UNIT 1

Astronomy Basics

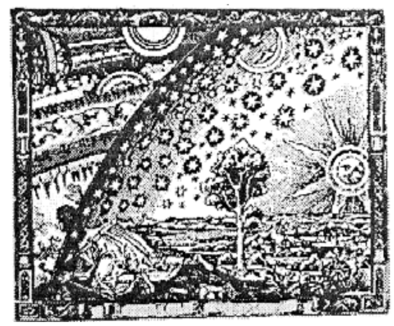
1.1 History of Astronomy

1.2 Basic Concepts of Astronomy

1.3 Earth-Sun Relationship

What Astronomers Do Reading

Introduction:
When you read about an astronomer in your local newspaper, what is the image that comes to your mind? (Before you read on, try this for yourself - close your eyes and picture an astronomer.)



For many people, the picture is a middle-aged man, dressed in warm clothing, in an open dome on a lonely mountaintop, peering intently into the eyepiece of a large telescope, searching for a faint glimmer of light from a distant star. Like so many stereotypes, this one isn't very close to the way things are today.

First of all, more and more astronomers these days are women. While women have made major contributions to the exploration of the universe for centuries, today it has become less and less unusual to find a woman as the director of a major project or observatory, as the featured speaker at a meeting, or as the president of a scientific society.

Question: What do astronomers do?

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

Vocabulary:
Astronomer
Telescope
Amateur
Constellations

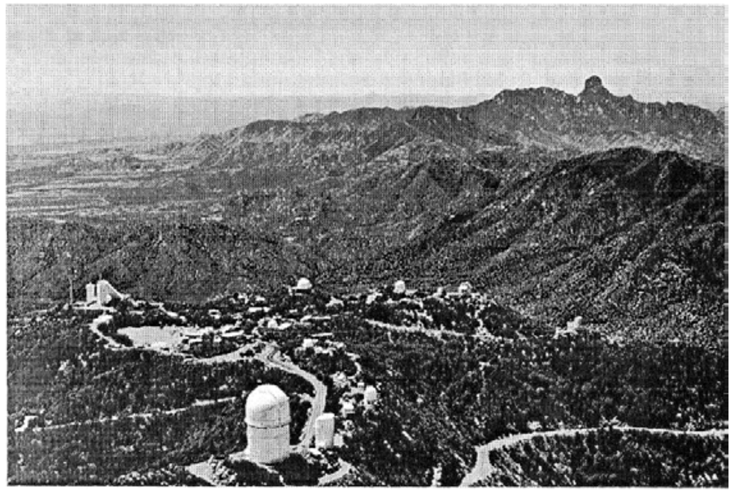
Materials:
This Reading

Procedure:
Read through the following passage.

Very little astronomy is done by looking directly through a large telescope. Rather than letting the faint shafts of light from planets, stars, gas clouds, or galaxies fall temporarily on an unreliable human eye, it is much more efficient to record the light on electronic detectors similar to those found in high-quality digital cameras. The astronomer may look through a smaller telescope to make sure the large instrument stays pointed correctly; but with the advent of computer-controlled pointing and video displays at the larger observatories, even this task can be carried out from another room. Thus warm clothing may no longer be necessary in some places, and astronomers no longer need 20/20 vision.

But perhaps the most important way in which reality differs from the stereotype is that there are many astronomers today who do not use a light -gathering telescope in their work at all. One group employs dish-shaped antennas for searching for natural radio signals from cosmic objects. Many fascinating celestial phenomena, from exploding galaxies to the magnetic field of the giant planet Jupiter, can best be explored by means of the radio static they emit.

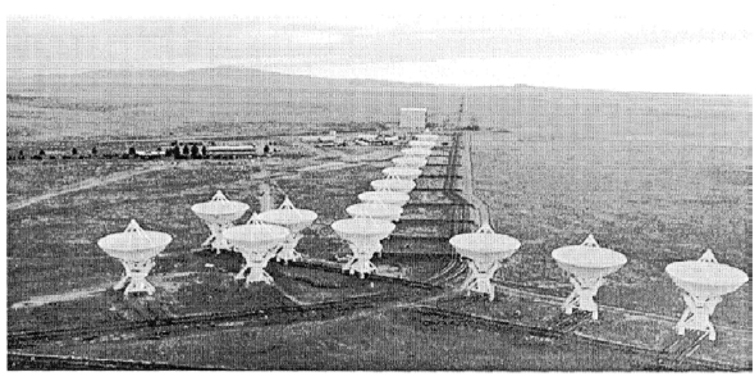
Similarly, there are astronomers who place special instruments at the end of their telescopes to look for infrared (or heat) rays from the stars. Because the Earth's atmosphere filters out many of the infrared rays, these astronomers can found on the world's highest peaks (such as the 14,000-foot summit of the Mauna Kea volcano in Hawaii), in jet aircraft 50,000 feet above the ground, or using telescopes situated in space.



Aerial view of the Kitt Peak National Observatory near Tucson, Arizona. Each dome houses a telescope. (NOAO/AURA/NSF)

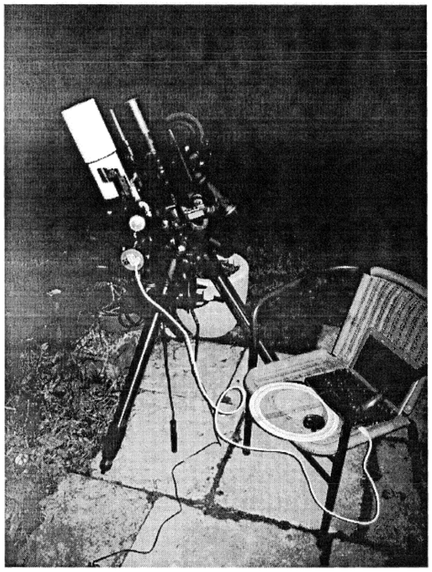
Another group pursues the even more difficult task of detecting high-energy radiation (such as X-rays and gamma rays) from space. These waves do not make it through our atmosphere at all and can only be observed by instruments flown on satellites launched by NASA (and similar organizations in other countries). And a large fraction of modern astronomers never use telescopes at all. These are the theoretical astronomers (or astrophysicists) whose instruments are paper, pencil, or a modern computer, and whose calculations and theories form the groundwork for the planning and interpretation of the observations other astronomers make.

