UNIT 2

<u>Motion of Celestial Bodies</u>

2.1 Telescopes

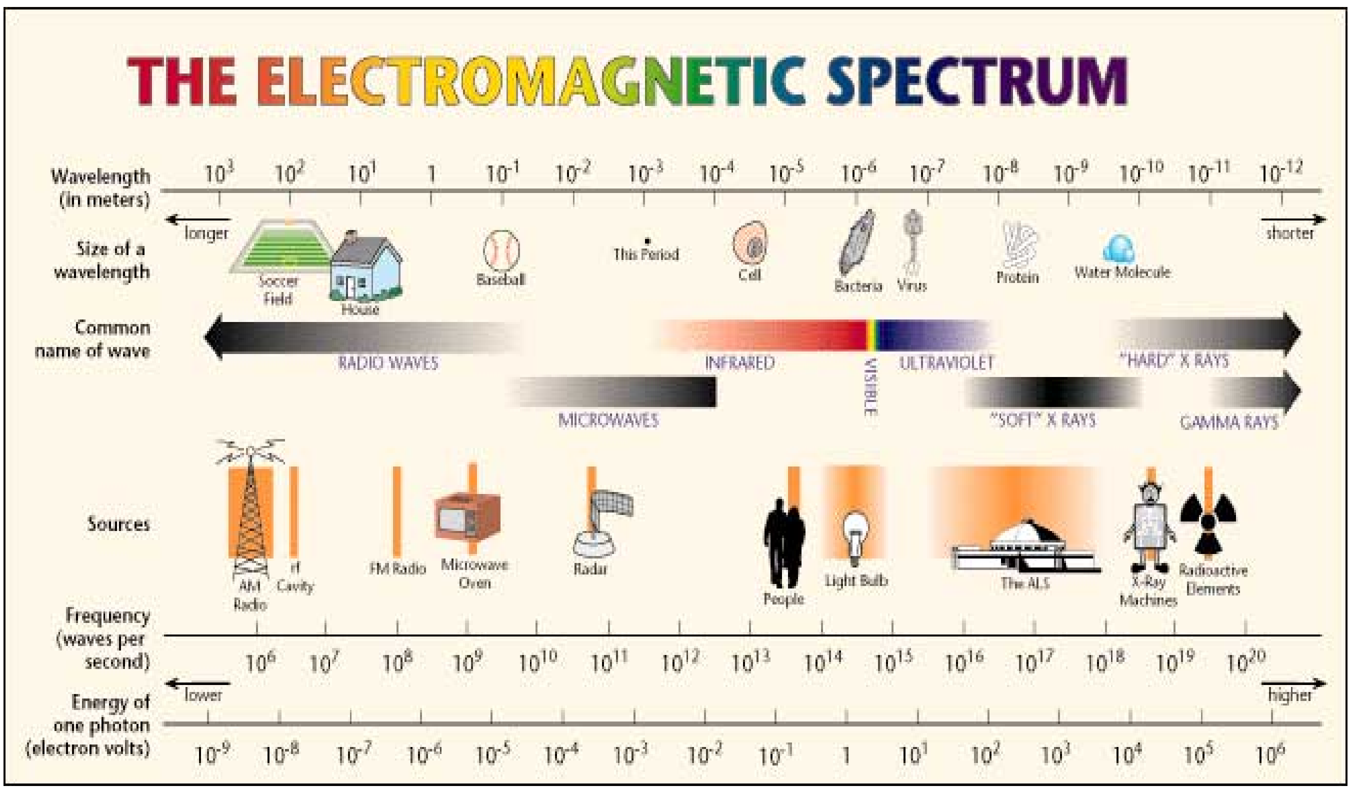
2.2 Celestial Spheres/Constellations

2.3 Motion of the Stars and Planets

Wavestown and the Electromagnetic Spectrum Assignment

Introduction:
Stars give off most of their energy in the form of electromagnetic energy. Electromagnetic energy is carried in the photons that zoom through space at the speed of light. The most important property of these waves is the frequency (number of times the wave vibrates per second). Electromagnetic energy frequencies are broken into seven categories based on the overall properties of the waves. These categories make up the electromagnetic spectrum.

Only a small portion of the electromagnetic spectrum is visible to the human eye. The other forms of light have wavelengths that are too long or too short for our eyes to detect. Light that has very long wavelengths has low energy while light that has short wavelengths has more energy. Below is a chart showing the breakdown of the electromagnetic spectrum. Additional information on the E.M.S. can be found at: *http://spaceplace.nasa.gov/magic-windows/redirected/#*



Radio Waves:
Radio waves have very long wavelength waves. Televisions, cell phones, and radios work on radio waves. These wavelengths are often used to transmit information (for example, a spacecraft can send radio messages about its mission). Radar uses radio waves, too. These radio waves are sent out, and when they hit an object they refl ect back. This is useful for determining the location of objects that might otherwise not be seen. Weather forecasters use Doppler Radar—this type of radar detects precipitation and the movement of that precipitation.

Microwaves:
These are actually shorter radio waves. They have more energy than radio waves. This form of light wave is used in microwave ovens and in some forms of long distance communication.
Infrared:

Infrared radiation comes from warm objects—the warmer the object, the more infrared radiation it emits. Even cold objects emit some infrared radiation. Some devices detect infrared radiation, they can be used during the day or night, since they are detecting heat given off by the objects. Some telescopes use infrared detection to fi nd and study stars, planets, and galaxies.

Visible light:
Visible light is the part of the electromagnetic spectrum that can be seen by the human eye. Visible light includes colors from red (longest wavelength) to violet (shortest wavelength). Visible light is actually composed of different shades of the colors: red, orange, yellow, green, blue, indigo, and violet

Ultraviolet:
Ultraviolet light is just past the visible light spectrum. Ultraviolet has a shorter wavelength, and more energy, than the previous forms of light that have been discussed. Most ultraviolet light is blocked by the Earth's atmosphere, but some does get to the surface. Ultraviolet light in small amounts is benefi cial by aiding in photosynthesis and providing vitamin D to people.
However, too much can burn skin, cause skin cancer, and damage vegetation. (NASA)

X-rays:
Earth's atmosphere completely blocks out all X-rays arriving from the Sun. X-rays can be useful in making internal images of the human body. X-rays can also "see" through objects such as suitcases and bags at the airport. They are able to penetrate certain substances but not others. This characteristic makes them a useful tool in studying bones and teeth. They cannot penetrate hard substances. Too much exposure to X-rays can be harmful to humans.

Gamma Rays:
Gamma rays are very short waves. They are very intense and dangerous in most situations. Fortunately, Earth's atmosphere blocks out all gamma rays arriving from space. However, like x-rays, gamma rays do have some useful applications on Earth, such as treating some types of cancer.

Question: How does the electromagnetic spectrum effect me?

Background: *(write a few things that you already know pertaining to about the question above)*

Vocabulary:
Electromagnetic Spectrum
Wave
Frequency

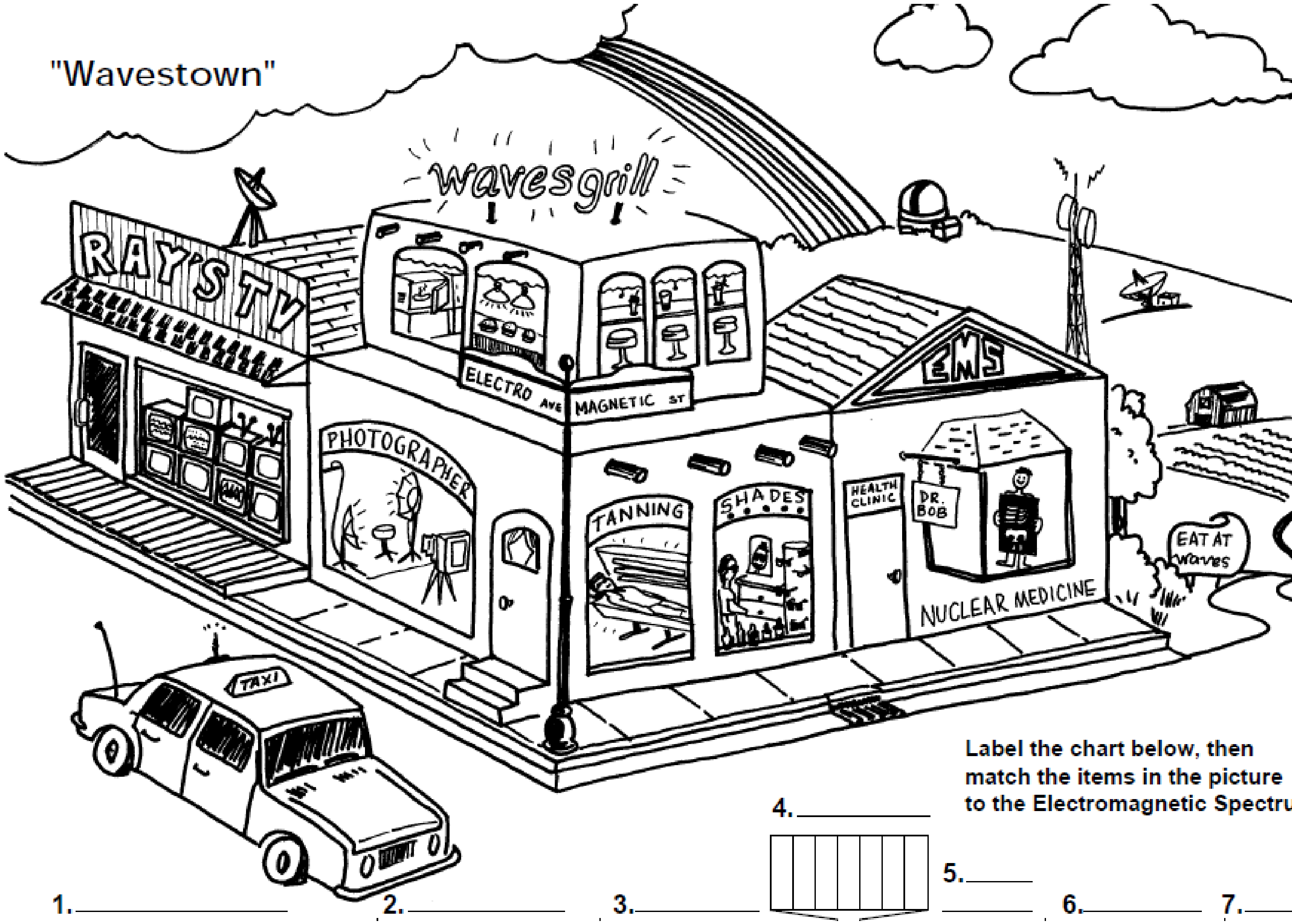
Materials: This assignment

Procedure:
Read through the following portions, answering questions as you read.

Label the types of waves on the diagram below the picture of Wavestown. Use a different color pencil for each of the types of waves.

Look for at least two examples of where you see each of the types of electromagnetic waves in Wavestown and then color those with the same colors you used in your labeling on the diagram.

"Wavestown"

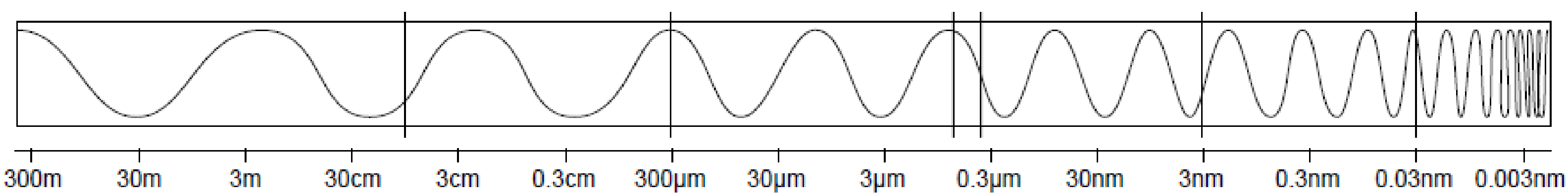


Label the chart below, then match the items in the picture to the Electromagnetic Spectrum.

4. ____________

5. ________

1. ____________________ 2. ________________ 3. ____________ 6. ____________ 7. ________



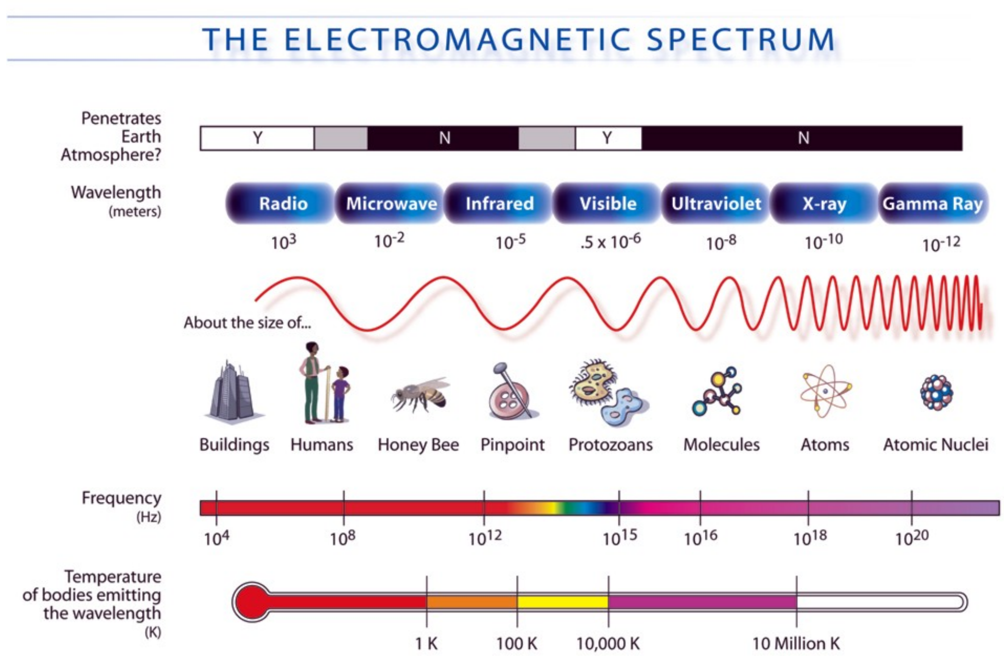
Analysis:

Answer the following questions on lined paper in complete sentences which restate the question in your answer.

