the common rule which will date Easter correctly about

80 percent of the time. Easter is fixed with the season of spring in the Gregorian calendar as it was in the Julian calendar.

The vernal equinox is represented as the first moment of spring. Spring occurs when the sun crosses the vernal equinox, the position where the celestial equator, the projection of the terrestrial equator into space, intersects the ecliptic, path of the sun. The sun, crossing the vernal equinox happens at a fixed interval.

The actual rule for Easter is the first Sunday, after the 14th day of the moon, on or after the 21st of March. Using the Gregorian calendar, the date of Christmas will be also be fixed to the season of the year as it was occurring in antiquity (early winter) while the date of Easter remains fixed with respect to the equinox. Christmas and Easter will never collide.

The Julian calendar was inaugurated in 45, BC by, Julius Caesar of Rome, the most powerful country in the world at that time. Caesar, was having an affair with Cleopatra, who would become the last Pharaoh of the Ptolemaic era in Egypt. Caesar brought Cleopatra to Rome, and with Cleopatra came her royal astronomer, whose name was Sosigenes. It was Sosigenes who develop the Julian calendar which was based on the sun rather than the period of the lunar phases (lunar calendar) that the Romans had been using for centuries. Supposedly, Cleopatra was in Rome when Caesar was assassinated on March 15, 44 BC. Cleopatra was desperate to align herself with Rome because she did not want Rome to conquer Egypt. When Caesar died, Cleopatra returned to Alexandria in Egypt. She eventually allied herself with Mark Antony (Second Roman Triumvirate) with the same goal, but when they lost the battle of Actium on Sept. 2, 31 BC, to Octavian, Cleopatra retreated back to Alexandria where she committed suicide the following year.

It is safe to say that if we didn't have astronomy to regulate time, and the calendar, the world would be in constant chaos. Astronomers bring us the ability to record the day and hours of time based on Earth's rotation and the year based upon the revolution of our planet. Timekeeping and the creation of a calendar are benchmarks of a civilized society, and astronomers in large part are responsible for that.

Alright so, eight hours later, they had only completed question two. Here is question three.

3. True Story: On October 17, 1604, Johannes Kepler went outside, looked up, and saw a bright new star in the foot of the constellation of Ophiuchus the Serpent Holder, what astronomers call a supernova. When do you think the star exploded?
   a. Before October 17, 1604.
   b. On October 17, 1604.
   c. After October 17, 1604.

True story… On October 17, 1604 Johannes Kepler when outside and looked up. Oh, who's Kepler? He was a German astronomer, that was living at the time when there was a great controversy going on in science as to whether the Earth revolved around the sun, or the sun orbited the Earth. Obviously the heliocentric (sun centered) theory was proven correct over the geocentric (Earth centered) model, but during the time of Kepler there was a lot of resistance to change in educated circles regarding early Greek philosophers and the Church. The ancient Greeks such as Plato and Socrates believed in a stationary Earth about which the sun orbited. Kepler believed that the Earth revolved around the sun, in other words, Kepler believed in the heliocentric theory.

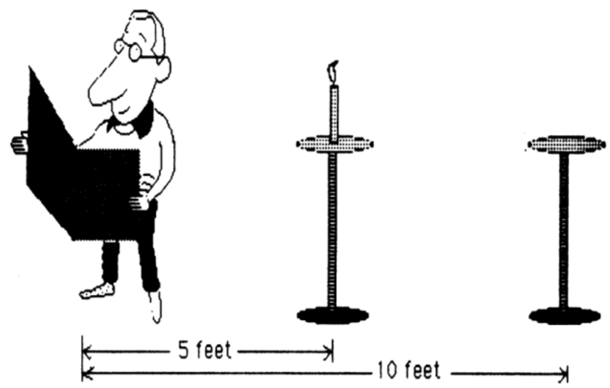
The prevailing theory considered by the Catholic Church at that particular time was to agree with the geocentric theory, i.e., the sun orbited the Earth. Mathematicians like Kepler and Galileo were coming to the conclusion from their observations and mathematics that the heliocentric theory was correct. This was a new concept for Renaissance Europe at that particular time. It should be noted that the Greek, Aristarchus of Samos (310-230 BC) did believe in a heliocentric model of the universe, but this school of philosophy lost out later Greeks who believed in a geocentric model and that all problems of humanity could be resolved through thought and contemplation rather than through experimentation.

Kepler went outside on October 17, 1604 and he saw a new star, one that has not been seen before. This was a big event because the prevailing thought concerning the geocentric model was that the heavens were immutable; they could not change. A new star becoming visible, a supernova, where no star was discernable before was another foot in the grave for the geocentric system.