All these astronomers work in a variety of settings around the world. Many are at colleges and universities, others are employed directly by a larger observatory (a facility with one or more telescopes), while still others work for NASA or other governmental agencies.



Some of the radio "dishes" making up the Very Large Array (of radio telescopes) in New Mexico.(Photo by Dave Finley, NRAO)

And we should not forget that many astronomers spend a good part of their time teaching and writing. In planetaria (star theaters), and colleges and universities across the country, many hundreds of talented individuals devote their time to making the often complex results of modern astronomical research comprehensible to students and the public. There is also one way in which astronomy differs from almost all other sciences. Assisting the approximately 6,000 professional astronomers in the U.S., is a large group of amateur astronomers - people in all walks of life for whom astronomy is a hobby and passion. There are still a number of areas where such amateurs can make significant contributions to science - discovering new comets or exploding stars, monitoring weather patterns on other planets, or following the behavior of stars that change their brightness in unexpected ways.



Two amateur telescopes joint on a mount. The one on the left hand side is for tracking and calibrating the mount via a PC, the right one is for photography. (Courtesy of Kapege.de)

Many of these amateurs share their fascination with and knowledge of the universe through school visits, evening "star parties': or an annual "Astronomy Day" in the spring. While their work may differ, there is one common belief which all these astronomers probably share. I think they would agree that their field, while it may not be immediately "relevant" to everyday life, affords us a much broader perspective and deeper view of who we are, where we came from, and where we are going in this awesome immensity we call the universe.

The study of astronomy has captivated humanity since ancient people first began to follow the courses of the planets and stars and learned the rhythms and cycles of the heavens. Today, many people pursue their interest in the universe by reading books about new discoveries, watching video documentaries, or following developments on the Web. Others enjoy getting to know the sky themselves, using binoculars or telescopes, and perhaps joining like-minded hobbyists in a club of amateur astronomers. Here are some suggestions describing various ways to get involved with astronomy.

Becoming an Armchair Astronomer

Most people begin their exploration of astronomy from the comfort of their own home, reading, listening, viewing, or surfing the web. Many colleges and universities offer introductory programs and courses (and open nights) for members of the public during evenings and weekends. Community colleges are often good places to find an inexpensive formal or informal course. For information on such offerings contact the astronomy, physics, or physical science department at your local college.

Members of a nearby amateur astronomy club (see below) can be useful sources of information on good astronomy courses, lectures, and teachers in your area. If you live near a city, chances are there is a planetarium near you that you can visit. A planetarium is a domed theater where a special device projects the entire night sky onto the dome and can often simulate other astronomical scenes as well. Planetaria are often associated with science or nature museums, colleges, high schools, or other educational centers. To find one near you, try the following web sites:

- Planetarium Finder from the International Planetarium Society:
  http://www.ips-planetarium.org/atw
- Planetarium Compendium from Loch Ness Productions:
  http://www.lochnessproductions.com/links/links.html
- Astronomy Organizations from *Sky & Telescope* Magazine:
  http://www.skyandtelescope.com/community/organizations

Larger planetaria often have classes, lectures, workshops and community events and you can subscribe to an electronic newsletter that will keep you informed on what's happening. Even if your local science museum or nature center does not have a built-in planetarium, they may have astronomy programs for schools and the public - give them a call. Some museums may also have "portable planetaria" in which they do programs, both on their own sites or in schools or community settings. Such a portable planetarium involves a dome which can be folded up small for easy transportation and then inflated when it's ready to be used. In Fall 2009, such an inflatable planetarium was set up on the White House lawn and the President of the United States, his family, and kids from around the Washington enjoyed a inside (together with a range of telescopes outside).

Getting to Know the Night Sky

After some time in the armchair, many astronomy enthusiasts get the itch to go outside and start becoming familiar with the night sky. They may enjoy camping or night hiking when the weather is good, or they may have a back yard that is away from city lights. It's at this point that people often rush out and buy an inexpensive telescope, a purchase they may soon come to regret. We suggest approaching the sky in stages - starting with the naked eye, moving on to binoculars, and only then considering a telescope. (Imagine for a moment that you get a terrific telescope tomorrow - how would you use it if you don't know where in the sky to point it?) The first (pleasant) task for beginning stargazers is to

get to know the bright stars and constellations. A planetarium (see above) is a good place to get a first lesson, since the projected sky on a dome is much more realistic than any flat diagram on a page. Almost every planetarium offers a program on getting to know the night sky.

Another excellent source of guidance about the sky is your local amateur astronomy club (see below.) If you have a friend, relative, or teacher who already knows the star patterns, a walk under the stars with that person is probably the best way to begin acquiring star lore. If you don't have such a person in your life, you might consider purchasing the Astronomical Society of the Pacific's Tours of the Night Sky, a set of four recorded audio tours, one for each season, which guides you step by step around the sky. Go to: www.astrosociety.org and click on AstroShop.

A useful device for learning the constellations (star patterns) and the stars they contain is a planisphere, or star finder - a dial-up wheel that lets you set the date and time, and then shows you what star patterns are in the sky at your location. Commercial planispheres are available in many telescope and science supply stores or through astronomy magazines such as Sky & Telescope and Astronomy.

You can also print out a star chart for your location and a particular evening at:

- The Evening Sky Map at Skymaps.com:
  http://www.skymaps.com/
- PBS' Seeing in the Dark TV Show Web Site:
  http://www.pbs.org/seeinginthedark/explore-thesky/your-sky-tonight.html
- Sky & Telescope magazine's Interactive Star Chart:
  http://skychart.skytonight.com/observing/skychart/skychart.asp
- To find the planets currently in the sky, try:
  http://www.lightandmatter.com/planetfinder/en/

A general set of downloadable materials for beginners from Sky & Telescope magazine can be found at: http://www.skyandtelescope.com/howto/basics/GettingStarted in Astronomy.html

One mistake many beginners make is to try to observe the night sky right after leaving a brightly lit room or automobile. The points of light in the sky are quite faint in comparison, and your eyes need time to get adapted to the night. (You experience this same issue when you arrive late for a movie and enter a dark theater. At first, you have trouble seeing things in the dark, but after 15 minutes, your eyes have opened to admit more light and you are perfectly able to see all the garbage under the seat in front of you that earlier patrons have dropped.). We recommend that you give yourself at least 15 minutes to allow your eyes to get adapted to the dark. (That fifteen minute time period is one reason many star gazers like to bring someone along with whom they enjoy spending time in the dark.)