1. How are the categories similar?
2. How are the categories different?
3. In the visible spectrum, which color of light has the most energy?
4. In the visible spectrum, which color of light has the least energy?
5. In the visible spectrum, which color of light has the longest wavelength?
6. In the visible spectrum, which color of light has the shortest wavelength?
7. What is the relationship between wavelength and frequency?
8. Which type of electromagnetic radiation can give you a sunburn?
9. Which type of electromagnetic radiation can be used to catch speeders (a.k.a. radar)?
10. Which parts of the electromagnetic spectrum were you exposed to in the past year?
11. Which parts of the electromagnetic spectrum were you exposed to today?
12. What is the frequency of a wave? Explain why this occurs?
13. What happens to the energy level a wave the wavelength becomes shorter?
14. What happens to the energy level a wave when the frequency of the waves increases?
15. Objects reflect different types of visible light. The light that a person sees with his/her eyes is the light that is REFLECTED by that object. Draw the table below and then fill it in. State which types of visible light are reflected or absorbed by each object.

Object	red	orange	yellow	green	blue	indigo	violet
red apple	*reflect*	*absorb*	*absorb*	*absorb*	*absorb*	*absorb*	*absorb*
leaf							
pumpkin							
piece of blank computer paper							

16. A black object that is left in sunlight gets much warmer than a white object that is left in sunlight. Using what you know about objects reflecting and absorbing light, can you explain why this occurs?



Tools of the Astronomer Reading

Question: What are the different types of telescopes and how do they operate?

Background: *(write a few things that you already know pertaining to about the question above)*

Vocabulary:
Refractor
Reflector
Detector
Electromagnetic radiation

Materials:
This reading packet

Procedure:
Read through the following passage.

Telescopes as Light Buckets
For thousands of years, the human eye was all that we had to observe the night sky. But when Galileo turned his crude telescope to the skies in 1609, he could suddenly see wondrous things - craters on the Moon, dark spots on the face of the Sun, tiny moons moving around Jupiter -- things that no one else had ever seen. Since then, astronomers have developed increasingly powerful telescopes to learn more about the planets, stars and galaxies that make up our universe. Some telescopes collect and focus light using a glass lens through which light passes (refracting telescopes), while others use a mirror from which it is reflected (reflecting telescope).

In either case it is the *area* of the lens or mirror which is the crucial factor in determining how much light a telescope can collect. If you collect more light, you can see fainter objects. Which will collect more water in a rainstorm, a small cup or a large bucket? Similarly, light from planets, stars and galaxies is constantly "raining down" on Earth, and larger telescopes, acting like "light buckets, will collect more light than smaller ones.

Since the lenses in our eyes are so small (which is fine for looking at a sunlit scene on Earth), they cannot see faint traces of light in the night sky. Galileo's small telescope was able to gather about 100 times as much light as the human eye. This is how Galileo was able to spot the moons of Jupiter, when no one had ever been able to see them before. The extra light collected suddenly made things visible in the night sky that were too faint for the unaided eye to see.

Scientists sometimes joke that the history of astronomy can be summed up as a search for bigger light buckets. Every time we have built a larger collector of light (or other waves), we have discovered things that were too faint to be detected before - and opened up new worlds and new ideas for exploration.

Refractors Versus Reflectors

The first telescopes used a lens to collect, bend, and focus light (just like our eyes do). But lenses have a number of disadvantages. As you know from the lenses in eyeglasses, the lens requires both sides to be dear so the light can go through the lens. That's why the lenses in your uncle's glasses are held only around the edges. The larger the lens, the more it tends to sag because of its weight And lenses tend to bend different colors of light differently, which makes the various colors spread out in an image. Thus there's a limit to how big you can make lenses. The largest refracting telescope in the world, at the Yerkes Observatory near Chicago, has a lens that is 40 inches (about 100 cm across.)

The four 8.2-meter reflectors that make up the Very Large Telescope of the European Southern Observatory, located on a high and very dry plateau on Paranal Mountain in Chile. Working together, these four telescopes electronically combine the light they receive to make the largest visible-light "bucket" in the world. *(ESO)*

It was the great physicist Isaac Newton who first showed how to make a practical telescope using mirrors. The big advantage of a mirror as your light bucket is that the light reflects off the mirror *surface*- it doesn't go through the mirror like it does for a lens. Therefore only one side of the mirror must be kept clear and the bottom side can be used to hold and support it. Mirrors, when made the right shape, also don't separate the colors of light like lenses do. For these and other reasons, mirrors can be made much larger than lenses and today all the major telescopes astronomers use for research are "reflectors:'

Astronomers have found ingenious ways to make bigger and bigger mirrors in recent decades. Some giant mirrors are made from several segments which are kept aligned by computer-controlled devices. Other mirrors are made while the hot mirror material is spun at high speed and can be made much more light-weight through this process. Sometimes several large mirrors are used in the same location and the light they collect is brought together to make the equivalent of a much bigger mirror. As a result, we have huge light buckets today that Galileo and Newton did not even dare to dream.

Resolving power is another important characteristic of a telescope is its resolving power - its ability to make out fine detail. In theory, the bigger the telescope, the better its resolving power - the finer the detail it can make out - whether we are looking at the weather on Jupiter, or the collision of two far-away galaxies of stars. Thus, another reason that astronomers build larger telescopes is to try to see the inner workings of distant objects. Alas, many large telescopes cannot see fine detail anywhere near as well as theory predicts. That's because telescopes on Earth have to look through miles of air and our atmosphere dances, jiggles, and is full of water vapor, ash, and human pollution. The dancing and blurring of images by our atmosphere is the reason stars appear to twinkle when we look at them from the ground.

The higher up we put our telescope, the less air it has to look through and the clearer our view. This is why all observatories with large telescopes are built on high mountaintops, where the air is clear and clean. As you can imagine, the best solution to the blurring effects of air is to rise above the problem - literally. Telescopes above our atmosphere, such as the Hubble Space Telescope, can enjoy the resolving power that laws of physics promise, but don't deliver on Earth.

Detectors

A telescope is a passive collector of light (or other waves), just as your car antenna is a passive collector of waves from local radio stations. Before you can listen to the news and traffic, you need to attach that antenna to a *detector*, a device that actually receives the waves and can record or translate them. In the case of your radio, the detector is your radio set, which turns the radio waves sent by your favorite radio station into sound you can hear.

Telescopes also need detectors attached for us to be able to see the images they form. For centuries after Galileo, the only available detector was the human eye. Astronomers made sketches of what they saw- and we still treasure those early sketches for the pioneering information they contain. But in the second half of the 19th century, the invention of photography changed astronomy profoundly. A photograph allows us to make a permanent record of what is in the sky - a record that is not fooled by the prejudices of the human brain as early observers sometimes were.

Hubble Space Telescope above the Earth. The Hubble has a 94-inch (about 240-cm) diameter mirror; that's far from the largest mirror astronomers have at their disposal, but it has the advantage of being in the vacuum of space. *(NASA/ESA/STScI)*

Even more important, photographs allow us to add together the light that comes in over many minutes or even hours. This is called a long exposure, and it has the same effect as getting a bigger light bucket - you can collect more light and see things in the sky that are fainter. It was photography that made the studies of the galaxies (the great cosmic islands of stars) possible. Today, digital photography allows astronomers using electronic cameras to record fainter objects than ever. In addition, the electronic images are stored as digital data, which can be readily "processed" and enhanced using computers to bring out even more detail. Electronic detectors (whose technical name is CCD's) have revolutionized our search for faint objects - such as asteroid, dwarf planets, or exploding stars in other galaxies. Together huge telescopes and super-efficient detectors are giving us unprecedented views of the universe.

My Dome is My Home

The Parkes Radio Telescope in Australia. The diameter of the "dish" (antenna) is 64 meters. This metal "bucket" catches radio waves from space. *(ANTF/CSIRO image)*

As we saw, astronomers today are finding clever new ways to build even larger telescopes at lower cost, and to install them in observatories located at high, dry, and clear locations in parts of our planet sometimes quite far from civilization. In the design of these new "monster" telescopes, scientists and engineers are pushing the envelope of what mirrors, motors, and computers are capable of.

When we think of building not just the telescope itself, the support structure and building that go it, we must several issues. For example, telescopes and their buildings are securely attached to planet Earth (as they should be.) But this means they are operating on a moving platform. Every day, the Earth makes a complete turn on its axis. If your telescope is looking at a specific planet, star, or galaxy in the sky, the turning Earth will soon take your object out of the telescope's field of view, and you will be looking at or photographing something else. To keep the telescope pointed at the same object for any length of time, your telescope must turn in the exact opposite direction from the Earth, and must do so smoothly - so it does not disturb an image you might be taking for many minutes or hours.

Then when you are ready to observe a different object in the sky, you must be able to turn the telescope quickly and efficiently to the new location in the sky. All this requires a clever combination of movable support and motors -- which increase in cost and complexity as the size of your telescope increases.

Furthermore, a modern telescope is much too delicate an instrument to leave unprotected from the weather and changes in temperature. Thus every large telescope is housed in a building, usually with a dome shaped roof that allows a slit to open and view the right part of the sky. As the telescope turns, the dome must be able to move with it and always have the opening right above the telescope. Many times, the dome and support structure of a large telescope have cost as much or more as its mirror did.

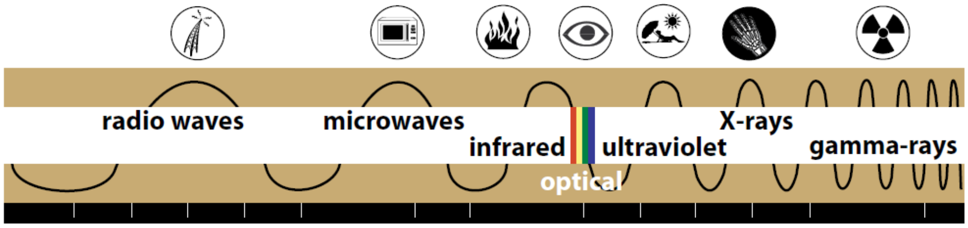
Observing "Invisible" light

The first telescopes collected and focused visible light the kinds of waves our eyes are sensitive to. But there is a wide range of other types of light (invisible to our eyes) given off by objects in the universe. Because all such waves are given off by electric and magnetic changes within atoms, scientists call the array of different forms of light *electromagnetic radiation.* Astronomers normally speak of each different type of light as having a different *wavelength.* Think of a wave on the surface of a pond. It has crests and troughs where the water is slightly higher and slightly lower than the height of the undisturbed water. The distance between crests is called the wavelength of the wave. The entire pattern of crests and troughs moves across the water at a definite speed.

A fisherman standing on the shore of the pond sees the float on his line bob up and down as the crests and troughs go by. The number of crests which pass the float each second is called the *frequency* of the wave. Electromagnetic waves are similar to water waves in many respects. They can have any value of wavelength; those with the shortest wavelengths (one trillionth of a meter) are called gamma-rays, those with the longest (ranging from millimeters to hundreds of meters) are radio waves. Visible light falls somewhere in the middle, with an average 'wavelength of five ten-thousandths of a millimeter. While wavelengths and frequencies differ for different kinds of electromagnetic waves, the speed at which each travels through empty space is the same
for all wavelengths - 300,000 kilometers per second (186,000 miles per second)- the speed of light. Astronomers have built a remarkable array of different telescopes to observe all the different wavelengths of light coming from celestial objects. Some electromagnetic radiation, like visible light and radio waves, can be seen by telescopes on the ground; others, like x-rays and ultraviolet light, are absorbed by our atmosphere and can only be observed from space. But whatever the location of the telescope, special detectors have been developed used to pick up the types of waves we are looking for. Although the detectors for radio waves and x-rays may not look very similar, each is designed to glean as much information as possible from the waves its "light bucket" has collected.

Fingerprinting the Universe

The light from a celestial object often contains a surprising amount of information about the source that gave it off. White light on Earth spreads out into its component "colors" when it passes through a prism or raindrops (which is how we get a rainbow). Similarly, light from a celestial object, like a star, can be spread out by astronomers and separated according to wavelengths (colors), with an instrument called a spectrograph. *Spectroscopy,* the study of the spread out light from objects in space, is a key part of most astronomical work, and it can be done for both visible and invisible waves.



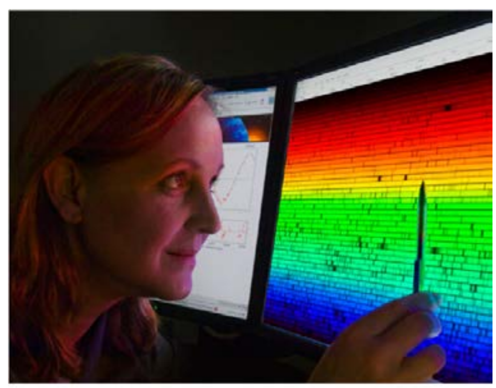
The Electromagnetic Spectrum — the array of waves of different wavelengths that astronomers study. Optical is another term for visible light.

By studying how much light is present at each wavelength in the light from the star, astronomers can tell what atoms and molecules it's made out of. That's because every atom and molecule will absorb or emit light only at certain wavelengths. The pattern of which wavelengths are absorbed or emitted is like a fingerprint, which uniquely identifies each atom or molecule from every other. Thus if you see something at a wavelength that corresponds to hydrogen, for example, you know that hydrogen must be present in the star. Careful analysis of these "fingerprints" in the light from celestial objects can also tell astronomers what their temperature is, how fast they're spinning and whether they're moving through space.