Returning to the question. Did the star explode before October 17, 1604; on October 17, 1604; or after October 17, 1604. You are correct, definitely before October 17, 1604. Modern observations have positioned the star about 20,000 light years distant from the sun. It took about 20,000 years for the light from that exploding star to reach Johannes Kepler's eyes so he could realize that a new star had actually become visible. Kepler did not know the distance to the star, only that it appeared in a sky that the geocentric model stipulated was unchangeable. We know the supernova’s distance today because we can see the remnants of that event and can make astronomical measurements based on an angle-measuring system called parallax, which is very similar to surveying.

Question four…

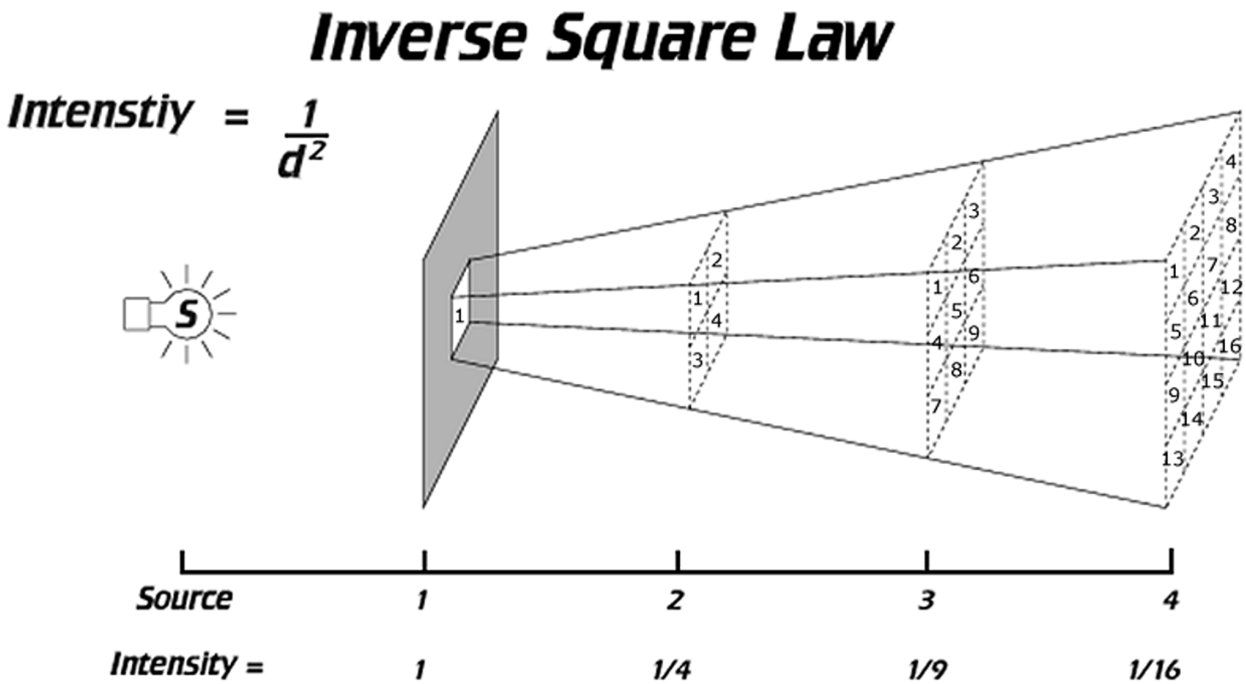
4. The man is reading a newspaper by the light of a single candle five feet away. Indicate the number of candles necessary to light up the paper to the same brightness, if the candleholder was moved to a distance of 10 feet from the newspaper.
   a. 1 candle   d. 4 candles
   b. 2 candles   e. 5 candles
   c. 3 candles   f. more than 5 candles



A man is reading a newspaper by the light of a single candle five feet away. There's your unit distance. Make that a relative distance equal to one. Indicate the number of candles necessary to light up the paper to the same brightness if the table were moved to a distance of ten feet. In other words that would be a relative distance of two units. We are doubling the distance.

Four candles are the correct answer. This can be ascertained using the inverse square rule. Intensity is equal to one over the distance squared ($I = 1/d^2$). Here, five feet is going to be equal to one unit of distance and 10 feet will equal two units of distance. At a unit distance, intensity equals 1 over 1 squared ($I = 1/1^2$), which is equal to one over one which is equal to one—

one unit of intensity. Ten feet is equal to two units of distance. If we solve this equation in relative units the intensity will be equal to one over two squared ($I = 1/2^2$) which is equal to one over four. Intensity is equal to one over four or one fourth the brightness at a distance of 10 feet or two units of distance. To attain one unit of brightness, I need to multiply ¼ by 4 to equal one. It will take four candles at a distance of 10 feet to equal the same brightness of the single candle at five feet.