To read a planisphere or sky map when it is dark outside, you will need a flashlight. Unfortunately, a bright white flashlight beam can ruin the dark adaptation of your eyes. Experienced star gazers always bring a red flashlight with them, which doesn't ruin your night vision the way a white beam does. If you don't happen to have a red flashlight (and few of us do), you can make one by rubber-banding a red cloth or red cellophane on a regular flashlight. Even a single-layer grocery bag from the supermarket can serve as a way of making a sort-of-red flashlight. Bear in mind that the sky can at first seem confusing, with too many stars and too many possible connect-the-dots patterns. It's like getting to know the layout of a new city - you rarely feel oriented after only one day of exploration. Give yourself many nights and many chances before you get mad at yourself for not being a sky expert.

Binoculars

Once you know the sky a little bit, and can identify some star patterns and recognize which of the bright points up there are the planets, you may be ready for a star gazing instrument. You or someone you know may already have such an instrument at home or at school - a pair of binoculars. Since these are much less expensive and cumbersome than telescopes, they make a logical second step for getting to know the sky. Also, binoculars show you a larger area of the sky at a time than telescopes do, so they make it easier to "sweep" the sky and find things.

Binoculars are rated using two numbers connected by a multiplication sign. So a 7 x 35 pair of binoculars magnifies (enlarges) things in the sky by a factor of 7 and has lenses to do this that have a diameter of 35 millimeters (3.5 centimeters). The bigger the lenses are, the more light they collect and the brighter they can make the dim objects in the sky.

Binoculars with a magnification of more than 10 are not so easy to use - they are so heavy that a tripod is required to hold them steady. For beginners, 7 x 35 or 7 x 50 binoculars are just fine.

It's probably best to borrow a pair of binoculars from a relative, friend, or neighbor, if possible, and "test drive" it for astronomical observations. (Although, we should mention that some of the less expensive binoculars people buy for casual use or their kids may not be all that useful for astronomy.) Still, it doesn't hurt to try out a pair of binoculars to see how you like the experience of using them at night. Some people love the feeling of being able to "spy on the sky" by moving around with the binoculars, while others find that their arms get tired long before their thirst for sky viewing is satisfied.

Here are some basic web guides to using binoculars for astronomy:

- Astronomy Magazine Guide to Using Binoculars (by Richard Talcott):
  http://www.astronomy.com/asy/default.aspx?c=a&id=2225
- Sky & Telescope's Introduction to Binoculars for Astronomy:
  http://www.skyandtelescope.com/howto/howtoequipment/3389576.html
- The Universe Today Binocular Astronomy Page:
  http://www.universetoday.com/13665/binoculars-for-astronomy/

Telescopes
When you are ready to get more serious about astronomy, you will want to own a telescope - an instrument for observing the night sky. A telescope is a "light bucket"- just like a bucket can catch more rain-water than your palm, a telescope can collect far more light than your eye. The more light you collect, the brighter the faint objects in the sky will look in your telescope. To collect light, telescopes use either a mirror (reflector telescope) or a lens (refractor telescope). Like buying a car or a good camera, buying a good telescope is a decision that deserves some research. How you intend to use a telescope is a major factor in helping you decide what kind of telescope to buy. For example, will you always use the telescope in one location, so that it won't have to be moved very far, or do you need it to be portable? Do you want to use it just to look through, or will you be doing photography with it? Are you already familiar with the night sky, or do you want a computer controlled telescope that can help you find interesting things in the night sky automatically? And, as with any significant purchase, what kind of budget do you have? Often beginners are not sure what the possible questions to ask really are, which is why we recommend "test driving" some telescopes at a local amateur club meeting or "star party:' In many parts of the U.S. (and around the world) amateur astronomy clubs hold evening observing sessions, where a number of club members bring out their telescopes and show friends and the public the sky. At these sessions, the experienced telescope users are happy to share their ideas about how to buy a telescope and what kinds of telescopes are best for what purpose. A few clubs even have "loaner telescopes" for their members to check out. See the section on astronomy clubs below to help you find one near you. For more advice on telescope buying for beginners, see:

• Astronomy magazine's "Guide to Buying a Telescope" (by Michael Bakich):
  http://www.astronomy.com/asy/default.aspx?c=a&id=2281
• Sky & Telescope magazine's "Choosing Your First Telescope" (by J. Kelly Beatty):
  http://www.skyandtelescope.com/equipment/basics/12511616.html
and another one with that title by Joshua Roth:
  http://www.skyandtelescope.com/howto/howtoequipment/3304526.html
and their "How to Choose a Telescope" (by Adrian Ashford):
  http://www.skyandtelescope.com/equipment/basics/3303926.html
• Jay Freeman's "Recommendations for Beginning Astronomers":
  http://www.weatherman.com/BEGINNER.HTM
• Michael Edelman's "The Heretic's Guide to Buying Your First Telescope":
  http://www.findascope.com
• Ed Ting's "So You Wanna Buy a Telescope: Advice for Beginners":
  http://www.scopereviews.com/begin.html

When you are ready to buy, do some comparison shopping on the internet and using ads in the astronomy magazines, such as Astronomy and Sky & Telescope. It's probably best to avoid department stores with their off-brand, cheap telescopes, unless you have guidance from someone knowledgeable.

Joining an Astronomy Club
There is a natural tendency for people who enjoy the same hobby to form local groups and get together, and astronomy is no different Many areas of the U.S. (and many other countries) have active astronomy clubs, where amateur astronomers gather to exchange information, share observing tips, and have a chance to socialize and network. A typical club will have a monthly meeting, with a guest speaker, occasional "star parties" (where a number of club members bring a telescope), and a regular newsletter (sent either by mail or published on the Web.)

Many of the astronomy clubs in the U.S. have joined together to create an umbrella organization called The Astronomical League. Also, with support from NASA, the Astronomical Society of the Pacific has built The Night Sky Network, an organization of dubs who have a particular interest in reaching out to the public. To find an astronomy club near you, you can try the following web sites:

• The Night Sky Network Club Finder:
  http://www.nightsky.jpl.nasa.gov/club-map.cfm
• Astronomy Magazine Club Finder:
  http://www.astronomy.com/asy/community/groups/
• Astronomical League Club Directory:
  http://www.astroleague.org/societies/list
• Go-Astronomy:
  http://www.go-astronomy.com/astro-club-search.htm

Also, astronomy instructors at your local college usually know where the nearest astronomy club is and when it meets.