Interference

A major problem for all telescopes built on the ground is interference from man-made sources. For example, the glow from city lights can make it difficult to see faint objects with nearby visible-light telescopes. (Astronomers call the growing issue of human lights encroaching on the darkness of the night around the globe "light pollution") In addition, "blurring" by our atmosphere also degrades the quality of visible-light images of the sky. To get around both these problems, observatories tend to be built atop remote mountains, far from cities and at altitudes that get above enough of the Earth's atmosphere to lessen the blurring.

Because of their longer wavelengths, some radio waves are not affected by the Earth's atmosphere, but everything from cellular phones to ham radios and even electrical appliances can interfere with the detection of faint radio signals from space. The National Radio Astronomy Observatories in the U.S., for example, have staff members whose job it is to make sure that all the sources of interference near the telescopes are shielded. Telescopes in space have none of these problems, although they are difficult and expensive to launch, maintain and operate. And if something breaks, you can't just walk over to the telescope and fix it.


Astronomer Debra Fischer (Yale University) examines a spectrum of light as part of her hunt for planets around other stars.

Still, these problems are minor to what our telescopes can now achieve. Over the years, astronomers have studied the sky at virtually every wavelength region, some in more detail than others. We have learned so much more about stars, galaxies and the universe as a whole than we ever could have if we had only looked at the sky in the visible light to which our eyes are tuned. None of these telescopes or detectors is cheap, however, and funds must usually be pooled from governments, universities, private foundations, and wealthy individuals who might like to leave such a tool for exploration as their legacy. Just as our society invests in the creation of good music, the making and display of works of art, and the support of writers and poets who enrich our lives, so investment in the exploration of the universe is something that will continue to enlarge and change our view of ourselves - much as Galileo's first tentative observations did 400 years ago.

Analysis:

Answer the following questions on a separate sheet of lined paper.

1. What did Galileo see when he turned his telescope to the sky?
2. What does the author mean by the term "light bucket"?
3. Give another example of a figurative "bucket" in your life?
4. Draw a Venn Diagram comparing reflecting telescopes and refracting telescopes.
5. What is meant by resolving power?
6. Even though Hubble is not technically a telescope, why do you think we still call it one?
7. Why are space telescopes put into space?
8. Why do scientists design telescopes so large?
9. What is meant by observing "invisible light"?
10. What can astronomers learn about a star or object through spectroscopy?
11. What types of things can interfere with radio telescopes?
12. As a nation, should we have invested 8 billion dollars in the space telescope program in the past 20 years? Explain and support your position.

Lens & Light Lab

Introduction

Microscopes let us peer inside invisible worlds our eyes could never see, telescopes take us far beyond the Earth to the stars and planets of the night sky, movie projectors throw enormous images onto screens, and lighthouses cast reassuring beams of light far across the ocean. Amazing curves of glass or plastic called lenses make all these things possible. Let's take a closer look at what they are and how they work!

What are lenses?

A lens is a transparent piece of glass or plastic with at least one curved surface. It gets its name from the Latin word for "lentil" (a type of bean used in cooking - see the picture of one on the right), but don't let that confuse you. There's no real reason for this other than that the convex lens (the most common kind of lens) looks very much like a lentil!

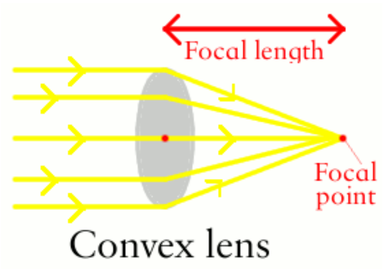
How do lenses work?

A lens works by refraction: it bends light rays as they pass through it so they change direction. That means the rays seem to come from a point that's closer or further away from where they actually originate—and that's what makes objects seen through a lens seem either bigger or smaller than they really are.

Types of lenses

There are two main types of lenses, known as convex (or converging) and concave (or diverging).

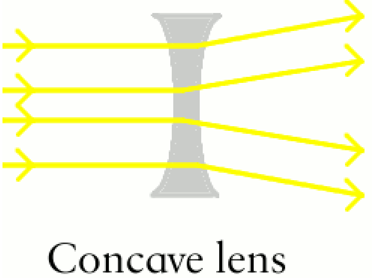
Convex lenses



In a convex lens (sometimes called a positive lens), the glass (or plastic) surfaces bulge outwards in the center giving the classic lentil-like shape. A convex lens is also called a converging lens because it makes parallel light rays passing through it bend inward and meet (converge) at a spot just beyond the lens known as the focal point.

Convex lenses are used in things like telescopes and binoculars to bring distant light rays to a focus in your eyes.

Concave lenses



A concave lens is exactly the opposite with the outer surfaces curving inward, so it makes parallel light rays curve outward or diverge. That's why concave lenses are sometimes called diverging lenses. (One easy way to remember the difference between concave and convex lenses is to think of concave lenses caving inwards.) Concave lenses are used in things like TV projectors to make light rays spread out into the distance. In a flashlight, it's easier to do this job with a mirror, which usually weighs much less than a lens and is cheaper to manufacture as well.

Compound lenses

It's possible to make lenses that behave in more complex ways by combining convex and concave lenses. A lens that uses two or more simpler lenses in this way is called a compound lens.

Question: How do lenses effect light?

Background: *(write a few things that you already know pertaining to about the question above)*

Vocabulary:
Concave lens
Convex lens
Double concave lens
Near-sighted
Far-sighted
Refract
Reflect

Materials:
Concave lens
Double concave lens
Mirror
Pipette or dropper
Convex lens
Lens holder
Beaker of water
Microscope slide

Procedure & Analysis:
Follow the steps of the lab and answer the questions as you go.

Station 1: Exploring Lenses
Take two concave & one convex lens back to your table.

1. Draw a Convex lens:

2. Draw a Concave lens:

3. Take one concave lens and place it over the words on your paper. Look through the lens and pull it toward your eye. As you pull it further and further away (toward your eyes) what happens?

4. Take two concave lens and repeat the same process. What happens as you pull it further away?

5. Compare the results of the double concave lens and the single concave lens. What happened?

6. Take one convex lens and one concave lens and stack them. What happened as your pulled the lens closer to your eyes?

7. If you were near-sighted, which type of lens would be used to put in your glasses? Why so?

8. If you were far-sighted, which type of lens would be use to put in your glasses? Why so?

Station 2: Exploring Reflection

9. Take a mirror back to your table. Write your name in the space below, so that it looks correct in the mirror.

10. Now remove the mirror and look at the paper. What do the words look like?

11. Using the idea of light waves and reflection, what is happening?

Station 3: Exploring Refraction

12. Look at the pencil in the beaker full of water. What do you see?

13. Light waves are traveling through the air and then entering the water. What is happening to the speed of those light waves as they pass through the water?

14. What is this causing the pencil to appear this way?

Station 4: You are Newton (with his prism)

Newton was studying telescope lens making, and was coming across some problems. He found that certain shaped lens produced rainbows on the wall. He began wondering if light crystal objects always changed sunlight into a rainbow. Now you are going to perform a modified version of Newton's experiment.

15. The light crystal (prism) is on the overhead, the smaller flat side is down. What do you see on the ceiling?

What is happening is, as the white light from the overhead is entering the prism it is forced to exit at an angle, causing it not only to slow down (since light slows as it enters different objects – see the beaker with the pencil activity), but to also change it's direction. This bending is called REFRACTION. Each color has a slightly different wavelength and the light is dispersed by the different wavelengths causing you to see different colors of the rainbow.

16. Using this information, explain why a rainbow forms on a rainy day. (Hint: the raindrops may act similar to a prism.)

Station 5: Making your own lens

Lay a glass microscope slide on this lab sheet. Using an eye-dropper or pipette, place a single, small drop of water on top of the slide. If you need to, move the slide so that the droplet it directly above a word on your lab sheet.

17. What appears to have happened due to the presence of the water droplet?

18. What type of lens did you create?

19. What happens if you make the water drop bigger or smaller?

20. The words on the page are not getting bigger- what is actually happening to cause you to see the larger words?

Refracting Telescope lab

Introduction:
Telescopes have been used for centuries to observe the far reaches of our galaxy. The complexity of modern telescopes (such as the Hubble telescope) has increased dramatically since the first telescope, but they still follow the same lens and optics principles. In this lab, two simple types of telescopes will be constructed-an *astronomical* (or Keplerian) telescope and a *terrestrial* (or Galilean) telescope. By measuring the length of the focused telescope you will determine how each telescope's lens combination works to magnify an object. You will also observe the advantages and disadvantages of each telescope design.

Nearly 400 years ago, while experimenting with optical properties of lenses and optical lens systems, Galileo Galilei discovered a way to bring distant objects into better view by making them appear as if they were only a few meters away instead of a few hundred meters—he did this with a telescope. The first telescope used a simple two-lens system with an objective lens and an eyepiece lens.

The objective lens is a convex, or converging, lens and it focuses incoming light from a distant object through the back focal point of the lens to form a real image on the transmission side (exiting-light side) of the lends. The focal point of any lens is the point at which a beam of light parallel to the principle axis of the lens converges.

The eyepiece lens of the telescope then acts as a simple magnifier to magnify the very small real image produced by the objective lens. The eyepiece lens can be either a convex lens for an astronomical telescope or a concave, or diverging, lens for a terrestrial telescope. A simple magnifier is used as the eyepiece lens so that the final image is an enlarged virtual image. The result—the original object appears closer and larger than it did with the unaided eye.

Question: How does a telescope work to magnify things?

Background: *(write a few sentences about what you already know about the question above)*

Vocabulary: *(define the terms below)*
Astronomical telescope
Terrestrial telescope
Refraction
Focal point

Materials:
Astronomical telescope
Terrestrial telescope

Procedure:
1. Use the telescope to view objects that are relatively close (at your lab table) compared to objects that are relatively far away (across the room or outside).
2. Use your ruler to measure the objective focal length and then view objects. Draw a data table in your notes like the one shown below.

Data Table

Telescope Design	Eyepiece focal length	Objective focal length	Observations	Telescope length (nearest mm)
Astronomical	50 mm (convex)	250 mm (convex)		
Terrestrial	50 mm (concave)	250 mm (convex)		

Analysis:

Answer the following questions on lined paper.

1. What is the lens separation between the objective lens and the eyepiece lens for the sharply focused astronomical telescope? (You can assume that the center of each lens is positioned 9 mm inside the tube at each end).

2. Describe the image produced by the astronomical telescope. Is the image inverted or distorted?

3. Using the equation *m = focal length (objective lens) / focal length (eyepiece lens)*, determine the magnification of the astronomical telescope.

4. What is the lens separation between the objective the objective lens and the eyepiece lens for the sharply focused terrestrial telescope? (Assume that the center of each lens is positioned 15 mm inside the tube at each end.)

5. Compare the lens separation of the terrestrial telescope to the sum of the focal lengths of the two respective lenses. What does this tell you about where the focal point of the objective lens falls in comparison to the focal of the eyepiece lens for the terrestrial telescope?

6. Describe the image produced by the terrestrial telescope. Is the image inverted? Is there distortion?

7. Using the equation in question #3, determine the magnification of the terrestrial telescope.

8. What are the advantages of an astronomical telescope over a terrestrial telescope?

9. What are the disadvantages of an astronomical telescope over a terrestrial telescope?

10. If you were in charge of a team choosing to build a telescope that was 10 meters (33 ft) long, which one would you choose to build, an astronomical or a terrestrial. Explain why.

400 Years of the Telescope Video Questions *(this video is available through Netflix streaming)*

Answer the following questions on a separate sheet of paper. You do not need to answer them in complete sentences. Questions are spaced out with enough time for you to answer each (1-3 minutes apart).

1. Where is the Hooker Telescope located?
2. What did Edwin Hubble discover about the universe?
3. Who invented the telescope?
4. In 1609, Galileo observed what about the moon's surface?
5. What did the Greeks believe about celestial objects?
6. What did Copernicus suggest about our solar system?
7. What did Galileo observe about Jupiter, Venus, and the Sun?
8. Why was this a threat to the Catholic Church?
9. Why are refracting telescopes limited in how large they can be?
10. Newton in 1668, was the first to create a __________ telescope.
11. What invention made in 1839 allowed astronomers to be able to take photos with longer exposures?
12. What can star spectra tell about a star?
13. What is red shift tell us about galaxies in space?
14. What was the world's largest telescope?
15. Mona Kea has how many telescopes?
16. Separate telescopes help to see more detail and can see which band in the spectrum?
17. New telescopes, like Pan-STARR, will have _______ billion megapixel digital cameras.
18. How far into the future can the Pan-STARR telescopes detect killer asteroid collisions with Earth?
19. Why are space based telescopes are better than Earth based telescopes?
20. What is the first space based telescope and why did it sit in storage for a decade before it was launched?
21. Why did we keep sending missions to service Hubble?
22. What is the Hubble Deep Field?
23. What is happening to the speed that the Universe is expanding?
24. What is dark energy?
25. There are three future telescopes being built. How large will they be?
26. How do we detect stars that orbit other suns?

Space Telescopes Lab

Introduction:
Few results from recent astronomical research have captured the public imagination as much as the colorful images from space telescopes. One might ask why we needed to put telescopes into space to get such amazing images. The answer is quite simple; one of the problems with Earth-based telescopes is that the atmosphere contains moving pockets of hot and cold air. We learned back in elementary that hot air rises. This shift between different temperatures can be seen by looking at a blacktop road from a distance on a hot sunny day. The shimmering water-like appearance is called a mirage and is caused by the rising hot air coming into contact with the dropping colder air taking its place.

A similar effect is happening at any given moment in our atmosphere. In fact, it is what causes stars to appear to twinkle in the night sky. Air warmed by the sun striking the ground rises into the atmosphere while cooler air is dropping. This effect does vary from location, temperature, number of hours the sun warmed the ground and the angle of the sun, to name a few. The higher you are up in the atmosphere, the less effect this has on the shimmering effect in the atmosphere (Hence why many of the astronomical observatories are located at the top of mountains).