In the next slide illustrating the inverse square law, we have the light source at a unit distance away from a square aperture, which has an opening of one unit by one unit. The light is coming through that aperture at a unit intensity as it continues to spread outward after passing through it. At two times the distance, the square created by the original aperture (opening) happens to be four times the area. This means that each one of these unit squares must have only one quarter the intensity of the strength of the light coming through the original aperture square. If we move to three units of distance away, the square then becomes three times three or a total of nine units of area. Each square has a brightness of 1/9th the original illumination that came through the aperture. If I go to four units of distance away the intensity of each square become only 1/16 the original brightness. I would need 16 times the light intensity of each square to equal the intensity of illumination transmitted through the original opening.

A more practical situation might be the intensity of sunlight at Jupiter's distance as compared to the intensity of the sun's light at the Earth's distance from Sol. Would the sun be brighter or dimmer? We can quantify that. The intensity of sunlight falling onto Jupiter is one over five squared ($I = 1/5^2$ or 1/25). Where does the five come from? Earth is one astronomical unit from the sun, 93 million miles distant, and Jupiter is 5.2 AU from Sol. I'll use 5 AU because we can perform the calculations in our heads. So, what is five times five? Twenty-Five is correct. The sun is $1/5^2$ or 1/25 the intensity of what the sun's energy is on the Earth at Jupiter's distance from the sun. Earth receives 25 times more sunlight than Jupiter.

Sunlight at Pluto's distance from the sun, which is about 30 astronomical units, is $1/(30)^2$ or 1/900 as intense. When you read about the intensity of sunlight at Pluto or any planet in a book, you will now know how that information is obtained. Electromagnetic radiation and magnetism fall off with a rate that is proportional to the inverse square rule. So, $1/d^2$ is just one of those equations that can make life more enjoyable and can help you visualize astronomical concepts with a little more precision. I could do the opposite type of problem using the planet Mercury. Mercury is one third of an astronomical unit away from the sun. What's one third times one third (1/3 x 1/3)? One times one is one; three times three is nine. Now I have one over 1/9 or (1/1/9). How many 1/9ths equal the number 1? There are 9, 1/9th in the number one. The sun is nine times brighter at Mercury’s distance from the sun than it is on the surface of the Earth. Mercury receives nine times the amount of electromagnetic radiation than the Earth receives. Pretty cool or hot depending upon how you look at it.

Around the time of Isaac Newton (1643-1727), the concept of gravity varying as the inverse square of the distance was something that scientists considered to be correct, but had not yet proven. Newton was able to quantify gravity; he was able to show how gravity’s force varied with distance. He too believed that the inverse square rule was valid for gravity. He also felt that the force of gravity went beyond the boundary of the Earth and went about proving it. The idea supposedly originated when Newton was sitting underneath an apple tree at his manor (farm) house in Woolsthorpe, England and saw an apple fall from the tree. He considered whether the Earth’s gravity that pulled the apple to the ground was the same force that caused the moon to revolve in a closed orbit around the Earth. Newton proved that it was so. Historians don’t know whether this story of the apple falling from the tree is true or a myth because it was told by an individual 70 years after Newton’s death.

What is even more remarkable in my mind is that to prove the case of the moon being influenced by Earth's gravity, Newton had to invent a new type of mathematics. You've heard of the dreaded calculus? Newton along with a German mathematician Gottfried Wilhelm (von) Leibniz (1646-1716) independently invented Calculus. You have got to admit that Newton was intelligent, in fact perhaps the most brilliant person to have ever have lived on Earth. In his calculations, Newton invoked the inverse square rule with respect to how gravity varied with distance and it turned out to be correct. In his first calculation of the orbit of the moon, he found that observations and theory matched pretty nearly so, but as he continued reworking this problem throughout his life, Newton was able to refine it, and its solution became closer and closer to what we calculate today. The inverse square rule works for gravity and it works for electromagnetic radiation. I think it is much more noteworthy equation to memorize than $E = mc^2$. Yet, everybody just seems to know Einstein's famous equation, so you may as well add one more mathematical asset to your repertoire.

Here comes the next question.

5. What causes the seasons?
   a. The Earth's distance from the sun...
   b The Earth's axis flipping back and forth as it travels around the sun…
   c. The sun's motion around the Earth…
   d. A tilted axis pointing in the same direction…
   e. The shifting seasons on the Earth…
   f. The change in the amount of daylight…

That last statement (f), I have no idea why Harvard put that into the quiz, but I'm glad you realized that it was incorrect. "D" is correct.

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When is the Northern Hemisphere closest to the sun? Generally, Earth reaches perihelion (closest position to the sun) in its orbit on the second or the third day of January each year. The word perihelion comes from the Greek; peri meaning close and Helios from the Greek word sun. We are farthest from the sun around Independence Day, July 4, but it can also be the 3rd or 2nd of July too. It's easy to see that the seasons have virtually nothing to do with Earth's distance from the sun. Most Americans do not know this fact as it was demonstrated by Harvard students. Ask your friends and family about the seasons. I'll bet they get it wrong.