Other Approaches to Astronomy
While the vast majority of astronomy hobbyists are either armchair astronomers or amateur sky observers, there are a few other ways that people have approached an interest in astronomy over the years. We'll just mention a few to give you a sense of the range of approaches, and leave the pleasure of finding others to your continued exploration.

• Astronomical Philately (stamp collecting): Astronomy Study Unit of the American Topical Association:
  http://www.astronomystudyunit.com/
• Astronomy through Science Fiction:
  http://www.astrosociety.org/education/resources/scifi/html
• Astronomy through Environmental Action: Curbing Light Pollution (International Dark-Sky Association):
  http://www.darksky.org

Whatever the path you select to become more involved in astronomy, you have many hours of enjoyment and stimulation ahead of you. We wish you clear skies and a dear mind as you explore.

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

1. Other than telescopes, how do astronomers gather information?
2. Why might someone get into astronomy?
3. What is an Armchair Astronomer? Give one source that would give you more information on becoming one.
4. Where might one find a sky map?
5. Why might someone use binoculars to look at stars?
6. Why would it be important to find the right telescope for you?
7. What is a good source for more information on purchasing telescopes?
8. Other than for liking astronomy, why might someone join an astronomy club?
9. What is a good source for more information on astronomy clubs?
10. What is one other approach to astronomy other than looking at actual stars?
11. What do Astronomers do?
12. What about astronomy would you like to know more about as being part of this class?

Introduction to Astronomy Scavenger Hunt

Introduction: Of all the sciences, Astronomy is often the least taught in K-12 education. Yeah, we know the planets and that other stars exist in these things called galaxies but how much about Astronomy do we *really* know? Well- here is your chance to get to learn a little more of what Astronomy is all about!

Question: What is Astronomy?

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

Vocabulary:
None

Materials:
Computer access

Procedure:
Following the instructions, read through the assignment. Answer the questions incomplete sentences on a separate sheet of paper. Be sure to restate the question in your answer.

Answer the following questions the best you can ***before*** you start the scavenger hunt.

1. What is astronomy?

2. What would you like to learn about astronomy?

3. Why do we study astronomy?

4. What do astronomers do?

5. Can you list any famous astronomers or scientists associated with the field of astronomy?

6. What is the scientific method? List the steps.

7. What is the difference between astronomy and astrology?

8. What is a scientific theory?

9. List any news or current events you have heard lately that may deal with astronomy.

Go to http://www.windows2universe.org/the_universe/uts/timeline.html

10. I invented the first telescope. Who am I? When did I do this?

11. I discovered Pluto. Who am I? When did I do this?

12. My Geocentric Theory of the universe was held for thousands of years even though I was wrong. Who am I? When did I propose this theory?
    What was the difference between this theory and the current beliefs?

13. I was the first to measure the circumference of the Earth, later to find out I did with surprising accuracy. Who am I? When did I do this?

14. We discovered Neptune together. Who are we? When did we do this?

15. I correctly predicted the return of a comet. The comet was eventually named after me, even though I did not get to observe the return that I predicted. Who am I? When did I do this?

16. I developed the first catalogue of stars and first sky map with over 850 of the brightest stars. Who am I? When did I do this?

17. I proposed the heliocentric model for the universe, which is still believed today. Who am I? When did I do this? What is the difference between my theory and the one that was previously held true?

18. We introduced a diagram that shows how different characteristics of stars are related (i.e. temperature and brightness). Who are we? When did we do this?

19. I composed a catalogue of galaxies, nebula and star clusters, which I discovered while looking for comets. Who am I? When did I do this?

20. I showed where the center of the Milky Way galaxy is. Who am I? When did I do this? Where is the center?

21. I discovered Uranus? Who am I? When did I do this?

22. I discovered the first asteroid, Ceres. Who am I? When did I do this?

23. I discovered that there are galaxies outside the Milky Way. Who am I? When did I do this?

24. I discovered the four Jovian moons (moons of Jupiter). Who am I? When did I do this?

25. We discovered Pluto’s moon, Charon. Who are we? When did we do this?

How Fast You Move When You Are Sitting Still Reflection

Introduction:
When, after a long day of running around, you finally find the time to relax in your favorite armchair, nothing seems easier than just sitting still. But have you ever considered how fast you are really moving when it seems you are not moving at all?

Question: How fast do we move when we are sitting still?

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

Vocabulary:
None

Materials:
This reading

Procedure:
Read through the following passage.

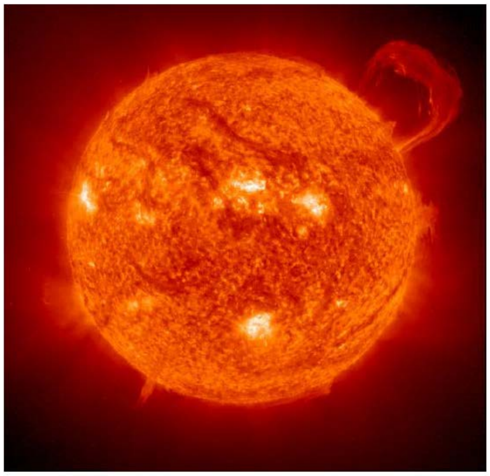
Daily Motion
When you are in a car traveling down the expressway, you sometimes get the illusion that the car is standing still the trees or buildings are moving backwards. In the same way, because we "ride" with the spinning Earth, it appears to us that the Sun and the stars are the ones doing the moving as day and night alternate. But actually, it is our planet that turns on its axis once a day-and all of us who live on the Earth's surface are moving with it. How fast do we turn? To make one complete rotation in 24 hours, a point near the equator of the Earth must move at close to 1000 miles per hour (1600 km/hr). The speed gets less as you move north, but it's still a good clip throughout the United States. Because gravity holds us tight to the surface of our planet, we move with the Earth and don't notice its rotation1 in everyday life.