Another fact to keep in mind is that the Earth's magnetic field and atmosphere also partially block or absorbs certain wavelengths of radiation, like ultraviolet, gamma- and X-rays, before they can reach Earth. Scientists can best examine an object like a star by studying it in all the types of wavelengths that it emits. Newer ground-based telescopes are using technological advances to try to correct atmospheric distortion, but there's no way to see the wavelengths the atmosphere prevents from even reaching the planet. The most effective way to avoid the problems of the atmosphere is to place your telescope beyond it. Or, in Hubble's case, 353 miles (569 km) above the surface of Earth.

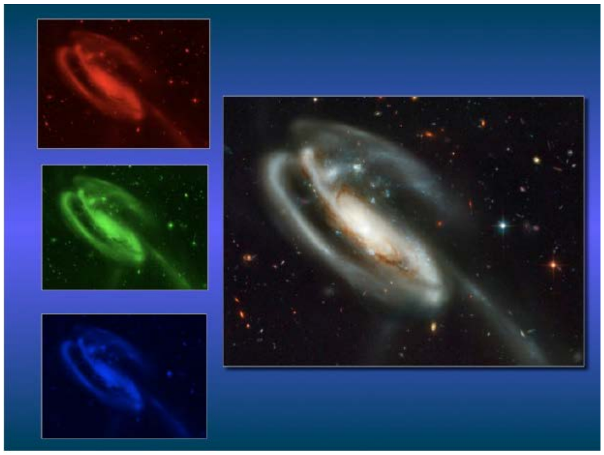
In an effort to get clearer images of space and learn more about black holes, pulsars, supernovas, and other high-energy astronomical events, NASA launched the Hubble Space Telescope in 1990, the Chandra X-ray Observatory in 1999, and the Spitzer Space Telescope in 2003. Although you may have only heard of the Hubble Space Telescope, all three space telescopes function in different, though similar means.

Images and space telescopes
Though the first astronomical photograph was taken in the mid 1800s, exquisite color photography in astronomy did not come of age until the 1970s. Even then it was restricted to a few exceptionally skilled photographers who pioneered film photography techniques to assemble richly colored astronomical photos.

Today, film has been replaced by digital imaging, much like how a digital camera works, just way more complex. Each point of light (pixel) is converted to a number and can then be manipulated using computers. Using ever larger arrays of digital pixels and sophisticated image processing software, astronomers can produce dramatic color photos that today grace covers of textbooks, magazines, and CD albums; some are even seen in movie trailers.

A common remark when first seeing pictures from space telescopes is that they look too good to be true. A reasonable and sometimes suspicious question is "Are these objects really so colorful or are the colors fake?" If you could fly out to these celestial wonders, they would look the same way to our eye? If not, are the pictures being overly colorized to seduce the public, as a few hardcore NASA cynics claim. What is "truth" when it comes to the colorful universe presented in Hubble (and ground-based) photos of the universe?

Creating a full color image from astronomical data is as much an art as a science. Our eyes are better at distinguishing differing hues of color than similar gray values, so edges and otherwise hard-to-see features often pop out in a color image.

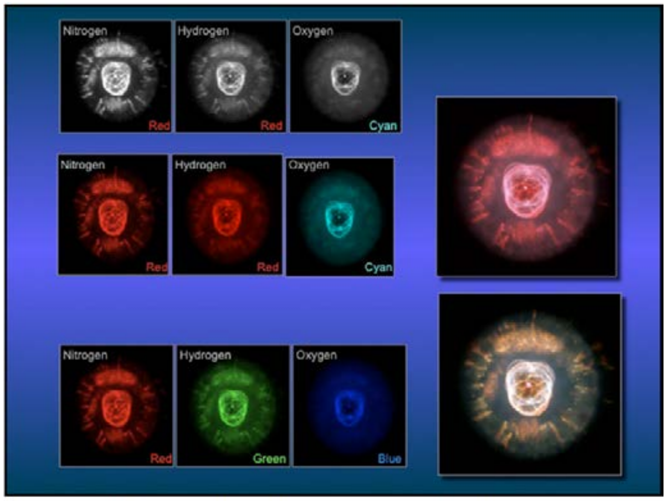


Natural color images of astronomical objects, such as this one of a galaxy, are assembled from photos taken through three "wideband filters" that each cover one-third of the visible spectrum. When the exposures are combined, a natural color image shows the glow of young blue stars and a more yellowish older population in the galaxy's central bulge. *(Image processing courtesy of Zoltan Levay)*

The human eye-brain "computer" has it own way of collecting and decoding the message of light transmitted from the eye's color receptors. The Technicolor film process, developed in the 1930s, strove for pure color fidelity by filming a scene simultaneously on three separated cameras which record images in red, green, and blue filters. The three film strips were then combined to create a rich and accurate color image.

Once a picture is "taken" with one of the space telescopes a few things must be done to it. The first step in image processing a Hubble image is to remove cosmic rays trails caused by high energy gamma rays and x-rays (these appear to be little bright worms that crawl across the image). The second step is to align the red-blue-green images and adjust them so that they perfectly align. You have to remember that not only is the Hubble Space Telescope traveling at 5 miles per second but it is also orbiting the Earth (every 93 minutes) and has to continually be re-pointed. The slight movements equate to the huge movements in the image - think back to when you were viewing a telescope, binoculars, or microscope and someone bumped you.

Even with all that care, artistic license is used sparingly to better illustrate details and structure in a nebula or galaxy. But we never choose color simply for the sake of glamorizing an image. The Hubble photos are inherently spectacular and evocative.

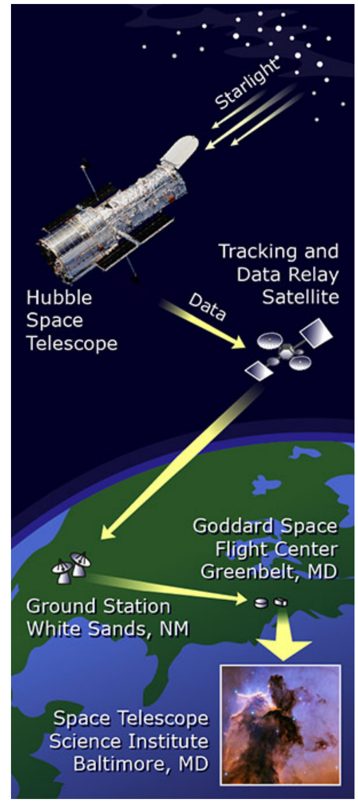


In this picture of the Eskimo nebula on the left, exposures were taken through the different narrow-band red filters and a blue filters corresponding to the emission from nitrogen, hydrogen and oxygen (top). When correct colors are applied, the image looks a monochrome pink. To stretch the color range, the slight shorter-wavelength hydrogen light red exposure was tinted green. The result is a more attractive image (bottom) that yields more information about the nebula's complex structure. *(Image processing courtesy Zoltan Levay)*

Similarly, Chandra is the largest space telescope ever launched and detects "invisible" X-ray radiation, which is often the only way that scientists can pinpoint and understand high-energy events in our universe.

Computer aided data collection and processing is an essential facet of astronomical research using space- and ground-based telescopes. Every 8 hours, Chandra downloads millions of pieces of information to Earth. To control, process, and analyze this flood of numbers, scientists rely on computers, not only to do calculations, but also to change numbers into pictures. The final results of these analyses are wonderful and exciting images that expand understanding of the universe for not only scientists, but also decision-makers and the general public.

Although computers are used extensively, scientists and programmers go through painstaking calibration and validation processes to ensure that computers produce technically correct images. As Dr. Neil Comins so eloquently states, “These images create an impression of the glamour of science in the public mind that is not entirely realistic. The process of computers transforming most telescope data into accurate and meaningful images is long, involved, unglamorous, and exacting. Make a mistake in one of dozens of parameters or steps in the analysis and you will get inaccurate results.”



The process of making the computer-generated images from X-ray data collected by Chandra involves the use of "false color." X-rays cannot be seen by human eyes, and therefore, have no "color." Visual representation of X-ray data, as well as radio, infrared, ultraviolet, and gamma, involves the use of "false color" techniques, where colors in the image represent intensity, energy, temperature, or another property of the radiation. Scientists use different "false colors" to highlight different properties of the astronomical object being studied. Ultimately, it is important that anyone viewing these images understands that "false color" image processing is being used and the object would not have this appearance if viewed by the naked human eye.

The purpose of this activity is to “gently” go through the steps of data and image processing with actual data from the Chandra X-ray Observatory. You will develop that data shown in the image, and also, the "false colors" used to display the image.

Question: How do space telescopes collect data and how do we turn that data into images ?

Background: *(write a few things that you already know pertaining to about the question above)*

Materials:
Calculator
Colored Pencils (with at least five different colors for each student group)

Procedure:
Read the following passage and scenario. Complete tasks A, B, and C.
In 1680, the British astronomer John Flamsteed observed a bright star that was never seen again. Evidence indicates that this bright star was the explosion that produced Cassiopeia A (Cas A) located in the constellation Cassiopeia, it is 10 light years across and 10,000 light years from Earth.

The observed expansion rate and the observed size of the supernova remnant, give an estimate of the age of about 320 years, near the same time that Flamsteed observed the bright star. The distance to Cas A is approximately 10,000 light years, so the explosion really occurred 10,319 years ago. When astronomers talk about such events, they are more interested in the age of the remnant as we see it, which is important for understanding its evolution. They take for granted that the actual event occurred earlier because of light travel time.

In this activity, you will use data collected from the Chandra X-ray Observatory to calculate the average pixel intensity of X-ray emissions from a supernova remnant. In order to do this, you will need to average pixel intensity levels into range levels and associate image colors to each level to create an image of a supernova remnant.

If it helps, you can find more information on Chandra and space telescopes at these websites:
The Chandra Mission http://chandra.harvard.edu/about/axaf_mission.html
Data Collection Instruments on Chandra http://chandra.harvard.edu/about/science_instruments.html
Chandra Images and False Color http://chandra.harvard.edu/photo/false_color.html

The Scenario

You and your partner have just discovered a brilliant new supernova remnant using the Chandra X-ray Observatory. The Director of NASA Deep Space Research has heard of your discovery and wants a report of your results in her office in 45 minutes. Unfortunately, your computer crashed fatally while you were creating an awesome image of the supernova remnant from the numerical data. Because the NASA director always wants to see cool images (not numbers) of newly discovered objects, you and your partner will have to create, by hand, an image of the supernova remnant.

To create the image, you and your partner will have to use "raw" data processed from the Chandra satellite. You have tables of the data, but during the excitement of the computer crash, you spilled soda over some of the information and will have to recalculate some values.

In addition to the graph, you and your partner will have to prepare a written explanation of your discovery and answer a few of the Director's questions.

Your Tasks

Before you are ready to present your findings to the NASA director, you will need to complete the following tasks.

Task A: Calculations

1. Your mission is to turn "boring" numbers into a super-cool picture. Before you can make the image, you will need to make some calculations.
2. The raw data for the destroyed "pixels" (grid squares containing a value and color) are listed in Table 1. Before making the image, you will need to fill in the last column of Table 1 by calculating average X-ray intensity for each pixel.
3. After you have determined average pixel values for the destroyed pixels, write the numerical values in the proper box (pixel) of the attached grid. Many of the pixel values are already on the grid, but you have to fill in the blank pixels. This is the grid in which you and your partner will draw the image.

Task B: Coloring the Image

You and your partner will need to complete the following steps in coloring the image.
Important Note: read all the instructions carefully before you start coloring!
1. You are allowed to use five and only five colors in drawing your image.
2. Each of the five colors will represent a range of intensity values. You and your partner should select the range of intensities assigned to each color. Fill in these range values and associated colors on the legend at the bottom of the image grid sheet.
3. Hint: as you assign colors to ranges, it is best to pick colors that are “close” to each other as you move from one range to another. For example, in the range with the lowest intensities you may assign the color red. In the next lowest range, you would then assign the color orange, rather than indigo. Before proceeding, have the instructor check you assigned colors.
4. Using colored pencils, shade in the grid using your color legend.

Analysis:
Answer the following questions on lined paper in complete sentences which restate the question in your answer.

1. In the table, some of the data were missing. In 3-4 sentences, describe how you “handled” these missing data in making your calculations and coloring your image.
2. Write a detailed description (1-2 paragraphs) of the prominent features of the supernova remnant. Be sure to describe how the image shows a fast outer shock wave, and a slower inner shock wave.
3. Because your computer crashed, you had to draw the image by hand. In 3-4 sentences, explain why would it have been easier to use a computer? (In your answer, consider that the Chandra satellite actually sends millions of data from each observation and how long it would take to process millions of data by hand).
4. Draw an artist’s impression drawing of what the actual supernova remnant would “look” like.

Table 1.
“Raw” data of the newly discovered supernova remnant collected from the Chandra X-ray observatory.

Mission Grid Coordinate	Number of X-ray Photons Detected					Average Number of Photons
	Observation 1	Observation 2	Observation 3	Observation 4	Observation 5	
A4	39	40	40	42	42	
B6	59	61	62	60	58	
B7	62	71	missing	63	missing	
B8	64	68	71	71	72	
C3	50	54	52	50	54	
C6	33	missing	missing	31	38	
C10	64	63	61	64	missing	
D2	41	missing	missing	missing	43	
D6	104	missing	105	108	108	
D7	140	144	142	141	137	
D10	62	50	57	50	52	
E7	41	43	43	36	40	
E8	214	210	210	210	214	
F2	missing	49	49	47	47	
F4	153	missing	154	155	156	
F6	148	135	missing	missing	130	
F8	152	141	147	145	144	
G2	49	51	48	50	missing	
G4	130	123	missing	missing	124	
H2	51	49	53	50	50	
H3	34	25	38	31	26	
H4	115	114	missing	128	123	
H6	95	97	missing	missing	missing	
H8	115	115	115	113	112	
H10	73	83	missing	80	81	
I3	missing	39	35	37	42	
I5	58	69	54	missing	65	
I9	68	77	80	81	missing	
J6	46	49	55	missing	48	
J7	61	69	79	74	54	

Supernova Remnant Image Grid

	A	B	C	D	E	F	G	H	I	J	K
1	0	1	1	1	1	1	1	1	1	1	1
2	2	5	35		48				46	18	7
3	23	36		35	30	27	21			13	0
4		43	24	8	216				54	21	3
5	36	58	37	44	36	20	33	105		23	4
6	32				12		18		24		17
7	24		32			17	12	126	64		21
8	18		36	237			155		22	74	6
9	16	75	38	34	26	12	14	21		37	4
10	8	71			42	23	64		31	16	2
11	3	3	2	1	0	0	2	0	1	0	0

Legend

Average number of photons					
Color					

Understanding the Starry Sky

Introduction:
When you go outside on a dark clear night and look up into the night sky you will see hundreds if not thousands of stars randomly spread across the sky. How do you tell one from another? The answer is you learn the constellations.
If you were shown a map of the world you could easily recognize the continents and countries and would be able to pick out cities and towns. The constellations help by breaking up the sky into more manageable bits like recognizing the continents, countries and cities on a map.
Question: What is a constellation?