However, if you lived in Australia, summer would occur when the Southern Hemisphere was closest to the sun because the season are opposite to those in the Northern Hemisphere. I spent a month in Australia in February of 2000. It's just a wonderful place, very friendly people, but a lot of weird animals, insect, and particularly spiders.

Since the Southern Hemisphere is closer to the sun when summer occurs, why does this area of the world not record the highest temperatures? If you look at the Southern Hemisphere you will see that most of it is covered with oceans. The water has a very high specific heat. In other words, it takes a great deal of energy to raise the temperature of water and that is the Southern Hemisphere's saving grace. The excess energy received during the summertime is absorbed by the water keeping the Southern Hemisphere actually cooler than the Northern Hemisphere.

Let me go on to the next question.

6. Which answer goes from smallest size to largest size?
   a. sun < Earth < moon
   b. Earth < moon <sun
   c. moon <sun < Earth
   d. sun < moon < Earth
   e. Earth < sun < moon
   f. moon < Earth <sun

The last lineup, moon-Earth-sun is correct. The moon is about 2000 miles in diameter, the Earth is about 8000 miles in diameter, and the sun is about 864,000 miles in diameter. The diameter of a sphere can be represented by a straight line moving from the surface of the sphere, through the center of the object, to the surface on the other side.

Next question…

7. What time could it be if you saw a thin crescent moon near the western horizon?
   a. sunrise
   b. noon
   c. anytime of the day or night
   d. sunset
   e. midnight
   f. not possible

Totally impossible was the reply from a student. How could it be impossible? That's my picture of the crescent moon near the western horizon, so it's not impossible. Since the crescent moon is near the western horizon it has got to be around sunset. Note the glow in my picture. The word crescent means to have horns and the horns are at the tips of the crescent. If you take a straight line between the crescent's horns and bisect it, and extend a line segment perpendicular towards the horizon, the line will be pointing in the direction of the sun, which is

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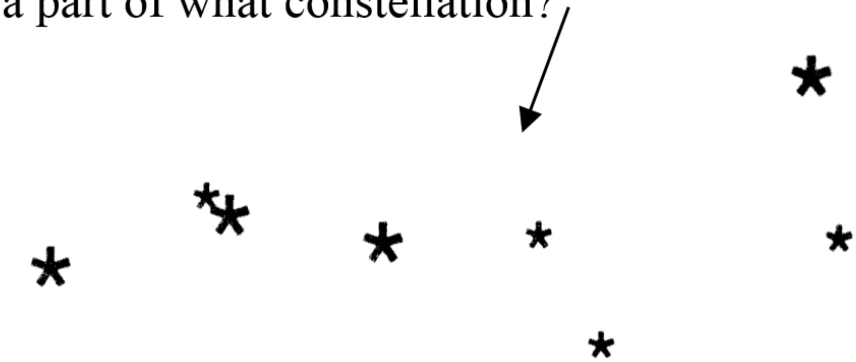
illuminating the moon through the process of reflection. Some of that light is moving across space, 240,000 miles, and going into your eyes. The image is being processed by your brain and you see the moon in all of its beauty. It's a neat little trick to be able to always know where the sun is by just simply noting how the crescent moon or how the other phases of the moon are pointing.

A question was posed as to the difference between sunset (sundown) and twilight, dusk or dawn. Sunset/sunrise is when the sun physically goes below the horizon or rises above the horizon. Twilight is the sunlight still coming above the horizon after the sun has gone down or before the sun has come up in the morning. For our location, it takes about an hour and a half for the sky to become completely dark after sunset, although probably after an hour, 15 minutes it would be difficult to tell the difference because of the copious amounts of light pollution in the sky. In a really dark location, twilight, especially the light of dawn, can be perceived as early as two hours before sunrise. I’ve had that experience when I observed from the Mars Desert Research Station near Hanksville, Utah one of the darkest locations in the continental US.

Question eight…

8. These stars are a part of what constellation?
   a. Orion
   b. Ursa Major
   c. North Star
   d. Pleiades
   e. Big Dipper



Ursa Major is correct. The Big Dipper is not an official constellation, but rather an asterism. An asterism is a group of stars that make a pattern, like a constellation, but it is not recognized by the professional group of astronomers. Other countries and cultures look at the Big Dipper and see something else. As an example, in England it is called the plough (British spelling).