The great circular streams of water in our oceans and air in our atmosphere give dramatic testimony to the turning of the Earth. As the Earth turns, with faster motion at the equator and slower motion near the poles, great wheels of water and air circulate in the northern and southern hemisphere. For example, the Gulf Stream, which carries warm water from the Gulf of Mexico all the way to Great Britain, and makes England warmer and wetter than it otherwise would be, is part of the great wheel of water in the North Atlantic Ocean. The wheel (or gyre) that the Gulf Stream is part of contains more water than all the rivers of the world put together. It is circulated by the energy of our turning planet.

The Earth as seen by the Apollo 17 Crew on the way to the Moon.
Image credit: NASA

Yearly Motion
In addition to spinning on its axis, the Earth also revolves around the Sun. We are approximately 93 million miles (150 million km) from the Sun, and at that distance, it takes us one year (365.25 days) to go around once.

The full path of the Earth's orbit is close to 600 million miles (970 million km). To go around this immense circle in one year takes a speed of 66,000 miles per hour (107,000 km/hr). At this speed, you could get from San Francisco to Washington D.C. in 3 minutes.



The Sun, seen in ultraviolet light with instruments aboard the SOHO satellite.

Image credit: SOHO

The Sun's Motion

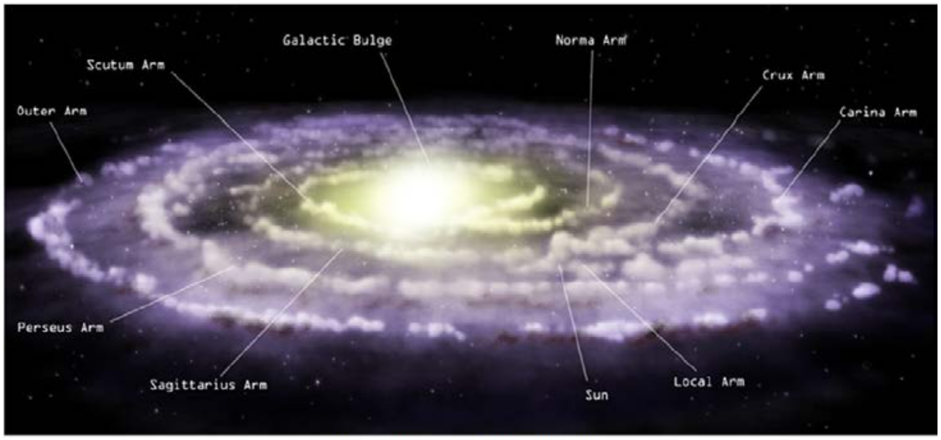
Our Sun is just one star among several hundred billion others that together make up the Milky Way Galaxy. This is our immense "island of stars" and within it, each star is itself moving. Any planet orbiting a star will share its motion through the Galaxy with it. Stars, as we shall see, can be moving in a random way, just "milling about" in their neighborhoods, and in organized ways, moving around the center of the Galaxy.

If we want to describe the motion of a star like our Sun among all the other stars, we run up against a problem. We usually define motion by comparing the moving object to something at rest. A car moves at 60 miles per hour relative to a reference post attached to the Earth, such as the highway sign, for example. But if all the stars in the Galaxy are moving, what could be the "reference post" to which we can compare its motion? Astronomers define a local standard of rest in our section of the Galaxy by the average motion of all the stars in our neighborhood. (Note that in using everyday words, such as "local" and "neighborhood", we do a disservice to the mind-boggling distances involved).

Even the nearest star is over 25 trillion miles (40 trillion km) away. It's only that the Galaxy is so immense, that compared to its total size, the stars we use to define our Sun's motion do seem to be in the "neighborhood”). Relative to the local standard of rest, our Sun and the Earth are moving at about 43,000 miles per hour (70,000 km/hr) roughly in the direction of the bright star Vega in the constellation of Lyra. This speed is not unusual for the stars around us and is our "milling around" speed in our suburban part of the Galaxy.

Orbiting the Galaxy

In addition to the individual motions of the stars within it, the entire Galaxy is in spinning motion like an enormous pinwheel Although the details of the Galaxy's spin are complicated (stars at different distances move at different speeds), we can focus on the speed of the Sun around the center of the Milky Way. It takes our Sun approximately 225 million years to make the trip around our Galaxy. This is sometimes called our "galactic year". Since the Sun and the Earth first formed, about 20 galactic years have passed; we have been around the Galaxy 20 times. On the other hand, in all of recorded human history, we have barely moved in our long path around the Milky Way. How fast do we have to move to make it around the Milky Way in one galactic year? It's a huge circle, and the speed with which the Sun has to move is an astounding 483,000 miles per hour (792,000 km/hr)! The Earth, anchored to the Sun by gravity, follows along at the same fantastic speed. (By the way, as fast as this speed is, it is still a long way from the speed limit the universe-the speed of light. Light travels at the unimaginably fast pace of 670 million miles per hour or 1.09 billion km/hr.)



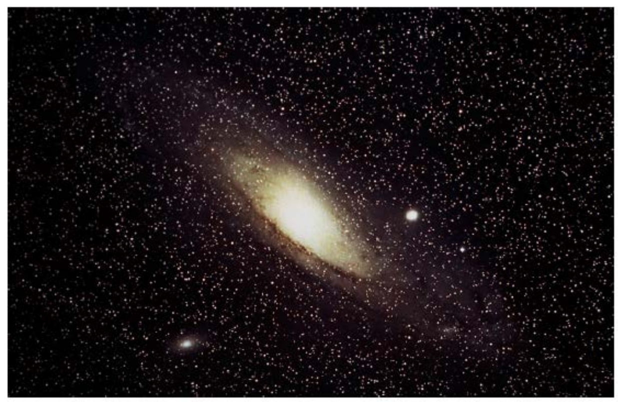
An artist's illustration of the Milky Way Galaxy

Image credit: NASA / CXC / M. Weiss

Moving through the Universe

As we discussed the different speeds of our planet so far, we always needed to ask, "Compared to what are you measuring this motion?" As you sit in your desk, your motion compared to the walls of the classroom is zero. Your motion compared to the Moon or the Sun, on the other hand, is quite large. When we talk about your speed going around the Galaxy, we measure it relative to the center of the Milky Way.