Background: *(write a few things that you already know pertaining to about the question above)*

Vocabulary:
Constellation-

Circumpolar constellations-

Zodiac-

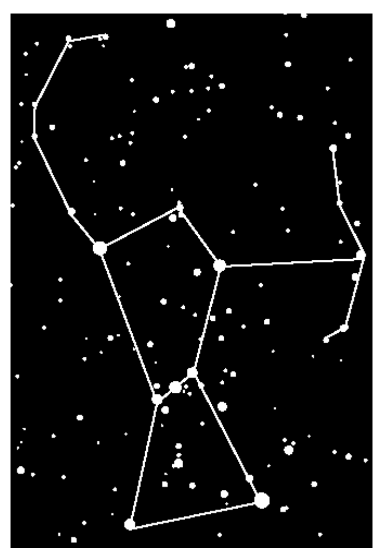
Right Ascension-

Declination-

Materials: This handout

Procedure:
Read through the following passage.

What are constellations?
Constellations are "pictures" in the sky that ancient astronomers perceived by imagining lines or relations between stars that appear grouped. We call the connect-the-dot patterns formed by the brighter stars constellations. A simple, geometric star pattern lies at the heart of each constellation. A constellation is a group of bright stars that form prominent patterns in the night sky, which have been historically ascribed to mythological figures. Constellations depict people, inanimate objects, real animals (birds, insects, and land and water creatures), and mythological animals (serpents, dragons, and flying horses).



Generally, there is little similarity between the geometric star pattern on which the constellation is based and the fully detailed drawing of the constellation. For example, the winter constellation, Orion, the Hunter, with four bright stars at the corners of a trapezoid and three stars in a row near the center, doesn't look much like a person.

A Brief History:
Throughout the centuries, people have looked to the stars to help them navigate across open oceans and deserts, know when to plant and harvest, and preserve their myths and folklore. Ancient peoples used the appearance or disappearance of certain stars over the course of each year to mark the changing seasons.

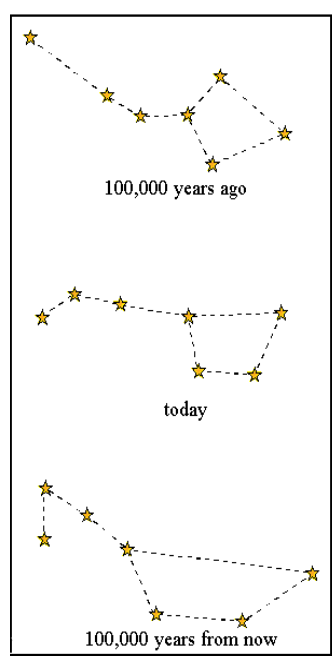
Our modern constellation system comes to us from the ancient Greeks. The oldest description of the constellations as we know them comes from a poem, called *Phaenomena,* written about 270 B.C. by the Greek poet Aratus. However, it is clear from the poem that the constellation patterns mentioned originated long before Arutus' time. No one is sure exactly where, when or by whom they were invented, but it is thought they originated with the ancient Babylonians and Sumerians. From there, the tradition of the constellations somehow made its way to Egypt, where early Greek scholars first heard about the constellations and wrote about them.

Today, Astronomers officially recognize 88 constellations covering the entire sky, in the Northern and Southern hemispheres. Currently 14 men and women, nine birds, two insects, 19 land animals, 10 water creatures, two centaurs, one head of hair, a serpent, a dragon, a flying horse, a river and 29 inanimate objects are represented in the night sky.

With few exceptions, the stars in any given constellation have no connection with one another. They are actually at vary different distances from the sun. Chance alignments of stars have created the patterns we see in the sky. These alignments are not permanent, however; they just seem that way during our short life times. The patterns the stars form still look much the same today as they did when the constellations were first named nearly 3,000 years ago, the stars seem almost "fixed" in place.

The stars are all moving relative to the Sun and each other, most with speeds of many kilometers per second. Because they are so very far away, it will take thousands of lifetimes to see significant changes in the star patterns. But, over time, they will change. As a result of the motions of the stars within it, for example, the handle of the Big Dipper will in about 50,000 years appear significantly more bent than it is today.

Zodiac:
As you hopefully know, the Earth orbits around the sun, completing one circuit every year. Because we are moving, we have a different viewpoint of the sun and sky every day. In particular, the sun appears to move against the background stars, completing one full trip around our sky in a year. The sun always appears to go past the same stars around the sky every year. This is because the Earth repeats its orbit every year, and so at the same time every year we have the exact same view of the sun and the stars. This path is called the ecliptic.



The zodiac is the group of constellations through which the ecliptic passes. In other words, over the course of a year, the sun passes through all of these constellations. Traditionally, the zodiac contained twelve constellations. The number of constellations is not an accident -- since many cultures have 12 months in a year (corresponding to the roughly 12 cycles of the moon that fit into a single year), ancient astronomers thought it made a nice balance if the number of constellations equaled the number of months in a year. The twelve zodiac constellations and their corresponding dates are below:

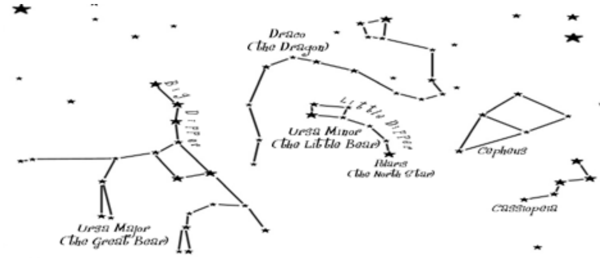
Sign	Begin	End
Aquarius	January, 21	February, 19
Pisces	February, 20	March, 20
Aries	March, 21	April, 20
Taurus	April, 21	May, 21
Gemini	May, 22	June, 21
Cancer	June, 22	July, 22
Leo	July, 23	August, 21
Virgo	August, 22	September, 23
Libra	September, 24	October, 23
Scorpio	October, 24	November, 22
Sagittarius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

Precession:
Watch a top spinning. In addition to spinning on its axis, a top will often wobble a bit. Earth, spinning daily on its axis like a top, also wobbles. This wobble, or precession, of Earth's axis takes 26,000 years for one complete cycle. This precession causes Earth's axis to point to different parts of the sky over the complete 26,000 year period. Hence the north star which is currently Polaris, changes with a 26,000 year cycle. Vega will be our north star for a time in the distant future.

The precession of Earth's axis is caused mainly by the tug of the gravity of the Sun and Moon on Earth's equatorial bulge. This wobble or precession has caused the intersection point between the celestial equator and the ecliptic to move almost a whole month relative to the stars beyond. For instance, those born between March 21 and April 19 consider themselves to be Aries. Today from March 11 to April 18 the Sun is actually in the constellation Pisces. You will find that once precession is taken into account your zodiac sign is different. Check out your real zodiac sign below:

Capricorn - Jan 20 to Feb 16
Aquarius - Feb 16 to Mar 11
Pisces - Mar 11 to Apr 18
Aries - Apr 18 to May 13
Taurus - May 13 to Jun 21
Gemini - Jun 21 to Jul 20
Cancer - Jul 20 to Aug 10
Leo - Aug 10 to Sep 16
Virgo - Sep 16 to Oct 30
Libra - Oct 30 to Nov 23
Scorpius - Nov 23 to Nov 29
Ophiuchus - Nov 29 to Dec 17
Sagittarius - Dec 17 to Jan 20

Circumpolar Constellations:
Depending on where you live some constellations are visible all year round and some constellations are seasonal. Because we live in the Northern Hemisphere the constellations that circle around the North Star "polaris" are visible all year. They are called circumpolar constellations because they travel in circles around it which mean they never rise or set. There are five main circumpolar constellations in the Northern Hemisphere Ursa Major, Ursa Minor, Draco, Cepheus, and Cassiopeia. Conversely in the Southern Hemisphere the three main constellations that are always visible in the night sky are Crux, Centaaurus, and Carina.



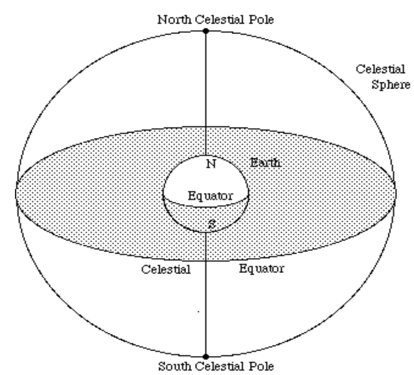
Right Ascension and Declination:
Right Ascension (RA) and Declination (Dec) are the names of the coordinates used to specify the position of an object, such as a star, in the sky. They are very similar to the Earth-based coordinates of longitude and latitude.

Declination is very much like latitude on the Earth. A Dec of 0 degreed points to the "Celestial Equator" just like a latitude of 0 is at the Equator. Similarly, a Dec of +90 degrees points to the "North Celestial Pole" and -90 degrees points to the "South Celestial Pole." The word Celestial is used to distinguish between, for example, the North Pole in the sky and the North Pole on the Earth. The Celestial Poles lie directly above the Poles on the Earth, so if you were at the North Pole, the North Celestial Pole would be directly overhead. Keep in mind that the places on the so-called Celestial Sphere are *directions* not *positions* . Two stars that appear next to each other on the sky may actually be very far apart in reality if one is much further away from the other.

Right Ascension is similar to longitude on the Earth, however it is numbered differently. Longitude starts at 0 degrees at the Prime Meridian and goes to 180 degree East or 180 degrees West. Since the Earth is a sphere, 180 E is equal to 180 W. Right Ascension, on the other hand, is measured in hours instead of degrees. It starts at 0 hours at the Vernal Equinox point and goes all the way around to 24 hours which is at the same place as 0 hours. So a star that has an RA of 12 hours is on the opposite side of the sky from one that is at 0 hours. The tricky part about RA is that the Vernal Equinox point doesn't stay still like the Prime Meridian does. As the Earth rotates, the Vernal Equinox point moves.

Analysis:
Answer the following questions on lined paper.

1. Why did ancient peoples rely on the constellations?
2. Are the constellations we see today fixed or will they change? Why or why not?
3. Explain why we see the North circumpolar constellations all year long?
4. Describe what the celestial equator and the North celestial pole are?
5. Explain why there are 12 constellations that make up the zodiac?
6. What is precession?
7. Do you think Earth’s axis will always point at the north star? Why or why not? Explain
8. What is the celestial sphere?
9. How did the precession of the Earth change your zodiac sign? What was it and what is it now?
10. Draw a diagram similar to the one below.
    On **that** diagram mark the following:
    A - where a a star might have a Dec. of +45
    B - where a star would have a Dec. of -45
    C - where a star would have a Dec. of +90



Astronomy vs. Astrology Activity

Introduction:
There was a time when astronomy and astrology were the same. The ancient astronomers believed that the Sun, Moon and planets were symbols of the Gods. Hence the planets have names from Greek and Roman mythology. Originally, these bodies were believed to influence the fortunes of kings and nations. The ancient Chinese astronomers had possibly the most detailed and accurate records of the sky, because Chinese emperors believed that the heavens sent signs and good omens for their dynasty. The Greeks introduced the notion that the planets influenced each and every person, not just the nobility. This notion was formalized by Ptolemy in 110BC. Many centuries later, the famous astronomer, Tycho Brahe (1546-1601) made his living by drawing horoscopes for the wealthy while he pursued his research measuring the movements of the stars and planets. Today, however, astrology and astronomy are quite distinct.

Question: Does modern Astrology have any merit with modern Astronomy?

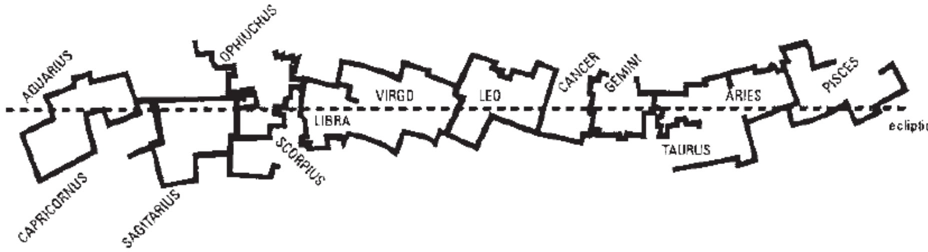
Background: *(write a few sentences of what you already know about what is asked in the above question)*

Vocabulary:
Astronomy
Astrology
Constellations
Signs of the Zodiac
Horoscopes

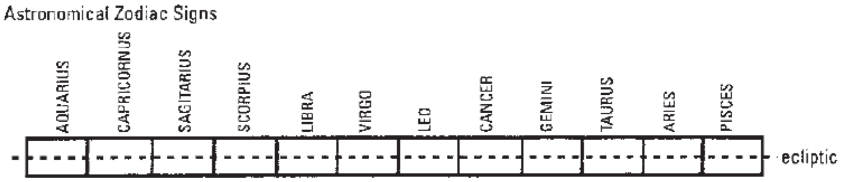
Materials:
Signs of the Zodiac chart (in this assignment)
Daily horoscope

Procedure:
Read the following passage and review the charts that follow.
In Ptolemy's time, over 2000 years ago, the Sun, Moon and planets as viewed from Earth moved through 12 constellations. These constellations are known as the zodiac constellations. According to astrologers, whichever of these 12 constellations lay behind the Sun when you were born is your star sign. Most astrologers today still base their star signs and charts on those established by Ptolemy, and use them to somehow make predications about things like who to marry or when to buy a lottery ticket.