My wife and I had a lovely lunch one time in London at a pub by that name. Pubs are different from bars in America, which have a kind of a seedy connotation. In England, a pub is where people in a local neighborhood come and gather in the evening to have a pint or two of beer with friends. It is more like a place to socialize. There is also food, such as shepherd’s pie, fish and chips, bangers (sausages) and mash, which cannot fail to warm the soul and ward off hunger. I almost exclusively had shepherd's pie when I was in pubs in Great Britain.

To continue, my wife and I were walking down a street in London, I spotted a placard of the Big Dipper associated with a pub. Signage to identify an establishment is one of the very

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interesting aspect of being in Great Britain and Europe in general. During Medieval times, people could not read, so store owners would hang a picture in front of their establishment to convey what was being sold inside. That tradition has continued to the present day even though most people now can read. The establishment was called "The Plough" because in England those same seven stars that we call the Big Dipper in America are called the plough (plow) in England.

It was a done deal that we would have lunch there. When my wife and I entered The Plough, the entire establishment was done in the motif of the Dipper or Plough. The neatly varnished tables were decorated with inlaid ploughs. There were Dippers on the walls and on the floor. It was a "dipper" menagerie—really interesting. In Germany and Denmark, a wheel is placed at the location of the Dipper's bowl to become the cart, wagon, or wheelbarrow. The Chinese, Japanese, and Koreans refer to it as the ladle much as Americans do. The Dutch call it the steal pan or saucepan. It is a salmon net in Finland. If you're Saudi, the Big Dipper becomes the sail, like a sail of a ship. It is also seen as a coffin. During the early spring, the handle of the Dipper sticks out of the desert as it was rising with its bowl, now a sail, highest in the heavens. Also, if you take the top stars in the bowl of the Dipper, Dubhe and Merak, and let them point the way to your left, you will glide past one of the most famous stars in sky, the North Star or Polaris. Polaris is the brightest star in the constellation of the Little Bear, Ursa Minor, which is the American asterism of the Little Dipper. It is the star about which the heavens in the Northern Hemisphere circle.

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Returning to the asterism of the Plough… It is best seen as a plow in late summer or early fall after sundown. The Dipper is now cup down, handle up. The Dipper's handle becomes the part of the plough where the horses or oxen are attached and where the farmer stabilizes and guides the plough. The Dipper's bowl is the device that cuts the furrows into the field, turning over the soil for the planting season.

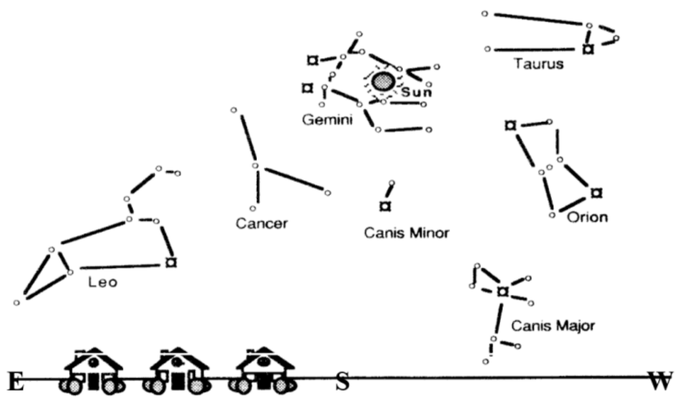
All these different cultures/nationalities have a different meaning associated with what Americans call the Big Dipper. Our Big Dipper stems from the pre-Civil War era when it was called the Drinking Gourd. Over the years that name has morphed into what we today call our Big Dipper, but the seven stars which create the picture have remained the same.

In December of 1927, the International Astronomical Union which is the governing body for astronomy across the world, mathematically defined the locations of the constellations visible in the Northern Hemisphere. The IAU considered the constellations like states with boundaries, the state of Ursa Major, the state of Ursa Minor, and the state of Draco the Dragon. Although the boundaries became official, the pictures were left unofficial. You can connect the stars as you see fit and make your own unique pictures from the luminaries that reside within the constellation's boundary.

Here is the next question…

9. If you could see stars during the day, this is what the sky would look like at noon on a given day. The sun is in the constellation of Gemini. In what constellation would the sun be located at sunset?

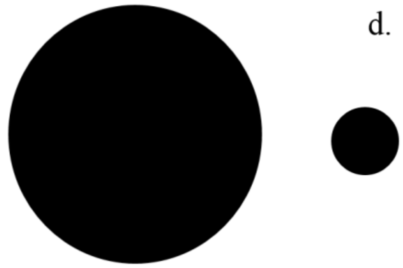
   a. Leo
   b. Canis Major
   c. Gemini
   d. Cancer
   e. Taurus



The logical conclusion would be to think that the sun is going to set in the vicinity of Canis Major, the Big Dog, but it does not do that. Instead the sun stays in the constellation of Gemini, as the Earth rotates and the sun nears the western horizon. In order to have the sun moving into the pattern of Cancer, the Earth must continue revolving around the sun to change its position against the stars in the sky. As the Earth's position changes day by day, the sun will gradually move from Gemini to the next constellation along the ecliptic, Cancer the Crab. The daily motion of the Earth as it orbits the sun is responsible for changing the position of the sun on the ecliptic. During the course of one revolution around the sun, our daystar moves through all of the zodiacal constellation, those star patterns that reside along the ecliptic or the path of the sun. The sun is going to rise in the constellation of Gemini, and then as Gemini sweeps across the sky towards its sunset position, Sol is going to remain in the constellation of Gemini as it sets. Gradually the sun will move towards Cancer.