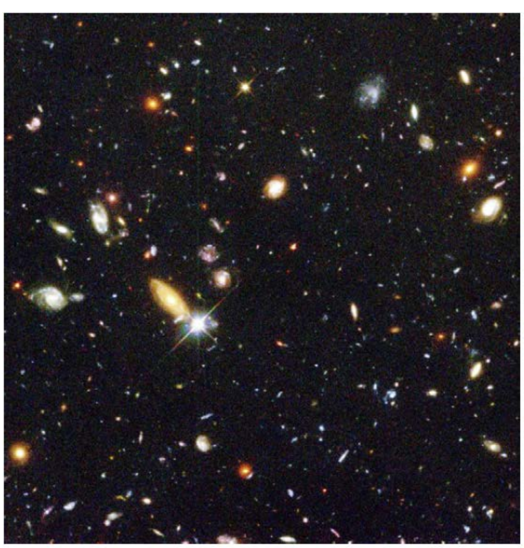
Now we want to finish up by looking at the motion of the entire Milky Way Galaxy through space. What can we compare its motion to--what is the right frame of reference? For a long time, astronomers were not sure how to answer this question. We could measure the motion of the Milky Way relative to a neighbor galaxy, but this galaxy is also moving. The universe is filled with great islands of stars (just like the Milky Way) and each of them is moving in its own way. No galaxy is sitting still! But then, a surprising discovery in the 1960s showed us a new way to think of our galaxy's motion.



The Sun travels with billions of other stars through the Milky Way Galaxy, which is thought to look much like the Andromeda Galaxy, pictured above.

Image credit: NASA Marshall Space Flight Center (NASA-MSFC)

The Flash of the Big Bang



The Hubble Deep Field image shows some of the most distant Galaxies in the Universe.

Image credit: Robert Williams and the Hubble Deep Field Team (STScI) and NASA

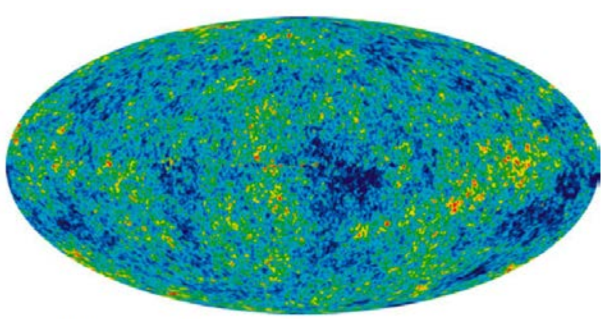
To understand this new development, we have to think a little bit about the Big Bang, the enormous explosion that was the beginning of space, time, and the whole universe. Right after the Big Bang, the universe was full of energy and very, very hot. In fact, for the first few minutes, the entire universe was hotter than the center of our Sun. It was an unimaginable maelstrom of energy and subatomic particles, slowly cooling and sorting itself out into the universe we know today.

At that early time, the energy in the universe was in the form of gamma rays, waves of energy like the visible light we see, but composed of much shorter waves with higher energy. Today on Earth, it takes a nuclear bomb to produce significant amounts of gamma rays. But then, the whole universe was filled with them. You can think of these gamma-rays as the "flash" of the Big Bang-just like fireworks or a bomb can produce a flash of light, the Big Bang resulted in a flash of gamma rays. But these gamma rays were everywhere in the universe. They filled all of space, and as the universe grew (expanded), the gamma rays expanded with it.

When people first think about the expansion of the universe, they naturally think of other expansions they have experience with: how the American colonies eventually expanded to become the 48 states of the U.S. or how an exploding bomb might throw shrapnel in every direction. In these situations, the space into which the colonies or the shrapnel is expanding already exists. But the expansion of the universe is not like any other expansion. When the universe expands, it is space itself that is stretching. the galaxies in the universe are moving apart because space stretches and creates more distance between them.

What does this mind-stretching idea of stretching space mean for our gamma rays? The gamma rays are waves of energy moving through space. As space stretches, the waves that are in space must stretch too. Stretched gamma rays are called x-rays. So as the universe expanded, the waves of energy filling space stretched out to become less energetic (cooler) x-rays. As the universe continued to expand, the same waves became ultra-violet light. Later they became visible light, but there were no eyes in the hot compressed universe to see them yet. (When we take the lid of a hot pressure cooker, the steam will expand into the room and cool down. In the same way, we can think of the waves of energy in the expanding universe as cooling down getting less energetic.)

Today, some 12 to 15 billion years after the Big Bang, there has been a lot of stretching. Space has expanded quite a bit. The flash of the Big Bang has stretched until it is now much longer, lower energy waves- microwaves and radio waves. But the waves have stretched with the space they occupy, and so they still fill the universe, just the way they did at the time of creation. Astronomers call the collection of all these stretched waves the cosmic background radiation or CBR. Physicists back in the late 1940's predicted that there should be such a background, but since no one had the equipment to find it, the prediction was forgotten. Then, in the mid 1960s, two scientists working for Bell Laboratories, Arno Penzias and Robert Wilson, accidentally discovered the CBR while helping to get communications satellite technology going for the phone company. After astronomers used other telescopes and rockets in orbit to confirm that the radio waves the two scientists had discovered were really coming from all over space, Penzias and Wilson received the Nobel Prize in physics for having found the most direct evidence for the Big Bang.



WMAP image of the Cosmic Microwave Background radiation

Image credit: NASA/WMAP Science Team

What, you might be asking yourself, does all this have to do with how fast we are moving? Well, astronomers can now measure how fast the Earth is moving compared to this radiation filling all of space. (Technically, our motion causes one kind of Doppler Shift in the radiation we observe in the direction that we are moving and another in the direction opposite.) Put another way, the CBR provides a "frame of reference" for the universe at large, relative to which we can measure our motion. From the motion we measure compared to the CBR, we need to subtract out the motion of the Earth around the Sun and the Sun around the center of the Milky Way. The motion that's left must be the particular motion of our Galaxy through the universe! And how fast is the Milky Way Galaxy moving? The speed turns out to be an astounding 1.3 million miles per hour (2.1 million km/hr)!

Light as a cosmic time machine

"Everything we see in the sky belongs to the past:' - Timothy Ferris

The universe tells us its story mainly through the waves it sends us. We learn about the planets, stars, and galaxies by their light-visible light, and also shorter-wavelength ultraviolet and longer wavelength infrared light, invisible to the eye but detectable by certain telescopes on Earth and in space-and by the till longer waves of radio energy that they send us. 'These waves do not arrive instantaneously.