In the 2000 years since the time of Ptolemy, the path of the Sun across the sky has changed due to the precession of the Earth. The Earth is like a spinning top that slowly wobbles on its axis. This causes the position of the Celestial Poles to shift and alters the apparent path of the Sun across the sky. The Sun now passes through the 12 zodiac constellations at quite different times than was the case 2000 years ago, and now spends more than two weeks in a 13th constellation – Ophiuchus (the Serpent Holder). Astrological signs assume that the Sun takes an equal amount of time to move through each zodiac constellation. This is not the case. The time the Sun spends in each constellation varies considerably, as the following table demonstrates. Compare your astrological and astronomical star signs. Are they the same?



Astronomical Zodiac Signs



Astrological Zodiac Signs

Constellation	Astrological Zodiac	Astronomical Zodiac
Aries	21 March – 20 April	19 April – 13 May (25 days)
Taurus	21 April – 21 May	14 May – 19 June (37 days)
Gemini	22 May – 21 June	20 June – 20 July (31 days)
Cancer	22 June – 22 July	21 July – 9 August (20 days)
Leo	23 July – 23 August	10 Aug – 15 Sept (37 days)
Virgo	24 Aug – 23 Sept	16 Sept – 30 Oct (45 days)
Libra	24 Sept – 23 Oct	31 Oct – 22 Nov (23 days)
Scorpio	24 Oct – 22 Nov	23 Nov – 29 Nov (7 days)
Ophiuchus	Not recognised as a sign of the zodiac by astrologers	30 Nov – 17 Dec (18 days)
Sagittarius	23 Nov – 21 Dec	18 Dec – 18 Jan (32 days)
Capricorn	22 Dec – 20 Jan	19 Jan – 15 Feb (28 days)
Aquarius	21 Jan – 19 Feb	16 Feb – 11 March (24 days)
Pisces	20 Feb – 20 March	12 March – 18 April (38 days)

What to do

1. Cut out the twelve horoscopes from a publication (newspaper, magazine, website).
2. On the back of each horoscope sign, write the name of the astrological sign.
3. Cut off the dates and zodiac designations of all twelve.
4. Trade your set of horoscopes with a classmate.
5. Read through the astrologer's predictions, choosing the prediction that most accurately describes their past days.
6. Have them write the birth date and zodiac sign above each of his or her chosen predictions.
7. Flip the horoscopes over and see how close you were to being correct.

Analysis:

Answer the following questions on lined paper in complete sentences which restate the question in your answer.

1. Tally up how many 'hits' and 'misses' you had were.
2. Do you think that the position of the Sun when you were born can determine your future? Why so?
3. Find another person in the class that has the same astrological sign as you. Compare similarities and differences.
4. How did your tally results compare with your lab and table partners?
5. Is astrology a science or an entertainment?
6. Why do you think people follow astrology?

If you're still a skeptic, you can also collect several horoscope columns for the same day or week and compare the predictions and statements of different astrologers for the same star sign.

ARIES (March 21-April 19): Even the least-important transactions may run smoothly. Expect to receive a helping hand just when you need it from someone who anticipates your needs. Make purchases of items of taste or beauty.

LEO (July 23-Aug. 22): You offer a desirable package just as you are; no plain brown wrapping paper is needed, as you have nothing to hide. It is quite easy for singles to find a congenial partner under these stars.

SAGITTARIUS (Nov. 22-Dec. 21): Bridges can be built. You might finally understand another person's point of view. A financial investment technique that has been fuzzy might come into focus. Extend a firm hand in friendship.

TAURUS (April 20-May 20): Your fair share might last a lifetime. Find ways to show solidarity and support for those who put their money or their time on the line for your benefit. Romantic moments can multiply under these stars.

VIRGO (Aug. 23-Sept. 22): A bed of roses shouldn't have thorns. Add some whimsical decorating touches to your home and turn it into your castle. A relationship matter that has caused doubts or worries will clear up.

CAPRICORN (Dec. 22-Jan. 19): Charity begins at home. Acts of kindness can make you feel that you are living on top of a pedestal. Take time to approach others with ideas or heart-to-heart talks. Buy items that must be durable.

GEMINI (May 21-June 20): You are smarter than you think. What some people view as evasiveness might work in your favor. In some instances, it is better to escape from a difficult situation instead of facing it.

LIBRA (Sept. 23-Oct. 22): Friends and lovers should not be confused. Consider it a privilege to meet new acquaintances or to offer help to a stranger. Group activities, however, could distract you from key one-on-one moments.

AQUARIUS (Jan. 20-Feb. 18): Beauty lies in the eye of the beholder, so give those eyes something to see. Pay attention to your appearance. Shine your shoes, get a haircut or put together an outfit that tells the world you have arrived.

CANCER (June 21-July 22): When you have made your bed, sleep in it. The story of the princess and the pea may bring home a message for you. Too much sensitivity to peer pressure can cause turbulence or misunderstandings.

SCORPIO (Oct. 23-Nov. 21): Groups or organizations can eat up your social calendar. It may be difficult to have some one-on-one time. Someone might prove understanding or intuitively say the perfect thing to put doubts to rest.

PISCES (Feb. 19-March 20): You can never have too much money or too many friends. The problem might be that the friends want too much of your money. The more you share with others, the more you will receive in return.

Even the least-important transactions may run smoothly. Expect to receive a helping hand just when you need it from someone who anticipates your needs. Make purchases of items of taste or beauty.

You offer a desirable package just as you are; no plain brown wrapping paper is needed, as you have nothing to hide. It is quite easy for singles to find a congenial partner under these stars.

Bridges can be built. You might finally understand another person's point of view. A financial investment technique that has been fuzzy might come into focus. Extend a firm hand in friendship.

Your fair share might last a lifetime. Find ways to show solidarity and support for those who put their money or their time on the line for your benefit. Romantic moments can multiply under these stars.

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Groups or organizations can eat up your social calendar. It may be difficult to have some one-on-one time. Someone might prove understanding or intuitively say the perfect thing to put doubts to rest.

You can never have too much money or too many friends. The problem might be that the friends want too much of your money. The more you share with others, the more you will receive in return.

"Backward" Motion of Planets

Introduction
Planets tend to move across the sky in an easterly direction. Occasionally, something strange occurs. A planet appears to slow down and begin moving backward toward the west. In this activity you are going to find out why this happens. The diagram below represents a part of our solar system. Earth and Mars are shown at several positions in their orbits around the sun. Each position is labeled with the name of the month when the planet will be located there.

Question: What causes some planets to appear to move backward across the sky?

Background: *(write a few things that you already know pertaining to about the question above)*

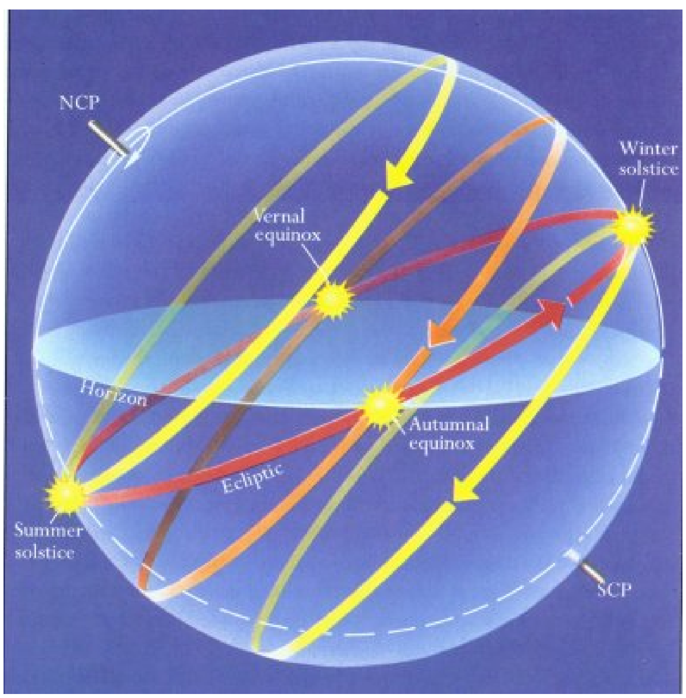
Vocabulary:
Ecliptic
Retrograde motion

Materials:
This lab sheet

Procedure:

Read through the following passage and complete the assignment that follows.

THE ECLIPTIC:



Though in truth the Earth orbits the Sun, we feel stationary, which makes the Sun appear to go around the Earth once a year in the counterclockwise direction (from west to east, counter to its daily motion across the sky) along a steady path called the ecliptic. Since there are 365 (actually 365.2422...) days in the year, and 360° in the circle, the Sun moves to the east at the slow pace of only a bit under a degree per day. At the same time it is constantly moving (rather, appearing to move) from east to west as a result of the Earth's rotation, just at a pace slightly slower than the stars because of its simultaneous easterly drift. The perpendiculars to the ecliptic plane define the ecliptic poles. The North Ecliptic Pole is in Draco, the South Ecliptic Pole in Dorado.

The Earth's axis is tilted relative to the perpendiculars to the ecliptic plane by an angle of 23.4° (separating the celestial and ecliptic poles by the same angle), which causes the circle of the ecliptic to be tilted relative to the celestial equator again by the same angle, which as a result is called the obliquity of the ecliptic. As it moves along the ecliptic against the background stars, which are there even if you cannot see them against the blue sky, the Sun therefore appears also to move north and south of the celestial equator.

As the Sun traverses the ecliptic path, it appears to move against a band of 12 ancient constellations called the Zodiac, which in traditional order are:
Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpius, Sagittarius, Capricornus, Aquarius, Pisces

RETROGRADE & PROGRADE:

Retrograde motion is an APPARENT change in the movement of the planet through the sky. It is not REAL in that the planet does not physically start moving backwards in its orbit. It just appears to do so because of the relative positions of the planet and Earth and how they are moving around the Sun.

Normally, the planets move west-to-east through the stars at night. This is referred to as prograde motion. However, periodically the motion changes and they move east-to-west through the stars. We call this retrograde motion. The retrograde motion continues for a short time and then the motion switches back to prograde. This seemingly strange behavior is easily understood within the context of a Sun-centered (heliocentric) solar system. The explanation for retrograde motion in a heliocentric model is that retrograde occurs roughly when a faster moving planet catches up to and passes a slower moving planet.

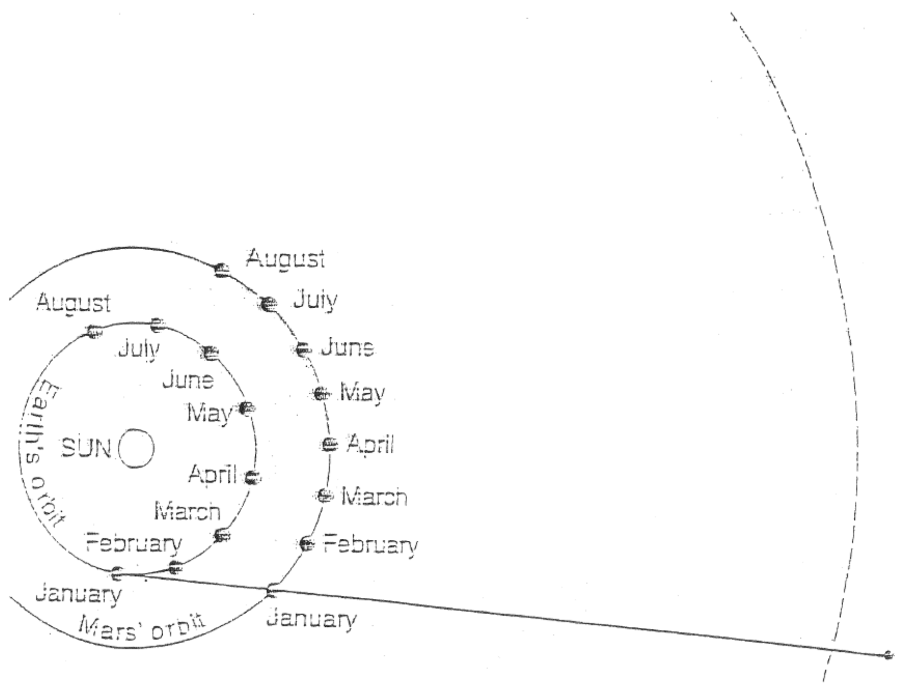
How the planet Mars would appear to have both prograde then retrograde then prograde motion is shown in the diagram below. Notice that it is all due to the fact that the Earth moves faster in its orbit than does Mars. So as we catch up to that planet in its orbit and then move beyond it, the motion appears to go through the pro-retro-pro cycle.

Read through the following passage and follow the steps as listed.

A. Trace the following diagram onto your lab sheet.

B. On your diagram, draw a line from each Earth position through the Mars position for the same month. Extend the line approximately one centimeter past the dashed line. Place a dot at the end of the line and label the dots in order, with the dot on the January line being number 1, the dot on the February line being number 2, and so on. **IMPORTANT:** Draw the lines that pass through the May and June positions slightly longer and place the dots slightly farther away than you did for the other lines. Notice that the line for January is already drawn and the dot is labeled.

C. Using a pencil, start with the dot labeled “1” and carefully connect the dots in order. This line represents the path the planet Mars would follow in the orbit around the sun as seen from Earth.



The dots that you put at the ends of the lines represent the positions where an observer on Earth would see Mars for the month indicated on the diagram. The line you drew connecting the dots represents the path Mars appears to follow.

Analysis:
Answer the following questions on a separate sheet of paper.

1. What is the ecliptic?

2. What is meant by retrograde motion?

3. What are the 12 ancient constellations?

4. What movement does Mars actually experience from January through August?

5. To an observer on Earth, what movement does Mars appear to experience during that time period?

6. During which of the following months does Mars appear to be moving backward in the orbit; January, March, May or July?