Question 10…

10. Assume these circles represent two objects in the solar system with their diameters drawn to scale. Which objects could they represent?
    a. Earth and moon
    b. sun and Earth
    c. Jupiter and Earth
    d. sun and Jupiter



I only heard a few hand slaps on your tables for the Earth and the Moon, but that is the correct answer. The Earth is 8000 miles in diameter, while the moon is roughly 2000 miles in diameter. The ratios of diameters or radii, moon to Earth, is one to four. How many moons could fit inside the Earth? What do you think? This may really surprise you. Just examine the size of the moon. Look at the size of the Earth. How many moons could fit into the Earth if it were a hollow sphere—four, six, eight, 10, 16?

Based upon the information which I have given you the number would be 64. The ratio of radii, Earth to moon is four to one. The volume of a sphere is a cubic relationship, (x times x time x), x^3. So, 4^3 is to 1^3 which is equal to 64 to 1. You could put 64 moons inside of the Earth before it would be completely filled based upon this ratio. In reality this number is actually 49 moons because the Earth is slightly smaller than 8000 miles in diameter (7917.5 miles) and the moon is slightly greater in diameter than 2000 miles (2158.8 miles).

The moon may look big when you're walking on it, but in relationship to the Earth, it is really quite small. Let me consider this concept in another way and play devil’s advocate. The moon is the largest secondary body, the largest natural satellite going around a primary body, in the solar system. The ratio of the size of the moon to the size of the Earth is the smallest ratio of a planet and a natural satellite in the solar system. We have moons that are bigger than Earth's moon, such as Ganymede and Callisto (Jupiter), Titan (Saturn), and Triton (Neptune). However, they are going around planets which are much, much larger than the Earth. Before, Pluto was demoted to a dwarf planet, back in August of 2006, it turned out that Pluto and its largest satellite, Charon, had the smallest ratio between a planet and a moon. Pluto was only twice the diameter of Charon, a two to one (2:1) ratio.

The final question, number 11…

11. What is the brightest star of the nighttime sky?
a. Venus
b. Sirius
c. North Star
d. sun

Sirius is the correct answer. Venus is a planet; the sun is the brightest star of the day plus the night sky. The North Star is the luminary about which the heavens pivot as the Earth rotates. It ranks as the 49th brightest star in the heavens if the sun is included. I asked that same question on an Internet survey many years ago. The answers were shocking. Forty-nine percent of the 2000 people responding chose the North Star. Another 25 percent responded with the sun. About 10 percent of the respondents gave me the correct answer, Sirius. You can easily find Sirius, the brightest nighttime star if you spot the winter constellation of Orion the Hunter with its three closely spaced belt stars that appear to be in a straight line. Use the belt stars as

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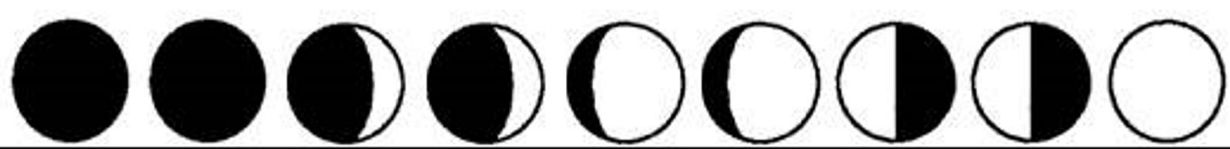
a sliding board and it will take you straight to Sirius the Dog Star, the alpha star of the constellation of Canis Major.

Phases of the Moon

I'd like to have you complete a little exercise. The first person to get it right will receive a free point. The second person that gets it correct will garner a half point. Raise your hand when you think you are correct, but understand that if you are wrong you are out of the race. I’ll come to you when you are ready. Inside the envelope which I have just handed everyone are nine disks. Two are black; two are half on—half off; two are banana-shaped, two are more than half lit, and the final disk is completely lit. Your job will be to start the sequence of moon phases with a new moon (all black), and run through the phases in their correct order and orientation, ending with a new moon.

The picture below gives the phase disks which will be contained in your envelope.



Students perform the exercise with a first and second winner for the free point and free half point.