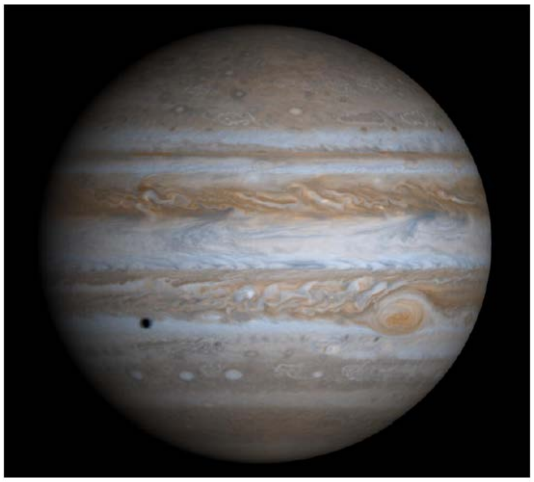
Although they travel at the fastest possible speed (the speed of light), they take a while to get here. The universe is big, so the news is delayed by the vast gulfs of space it has to cross to reach us. Light covers 186,000 miles EVERY SECOND (kids, please don't try traveling this fast without adult supervision!!!) In metric units, that's about 300,000 kilometers per second. How long does light take to reach us from familiar objects? Let's take a quick tour of the solar system, asking at each place how long its light takes to reach us here on Earth.

The Moon and the Sun

The closest object to us is the Moon. Its average distance is about 240,000 miles, so light from the Moon takes (240,000 miles divided by 1 86,000) miles per second to get to us. That's 1 and 1/3 seconds to get from the Moon to Earth. When astronauts orbited the Moon and later walked on its surface in the 1960's, television viewers noticed that they seemed slow to answer questions transmitted from Earth. That was because it took 1.3 seconds for the question to travel to the Moon, and another 1.3 seconds for the answer to get back to Earth. Those 2.6 seconds were exactly the round-trip travel time between the Earth and the Moon for the radio waves NASA uses for communication. The Sun is 93 million miles away, which means sunlight takes 8 and % minutes to get to us. Not much changes about the Sun in so short a time, but it still means that when you look at the Sun, you see it as it was 8 minutes ago.

The Moon as photographed by the astronauts returning home on the Apollo 11 mission *(NASA)*

The Planets



Jupiter, as photographed by the Cassini Spacecraft in 2000 *(NASA)*

The giant planet Jupiter, whose large moons Galileo discovered with his pioneering telescope, is more than 5 times farther from the Sun than the Earth is. We see a planet like Jupiter because it reflects sunlight. The sun's light takes about 43 minutes to reach Jupiter. The trip of the light from Jupiter to the Earth can take from 35 to 52 minutes, depending on whether we are on the same side of the Sun as Jupiter or on the other side.

The dwarf planet Pluto, so small and remote it was not discovered until 1930, orbits 40 times farther from the Sun than we do. Light from the Sun takes about 5 ½ hours to reach it and roughly the same time to return to By time the light reaches us, it has spread out so much that the planet looks very dim, and requires a really good telescope to spot.

Beyond the Solar System

Moving beyond the Solar System, our scale of distances and travel times needs to change. Now light will require years, not hours, to make its way to us. The star that is nearest to the Sun happens to be part of a system of three stars. (Unlike the Sun, which is a loner, many stars are found in groups of two, three, four or more.) The brightest star in our neighbor system is called Alpha Centauri (pronounced Al' fa Sen' to ree), and it is a virtual twin of the Sun. Light from Alpha Centauri takes more than 4 years to reach the Sun. (Astronomers say the star is 4 light years away.)

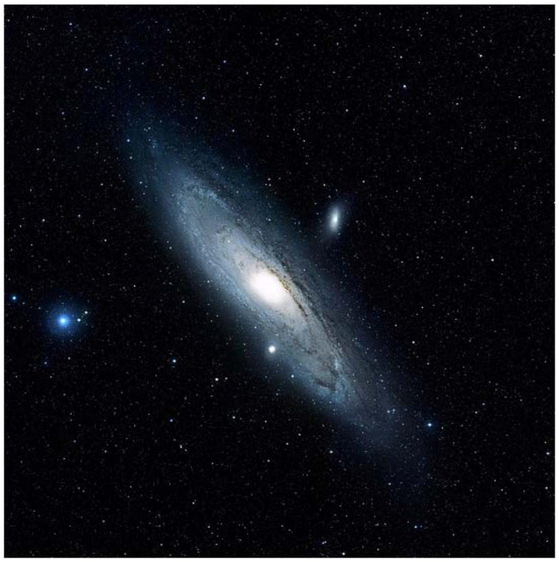
The Orion Nebula (a region where new stars are observed to be forming) photographed by the Hubble Space Telescope *(NASA)*

The brightest star in our skies is the "dog star", Sirius (pronounced Sea' ree us). It's the primary star in the constellation of the big dog, Canis Major. Sirius is roughly 9 light years away. Think of what you were doing 9 years ago. That's when the light we see from Sirius tonight first began its journey to us. Not far from Sirius in the sky is the bright star Betelgeuse (pronounced Beetle' juice). It is so far that its light takes about 640 years to reach us. Light that we see tonight from Betelgeuse left it in the 14th century.

In the same constellation, Orion, as Betelgeuse but even farther away is the Orion Nebula, a place where we see new stars forming. Its distance is about 1500 light years, meaning that the light we see from it left more than a thousand years before the invention of the telescope.

The farther away an object in space lies, the longer it takes its light to get to us and the older that light is when it reaches Earth. As we look deeper and deeper into the Milky Way Galaxy (the island of stars in which we live), we are looking deeper into the past. Light can take tens of thousands of years or more to reach us from distant parts of our galaxy. The full spiral-shaped disk of the Milky Way is roughly 100,000 light years wide, meaning light would take one hundred millennia to cross it.