7. Carefully observe what is happening to Earth and Mars in their orbits when Mars seems to loop "backward." What causes Mars to seem to move backward in its orbit?

8. Do you think that to an observer on Earth all the planets visible in the night sky would appear at some point to move backward?

9. Explain your answer to the last question.

10. Why would it be very difficult to observe Mercury and Venus to see if they experience such backward motion?

Parallax and Stellar Distances Lab

Introduction:
How are astronomers able to say that a star was a certain distance away from Earth when they've never been able to travel to the star to measure the distance? Astronomers and mathematicians are clever people that work well in solving challenging problems together. Stellar distances can be determined using proven principles, relationships and mathematical equations that have proven accurate on smaller scales, here on planet Earth.

Our star, Sol, appears much larger than all other stars in the night sky because it is so much closer to us than all the others. Sol is an average of 93,000,000 miles from Earth. In general, as distance between objects decreases, the apparent size of objects will increase.

As if the large distance of 93,000,000 miles isn't bad enough, distances to other stars are so much greater. Astronomers have developed units just to make the distances manageable to write and calculate.

Hold your thumb up at arm's length and toward an object such as a clock on the wall. Close your right eye. Then open your right and close your left eye. The clock (or other object) did not move, but it did appear to move. Half the amount that the clock appeared to move is called parallax, the distance of apparent shift of an object against a background.

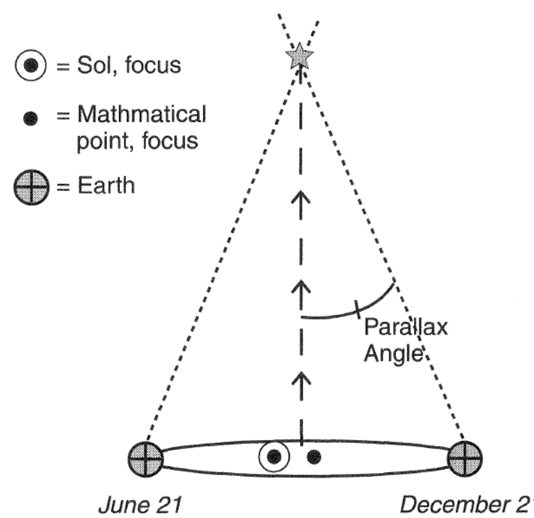
Astronomers don't use their thumb width to determine parallax of stars. They have to use something much bigger ... the entire orbit of Earth! Note the line on the diagram at the left that represents the angle of parallax to this star.

When astronomers observe stars in the night sky using powerful telescopes, they can take photographs to carefully measure the stellar parallax of that star. Then using basic trigonometry (and some other mathematics) they can calculate its distance from Earth.

The unit that is found by measuring parallax is called a parsec and is the equivalent of 3.26 light years or 31 trillion kilometers!

Question: What is parallax and how do we use it to measure distant stars?

Figure A.



Background: *(write a few things that you already know pertaining to about the question above)*

Vocabulary:
Parallax
Clusters
Superclusters
Light Year
Parsec

Materials:

Masking tape	Meter stick	Pen
Pencil	Pin	Rubber stopper

Procedure:

Answer the questions as you read through the parts of the activity.

Helpful definitions and conversions practice:

1 kilometer (km) = _______ m   1 meter (m) = _______ cm

1 centimeter (cm) = ________ mm   1 millimeter (mm) = _______ m

Part 1 - Defining Parallax

As you learned a while back, a circle can be broken up into 360 equal parts we call degrees (360°). If we take a part of that circle, that curved line is called an arc. The length of an arc is also measured in degrees, but we use smaller measurements to measure more precisely. As seen below, we can break a degree into 60 minutes and even further break a minute of angle into seconds of an angle.

1 degree (°) = 60 minutes (')   1 minute (') = 60 seconds (")

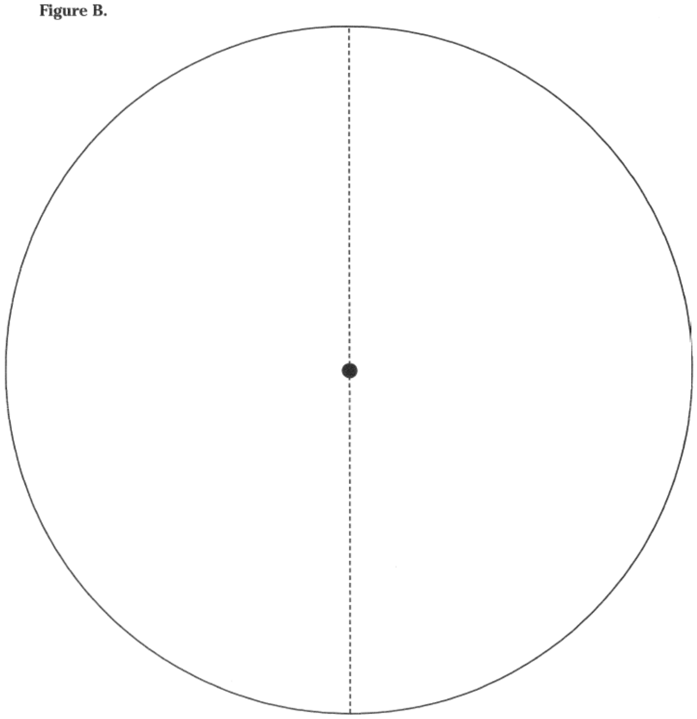
1° = 60'   1" = 60"

Devise a way to accurately split the circle in Figure B into 360 equal arc degrees (wedges). Extend two lines (1 arc degree apart) from the center of the circle to the paper's edge. Hold up your paper and find a distant object that appears to be 1" in size because of its distance to you.

Now, try to split that 1° into 60 equal arc minutes. Breaking an angle into that many points is quite difficult. Now take one of those 60 arc minutes and split it into 60 equal divisions of arc-seconds!

Of course, this is too much. Even your pencil point is too thick to show this accurately.
However, that is the arc distance that astronomers use to measure the distance of one PARSEC.

Figure B.



Stars and objects that measure that width are said to be one parsec away (PARallax SECond).

Part 2 – Measuring Parallax

1. Cut off a 60 cm-long strip of masking tape.
2. Center it on desk so that it runs down the length of the desk vertically.
3. Use a meter stick or ruler to measure sections of the tape and label them as follows:
    a. 0 cm at edge closest to you, to 50 cm at the far end. Mark off 5 cm intervals.
    b. At the 50-cm line, rest a meter perpendicularly (horizontally across the desk)
    c. On tape (the 50-cm line on the tape and the 50-cm line of the meter stick should be aligned). The meter stick should stand on its edge to the numbers can be read at eye level (See step 7.)
4. Stick a pin into a rubber stopper. The head of the pin will be used to represent a "star," and the distance of the pin your eyes is used to represent the distance of a star from Earth.
5. Place the stopper with the straight pin on the 5-cm line of tape. Place your nose at the table edge, close your left eye, and use the pin as a sight line.
6. Determine the value on the meter stick that the line up with. Record this value in the appropriate location on Table 1 (Parallax Data Table).
7. Now your right eye and record this value on Table 1. Continue this procedure to complete the table. Round data to the nearest mm.
8. Graph the data in Table 2. Label the X-axis "Distance (in cm)." Label the Y-axis
9. "Parallax (in cm)."

Table 1. Parallax Data Table

Distance (in cm)	Right Eye (in cm)	Left Eye (in cm)	Difference (=Parallax)

Table 2.

Analysis:

1. State the relationship between distance to a star and its parallax.

2. Why have astronomers developed the units of parsecs to measure distances to stars and galaxies when we have perfectly good kilometers?

3. The following are real stars in the night sky of the Northern. Hemisphere. Their parallax values are presented below. Complete their distances from Earth in light years an Km, just as astronomers do.

Star Name	Parallax (“ of arc)	Light Years from Earth	Km from Earth (Scientific notation)
Alpha Centauri	0.760		
Vega	0.123		
Sirius	0.375		
Polaris	0.005		
Aldebaran	0.048		

4. The diagrams below represent photographs that astronomers work with to determine parallax. These two views same night months apart. If you observe photographs notice that one star does not appear in the same position against background stars in photograph.

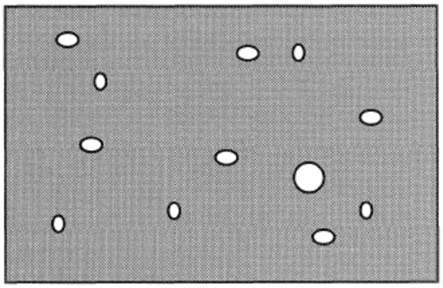


Photo A. Taken on June 21

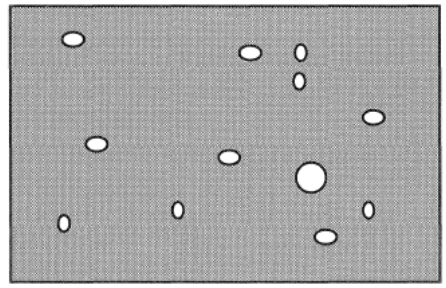


Photo B. Taken on December 21

Scale 1 mm = 0.01 arc second

Complete the following based upon these photographs A and B.

5. On both photographs, circle a star showing a parallax shift.

6. Draw the star from photograph B onto photograph A (be accurate!)

7. Measure the distance between the two stars on photograph A in mm. ________

8. Use this distance to convert the measurement into parallax angle. (use the scale provided).

9. Stellar parallax is half the measured parallax angle of the apparent motion of a star against its background stars. What is the stellar parallax for this star?

10. Calculate the distance in parsecs to this star.

11. Calculate the number of km to this star.

12. Circle a correct choices within the parentheses for the following sentences:

Parsecs are measurements of (time/distance/age/speed).

They are used for distances between (stars/cities/planets/galaxies/clusters/superclusters).

Light Years are measurements of (time/distance/age/speed).

They are used for distances between (stars/cities/planets/galaxies/clusters/superdusters).

Stellar parallax is the method used to measure (distances between galaxies/distances between stars/distances in space).

13. What is parallax?

14. How do we use parallax to measure distant stars?

Kepler’s Laws of Planetary Motion Lab

In the early 1600s, Johannes Kepler proposed three laws of planetary motion. Kepler was able to summarize the carefully collected data of his mentor - Tycho Brahe - with three statements that described the motion of planets in a sun-centered solar system.

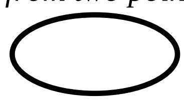
Kepler's three laws of planetary motion can be described as follows:

1. The path of the planets about the sun is elliptical in shape, with the center of the sun being located at one focus. (The Law of Ellipses)
2. An imaginary line drawn from the center of the sun to the center of the planet will sweep out equal areas in equal intervals of time. (The Law of Equal Areas)
3. The ratio of the squares of the periods of any two planets is equal to the ratio of the cubes of their average distances from the sun. (The Law of Harmonies)

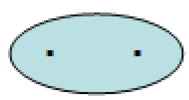
Part 1 - Kepler's First Law

Kepler's first law, often referred to as the law of ellipses, explains that planets are orbiting the sun in a path described as an ellipse. As you will find out in the first part of this lab, Kepler's first law is rather simple - all planets orbit the sun in a path that resembles an ellipse, with the sun being located at one of the foci of that ellipse.

The term ellipse come from the Latin word ellipsis and can be defined as *A curved line forming a closed loop, where the sum of the distances from two points (foci) to every point on the line is constant.*

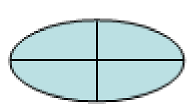


An ellipse looks like a circle that has been squashed into an oval. Things that are in the shape of an ellipse are said to be 'elliptical'. An ellipse is defined by two points, each called a focus. If you take any point on the ellipse, <u>the sum of the distances to the focus points is constant</u>. Later in this lab we'll learn that the size of the ellipse is determined by the sum of these two distances.



The position of the foci (plural of focus, pronounced 'foe-sigh') determine how 'squashed' the ellipse is. The foci always lie on the major (longest) axis, spaced equally each side of the center. If the major axis and minor axis are the same length, the figure is a circle and both foci are at the center.

The major and minor axes of an ellipse are diameters (lines through the center) of the ellipse. The center of an ellipse can be found by finding the midpoint of the line segment linking the two foci. The center of the ellipse is also the intersection of the major and minor axes. If you were to find the center of the ellipse and draw a line across the narrowest part of the ellipse, you have found the minor axis. If you do this again but draw your line across the longest point of the ellipse, you have found the minor axis. For good measure, the focus points always lie on the major (longest) axis, spaced equally each side of the center.



Eccentricity is the measure of the smooshiness or flatness of an ellipse. For this calculation, the focal length and major axis length of each ellipse needs to be determined. Eccentricity is found by dividing the focal length by the length of the major axis. A true circle has an eccentricity of "0." The flattest ellipse possible is a line, where two foci are as far apart as possible, and the eccentricity is "1." All ellipses have eccentricities between 0 and 1.

$$\text{Eccentricity} = \frac{\text{focal length (mm)}}{\text{Length of major axis (mm)}}$$

Unlike most other measurements, eccentricity HAS NO UNITS!

Question: What are the properties of ellipses?

Background: *(write what you already know about the question above)*

Vocabulary:
Ellipse
True circle
Major axis
Minor axis
Focus (singular)
Eccentricity

Materials:

Cardboard measuring 1" x 1", 2	Metric ruler, 30 cm
String, measuring 14 cm long, tied into a loop	T-pins, 2
Sheet of white or colored unlined paper	Stopwatch

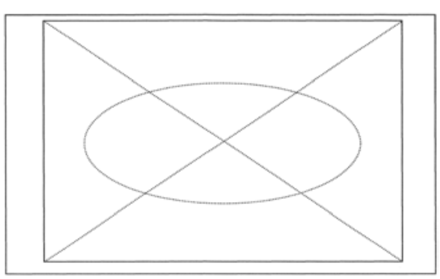
Procedure:
Answer the following questions on lined paper.