Students are now given a moon on a stick. In order to perform this demonstration, you need to be standing away from your lab chair which should be tucked under the table. This will give you a little more room to complete the exercise. You also do not want to be in my shadow. I'm going to describe what I'm seeing, because everybody will be positioned at a slightly different angle except for the students which are in line with me and the sun. You won't be seeing what I'm seeing, so you need to adjust your position by duplicating the description that I am giving to you as I verbalize the demonstration.

I would suggest putting your moon on a stick in your left hand to start the exercise. Hold your moon in front of the sun. The hemisphere, which is facing you is in nighttime. The other hemisphere, however, is in daylight. If you don't believe me, move your head forward so that you can see the other hemisphere of the moon. It is completely in sunlight. The hemisphere of the moon facing you is in darkness. This is called a new moon.

Is there a perpetually dark side of the moon? The answer is no because we know that in the present configuration of the moon, the nearside of the moon which is facing us is in darkness. The hemisphere which we cannot see, called the far side (not the dark side) is in full sunlight. There is no perpetually dark hemisphere of the moon. All parts of the moon see a day and night sequence which takes about one month to cycle through. The moon facing in the same direction as the sun. The hemisphere facing us is in nighttime, and the moon is invisible to us from the Earth. It isn't visible unless there is a solar eclipse which occurs when the moon moves directly in front of the sun. It is the only configuration (positioning) where you can visually see a new moon when the solar eclipse becomes total—when the moon completely hides the sun. Otherwise, if the solar eclipse is partial or annular (ringed), you will need the appropriate filtration to dim the sun so the moon can become visible against the disk of the sun.

What time the new moon rises and sets based upon the equalization of day and night? I realized that the wintertime days are short, and in the summertime, the days are long. If we equalize day and night, sunrise is at 6 a.m. and sunset is at 6 p.m., 0600 (zero six hundred) hours and 1800 (eighteen hundred) hours if we use military time. If the moon is in the same direction as the sun, and the Earth is rotating, the new moon will rise and set with the sun.

Revolve your moon around your head (Earth) in a counterclockwise direction (towards the left) until the moon is full, completely filled with reflected sunlight. Then stop. You will know that you have a full moon because if you pull your moon lower it should enter into the shadow of your head (the Earth). If your moon does not go into your shadow, that means that your moon is not quite full. So, find the correct position. Now the moon is hiding in the shadow of the Earth; Luna is hiding in the shadow of the Earth and you have a lunar eclipse. A lunar eclipse can only occur when the moon is full, but do we have a lunar eclipse every month? The answer is no, because the moon revolves around the Earth in an orbit that is slightly tilted (inclined) to the orbit of the Earth (the ecliptic). The same situation holds for a solar eclipse. They do not occur each month. Look at the words eclipse and ecliptic. They are related? Eclipses can only happen when the moon is on or very near to the ecliptic. That is the only way that the moon can line up with the sun to create a solar eclipse or the moon can enter the shadow of the Earth to create a lunar eclipse.

During 2021, the Lehigh Valley sees a total lunar eclipse, a deep partial lunar eclipse, and a deep partial sunrise solar eclipse. Both lunar eclipses are visible throughout North America, but the solar eclipse is visible mostly in the mid-Atlantic states and Canada only.

During 2022, the residents of the Lehigh Valley get to see two total lunar eclipses but no solar eclipse. The lunar eclipses will be visible throughout all of North America.

Does everyone agree that a full moon is opposite to a new moon? Will you also agree that when the moon is full, it is the other hemisphere of the moon that is now in nighttime. The far side of the moon is now in darkness. If a full moon is in opposition (opposite) to a new moon, when will the full moon rise and set? Equalizing the day, if a new moon rises at 6 a.m. and sets at 6 p.m., then the full moon must rise at 6 p.m. when the sun sets and set at 6:00 a.m. when the sun rises. The full moon will always rise closest to sunset each month.

Go back to a new moon. Then continue to revolve your moon in a counterclockwise direction. Go exactly halfway between a new moon and a full moon. As the moon moves away from the new moon position, you will see it reflecting more and more sunlight, until half of the moon is lit and the other half is in its own shadow. The light is to the right. So, the moon is half on and half off. If you look at the position of the moon with respect to the sun, you will note that the moon has gone through one quarter of its orbit and one quarter of its phases. We will refine the orbital period in the next lesson. Here the moon has reached the first quarter of its phases. The moon is at first quarter, half on, half off, with the reflected sunlight to the right.

The place where the light of day is fading into the darkness of night is called the “Arnold Schwarzenegger.” Incredible amounts of laughter and applause occur in the classroom. What was Schwarzenegger’s most famous character or series of movies in which he acted? The *Terminator* series wasn’t it? If you are holding your moon correctly, the straight line of the terminator will simply continue down the straight line of the stick. At the position of the terminator, day is being terminated (extinguished) into night or in this case night is being terminated into day.