Q1. What do you think will happen to the eccentricity of the ellipse when you move the foci farther apart?

Q2. What effect do you think having a larger major axis (and loop of string) will have on the eccentricity of the ellipse?

Follow these steps:

1. Draw a straight, light line in pencil from one corner of a sheet of unlined, horizontal paper to the opposite corner. Repeat this procedure with the remaining two opposite corners. A large "x" should be seen across the unlined paper as seen below:



2. Measure a distance of 3 cm to the right from the center of the paper (where the "x" is located) and make a small mark on the paper. Starting again from the center, measure 3 cm to the left and make another small mark on the paper.

3. Place a sheet of cardboard (1" x 1") under each mark.

4. Place one T-pin in each mark. The two pins should be a total of 6 cm apart. Each pin represents a "focus" of an ellipse.

5. Gently place a 14-cm looped piece of string over the two T-pins.

6. Place the (sharpened) pencil point inside the string loop, keeping the string against the paper. Pull outward gently on the pencil to remove the slack from the string loop. Trace the pattern with the pencil point around the two pins as the string allows. The shape will appear to be an "oval" shape.

7. Label this shape with the words "Ellipse A."

8. Label the two foci as "A".

9. Using Table 1 below, repeat steps 1-8 to draw the remaining two ellipses on the same side of the unlined paper.

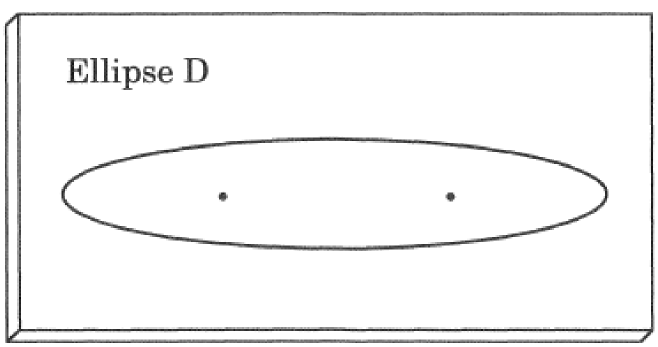
Table 1. Drawing Ellipses

Ellipses	**Foci**	**Place each pin:**	**Focal length**
Ellipse A	#1, #2	3 cm from center	6 cm apart
Ellipse B	#3,#4	1.5 cm from center	3 cm apart
Ellipse C	#5,#6	0.2 cm from center	0.4 cm apart

Analysis:

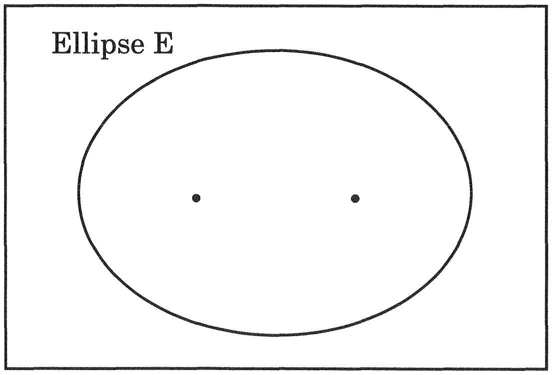
Answer the following questions on lined paper.

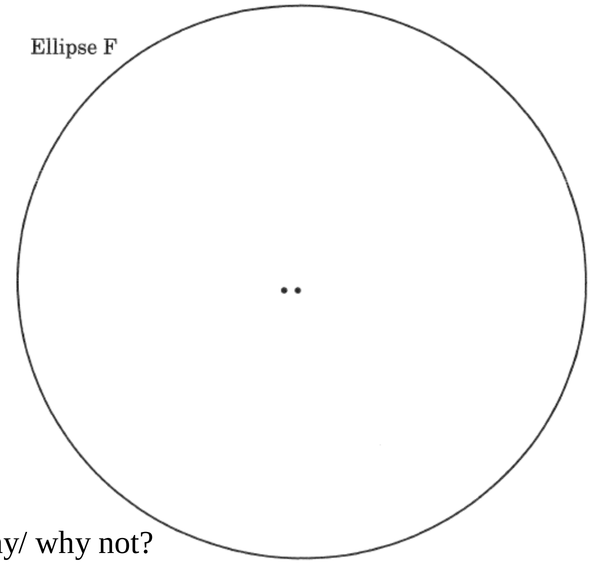
Q3. Calculate the eccentricity for Ellipse D. Use the equation, and **always** show all work. Make all measurement in mm. Round to the nearest *hundredth* place.



Q4. Ellipse D shows the shape of some well known comets that orbit Sol. These follow very eccentric orbits. Describe what "eccentric" means when describing an ellipse.

Q5.. Calculate the eccentricity for Ellipse E. Make all measurement in mm. Round to the nearest hundredth. Show your work.

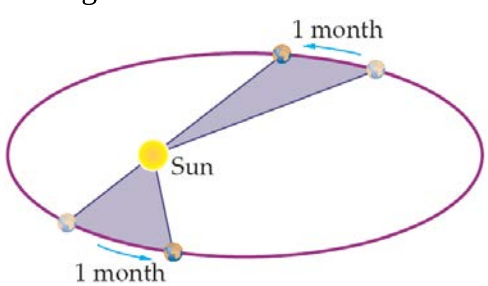




Q6. Was your prediction in question #1 correct? Why/ why not?
Q7. Was your prediction in question #2 correct? Why/ why not?
Q8. Ellipse F represents Earth's Orbit **drawn to** scale. This is how Earth's orbit appears. What shape does it most resemble by eye? What is its actual eccentricity? Show your work.
Q9. How are you able to determine its true shape without taking measurements?
Q10. If Earth's orbit is not a perfect circle, what does that mean for the observations made throughout the year of the apparent diameter of the Sun as seen from planet Earth?
Q11. What relationship is there between an ellipse becoming more eccentric and the appearance of the ellipse?

Part 2 - Kepler's Second Law

Kepler's second law, sometimes referred to as the law of equal areas, describes the speed at which any given planet will move while orbiting the sun. The speed at which any planet moves through space is constantly changing. A planet moves fastest when it is closest to the sun and slowest when it is furthest from the sun. Yet, if an imaginary line were drawn from the center of the planet to the center of the sun, that line would sweep out the same area in equal periods of time. For instance, if an imaginary line were drawn from the earth to the sun, then the area swept out by the line in every 31-day month would be the same. This is depicted in the diagram below.



As can be observed in the diagram, the areas formed when the earth is closest to the sun can be approximated as a wide but short triangle; whereas the areas formed when the earth is farthest from the sun can be approximated as a narrow but long triangle. These areas are the same size. Since the *base* of these triangles are shortest when the earth is farthest from the sun, the earth would have to be moving more slowly in order for this imaginary area to be the same size as when the earth is closest to the sun.

Question: What does the law of equal areas really explain?

Background: *(write what you already know about the question above)*

Vocabulary:
orbit
arc
satellite

Materials:
Planet Q diagram Colored pencils

Answer the following questions on lined paper.

Q12. What do you think will happen to the speed of a satellite as it moves through the course of its elliptical path?

Q13. Other than a planet, what other type of object moves in an elliptical manner?

Procedure:

1. Color in two opposing triangles (sets of opposing triangles have matching letters) on the Satellite Orbit around Planet Q Data Table. These two areas look very different, but in actuality have the same area.

2. Choose a partner to use a stopwatch ("Timer")-and a partner who will move a satellite on the orbit ("Mover").

3. Every 3 seconds, the Timer will call out to the Mover to move the "satellite" along its orbit to the next letter (in a counter-clockwise manner). The Mover must move the satellite through the orbit wedge arc for one entire letter, but take all three seconds to make the move. The Mover must anticipate the rate of motion of the satellite so as not to end up short on time or to go over.

Analysis:

Answer the following questions on lined paper.

Q14. What frame of reference was used for the planet? (its position was always compared to…)

Q15. When the satellite was closest in its orbit to Planet Q, how did the outside arc of the triangles on that side of the ellipse appear compared to the other side of the ellipse?

Q16. As the satellite revolved around Planet Q it physically moved closer to and then farther away while traveling in its orbit. How did this distance affect the force of the gravitational pull between the two objects?

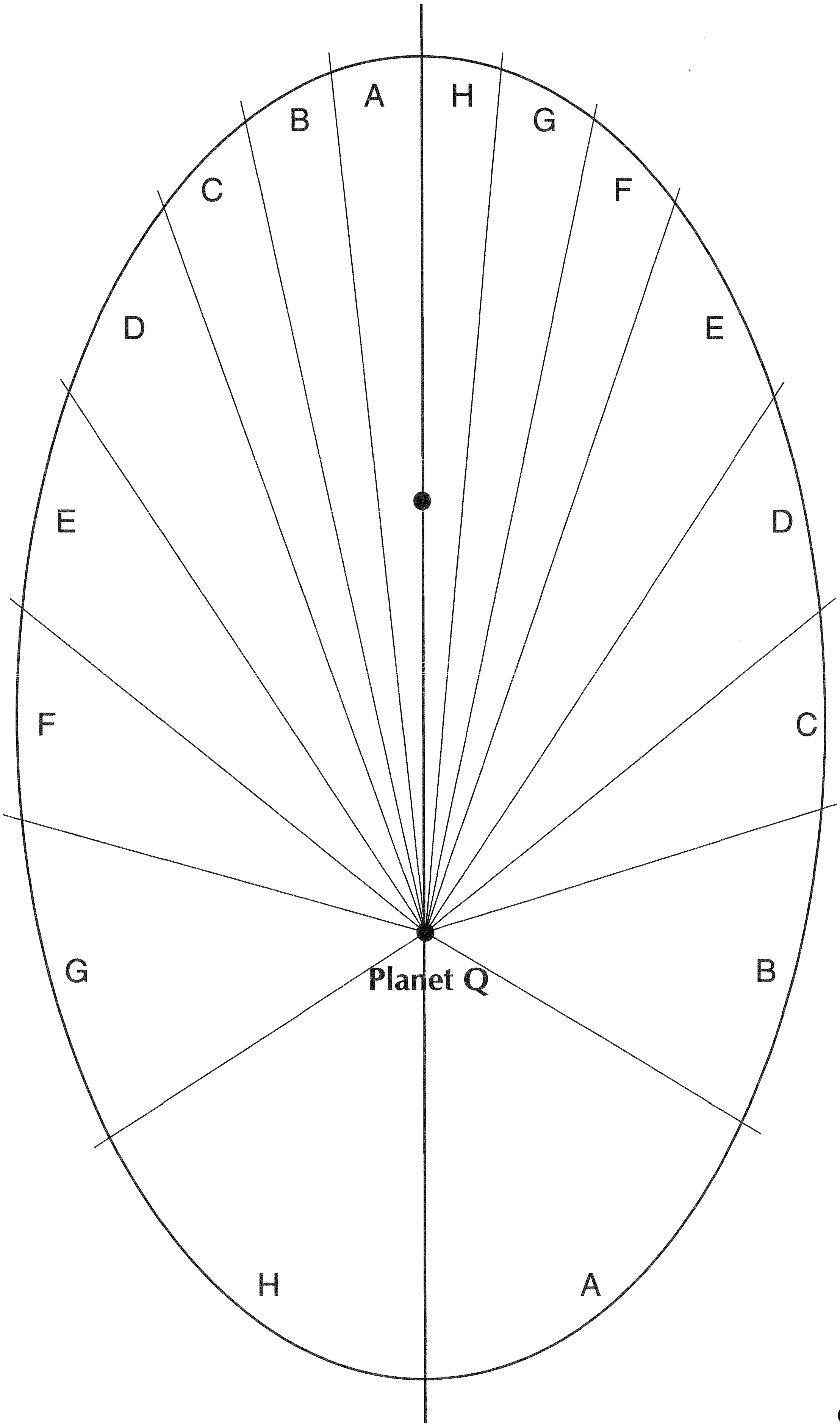
Q17. When the satellite was farthest in its orbit to Planet Q, how did the outside edge of the triangles compare to when it was on the other side of the ellipse?

Q18. For each of the two relationships below, make a small graph showing the relationship between the two factors:

a. Distance and gravitational pull between two objects.
b. Gravitational pull between two objects and orbital velocity.

Q19. Was your prediction in question #1 correct? Why/ why not?

Q20. In your own words, describe Kepler's Second Law.



Q

Part 3 - Kepler's Third Law

Kepler's third law - sometimes referred to as the law of harmonies **-** compares the orbital period and radius of orbit of a planet to those of other planets. Unlike Kepler's first and second laws that describe the motion characteristics of a single planet, the third law makes a comparison between the motion characteristics of different planets. The comparison being made is that the ratio of the squares of the periods to the cubes of their average distances from the sun is the same for every one of the planets. As an illustration, consider the orbital period and average distance from sun (orbital radius) for Earth and mars as given in the table below.

Observe that the T^2/R^3 ratio is the same for Earth as it is for mars. In fact, if the same T^2/R^3 ratio is computed for the other planets, it can be found that this ratio is nearly the same value for all the planets Amazingly, every planet has the same T^2/R^3 ratio.

Question: What does the law of harmonies really explain?

Background: *(write what you already know about the question above)*

Vocabulary:
satellite

Materials:
none

Procedure:
Calculate the missing portions of the chart of planets listed below and write the answers on your assignment sheet:

Planet	Period (in Earth years)	Avg. Distance from Sol (au)	T^2/R^3 (yr^2/au^3)
Mercury	0.241	0.39	
Venus	.615		1.00
	1.00	1.00	1.00
Mars		1.52	1.00
Jupiter	11.8		1.00
Saturn	29.5	9.54	
Uranus		19.18	1.00
Neptune	165		1.00

Analysis:

Answer the following questions on lined paper in complete sentences which restate the question in your answer.

Q21. What would be the value of *g*, acceleration of gravity, if Earth's mass was double its actual value, but its radius remained the same?

Q22. If the radius was doubled, but the mass remained the same? If both the mass and radius were doubled?

Q23. What happens to the period of an object when the distance between the two masses increases?