What time does the first quarter moon rise and set if the day is equalized? If the moon is new, it rises at 6 a.m. and sets at 6 p.m. If the moon is full, it comes up at 6 p.m. and sets at 6 a.m. Would the first quarter moon not have to be halfway between the times of rise and set of the new moon and the full moon? A first quarter moon rises at noon and sets at midnight. Make sure that you do not use 12 p.m. and 12 a.m. because there is no official international agreement on what 12 p.m. or 12 a.m. mean. I will expect you to answer noon or midnight or 12 noon and 12 midnight. To prove this concept correct, check your smartphone carrier contract policies because your phone contract will never end at 12:00 p.m. or 12:00 a.m. Most likely they will terminate at 11:59 p.m. or 12:01 a.m.

Go to a full moon and continue revolving the moon in its orbit, counterclockwise, until the terminator is once again a straight line. Now day is being terminated into night. The moon is once again in a quarter phase, but this time it has gone through three quarters of it phase cycle. We call this moon a third quarter moon. This phase can also be called a last quarter moon. Both terms are correct, but I like a last quarter moon better because the **l**ight is on the **l**eft for a **l**ast quarter moon. When I was teaching this to third graders, I would say light, left, last. The three "L's" acted as a reminder to help students remember the name of that phase. But please understand, if you learned this phase as third quarter, it is a perfectly acceptable term, and it can be used without penalty.

When does a last quarter/third quarter moon rise and set if the day is equalized? Remember a full moon rises at sunset and sets at sunrise while a new moon rises at sunrise and sets at sunset. What is the midpoint between those two times? Yes, a third quarter moon rises at midnight and sets at noon.

Halfway between a new moon and our first quarter moon, the moon has horns on each end. Keep in mind, if you are looking at this in the sky, you will only see the part of the moon that is reflecting the light from the sun. The other part of the moon is in its own shadow and will appear usually as dark as the night sky. That is one negative aspect of this demonstration, the shadowed moon is also seen. I don't know any better way of showing the phases where students can also participate. Having said that, the moon is now in a crescent phase. When the moon is horned, it has sharp tips. The word crescent mean horned. As the days proceed, is the moon getting brighter or dimmer? That is correct, brighter. We have two words that describe a moon that is being flooded with more light as the days progress and a moon in which the light is being diminished as it continues its phase cycle. It seems as if in the last 70 years, these words have lost meaning in the vocabulary of most people. One word is waxing which means to grow, while the other word is waning which means to diminish or to decrease. As an example, here is one way to remember these two words. You always wax your car before it rains (wanes). Since many folks don't wax their cars anymore, maybe that won't make sense either.

Moving right along as the class shows some restlessness… Position the moon between a first quarter moon and a full moon. You will now notice that Luna is more than half lit. Both sides of the moon are now bulging outward. The left "side" of the moon bulges outward where day is terminating into night (along the terminator) while the right side of the moon bulges outward due to the actual physical edge or limb of the moon intersecting the sky. The word for this phase is gibbous. Gibbous has two "B's" in it. The moon bulges outward from **b**oth sides.

Halfway between a full moon and a third quarter moon, the moon is still in a gibbous phase, but now the light is decreasing. The light is waning. What word is common for the moon after first quarter, but before third quarter, and not including the full moon? In all positions, the moon is more than half lit. It is in a gibbous phase. Before the moon is full, the phase would be a waxing gibbous moon. After the full moon, Luna would be in a waning gibbous configuration.

Finally, position the moon between last quarter and a new moon. The moon is diminishing in its daily brightness, but has become a horned moon once again. Its phase is now a waning crescent.

Allow the moon to circle (orbit) around your Earth. Can you get the feeling that it takes a number of days to go from a new moon to a first quarter moon, but the new moon and the first quarter moon happen on just one night? The new, first quarter, full, and last quarter moons occurs on just a single night. In fact, these phases occur in an instant of time when the angle that the moon makes with the sun and Earth is equal to zero degree (new), 90 degrees to the east of the sun (first quarter), 180 degrees from the sun (full), and 90 degrees to the west of the sun (last quarter).

Is there any way that we can further divide the lunar phases? The answer is yes. Rather than say the phases specifically, we can number the days of the lunar cycle from one through 29 and then we can further decimalize these days into whatever amount may be wanted. In addition, we can also look at the percentage of the moon that is reflecting sunlight. As an example, I could say that the moon is in its second day with 6.9 percent of its surface lit by the sun. The moon would still be in its waxing crescent phase.

I've done it all.

Now it is your turn to complete the exercise, *Know the Phases of the Moon (or die)*.

March 6, 2021
February 21, 2021