Other Galaxies



The Andromeda Galaxy (image made from Palomar Observatory plates by Davide De Martin)

Once we move outside the galaxy, we encounter even larger spaces and longer light travel times. One of the great scientific ideas of 20th century astronomy was the discovery that there are other galaxies out there~ stretching as far as our great telescopes can see. Billions of other islands of stars are scattered through the great dark ocean of space

The nearest large galaxy to the Milky Way is the Andromeda Galaxy. Sometimes astronomers call it M31, by its number in a famous catalog of fuzzy celestial objects. The Andromeda (pronounced An drah' mid ah) Galaxy lies about 2 ½ million light years from Earth. The light we see from it tonight left it more than 2 million

years ago, when our species was just beginning to establish its fragile foothold on planet Earth.
In this sense, astronomy is mostly ancient history: The farther away objects are, the older the story they have to tell us. Young people, raised on CNN, the Web, and "instant messaging" may at first bridle at the thought that the most recent information we an get from a neighbor galaxy might be millions of years old. But for astronomers, this delay in the arrival of light is one of the universe's greatest gifts.

After all, one of the fundamental tasks of astronomy is to fill in the history of the universe - from the Big Bang to the moment you are reading this paragraph. Astronomers might not be able to undertake such a task if the information from the universe were limited to current events. But the universe is a "time machine': Looking at more distant objects, we learn about more ancient times and phenomena. Large telescopes allow us to look billions of years into the past and to reconstruct the story of the cosmos eon by eon.

Object	Time for the Light to Reach Us
The Moon	1 1/3 sec
The Sun	8 minutes
Jupiter	35 to 52 minutes
Pluto	5 1/2 hours (on average)
Alpha Centauri (nearest star system)	4.3 years
Sirius (brightest star in our sky)	9 years
Betelgeuse (bright star)	640 years
Orion Nebula	1500 years
Andromeda Galaxy	2.5 million years

Analysis:

Write a written response to the two articles you just read. Please do not summarize or tell what you read, but instead what are your thoughts on the article; i.e. how did you feel as you read the article, how did this article compare to what you already knew about astronomy, what questions do you now have after having read the article, etc.

Use the rubric below as your guide.

Points earned	Total Points = 20	4-5	2-3	o
	Rough Draft	Completed in essay format	Partially Completed	No Evidence
	Grammar, Spelling, Complete thoughts and sentences	Effectively uses grammar, writes with complete thoughts, little to no spelling errors	Few grammar and spelling mistakes, uses complete sentences	No Evidence
	Essay Format	Completed essay format with intro., body paragraphs and a conclusion	Partial essay format, lacks intro, body paragraphs or conclusion	No Evidence
	Content Mastery	Presents with a deep understanding of the content and concepts from the articles, cites examples from the articles	Presents with an understanding of the content, uses limited examples from the articles	No Evidence

The Universe – Beyond the Big Bang
Day 1

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).

As you watch this video, put the following famous astronomers in numerical order with the earliest (oldest) being #1, and the latest (youngest) being #8.

_____ Ptolemy
_____ Aristotle
_____ Lemaitre
_____ Kepler
_____ Copernicus
_____ Newton
_____ Einstein
_____ Galileo

1. What is the theory about the origin of the universe?

2. Why should the Big Bang not be considered big? Why should it not be called a ‘bang’?

3. How fast is our solar system spinning?

4. What is the sun made of?

5. Early humans at Stonehenge and Chicinitza were trying to connect with this:

6. When did astrologers first divide the sky into the regions later known as the zodiac?

7. What was the early perception of earth in the universe?

8. What group first used mathematics to interpret the heavens?

9. How many planets could they see at that time?

10. What was Claudius Ptolemy’s contribution to understanding the universe?

11. After the fall of the Roman Empire, much of the knowledge of astronomy was lost. Who was the Polish astronomer who made the next big discovery regarding solar system motion? What was his major discovery?

12. Why did he not publish his works until he was on his death bed in 1543?

13. What the major contribution by Kepler to our understanding of how the universe moves?

14. What technology did Galileo Galilei use to prove Copernicus and Kepler were right?

15. What was the evidence Galileo saw regarding Venus that proved planets orbit the sun?

16. Why did Galileo get in trouble with the church and what happened to him?

17. What was Isaac Newton’s contribution to understanding the universe?

18. What did Einstein mean when he said the universe is infinite?

19. What was Einstein's space-time continuum compared to? (Also called the ____ of space).

20. What occurs according to the Space-Time Continuum?

21. What did Einstein receive his Nobel Prize in 1921 for proving?

The Universe – Beyond the Big Bang
Day 2

22. Space is not static but instead is doing this?

23. What was the point that exploded in the Big Bang first called?

24. What was Edwin Hubble's contribution to the understanding of the Universe?

25. How old did Hubble originally calculate the universe to be? (He eventually corrected this huge miscalculation).

26. What is the Steady State Theory?

27. What is the 'smoking gun' that was discovered invalidated one of the 2 major theories of the universe's creation? Specifically, what were they looking for?

28. What did scientists hear when they listened into space?

29. What was the source of what they heard?

30. What was one of the problems scientists discovered with the Big Bang Theory?

31. What was the theory that attempted to resolve this problem?

32. What did the WMAP satellite discover?

33. What are the four forces of the "super force" of the point of singularity?

34. How long after the Big Bang do scientists think it takes before the first star is born?

35. What forms from the left over materials from the formation of a star?

36. What happens to Earth as the Sun expands?

37. What happens to the outer planets as the planetary nebula passes them?

38. What causes the Big Rip?

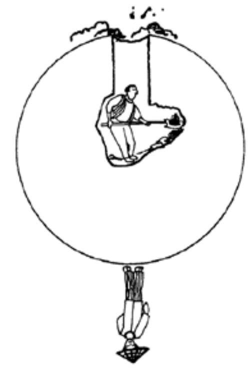
39. From where did the elements come that make up mankind?

40. What did you find most interesting from the entire video?

41. What did you learn that you would like to know more about?

42. What is one thing you would like to know more about?

Earth's Gravity and Shape Lab



Introduction:
Despite the evidence of our senses, we are told early as a child that the Earth is really shaped like a ball, that the Earth is a sphere. Perhaps you also remember someone telling you that you could dig a hole to China (which would more accurately place you in the Southern Indian Ocean about halfway between South Africa and Australia but is nonetheless geologically impossible). These statements seem unbelievable to us at first but are truly significant learning experiences. In fact, when the ancient Greeks came up with the idea of a ball-shaped Earth, they had to explain why people who lived on the other side of the world didn't fall off. Aristotle, who lived about 2,300 years ago, thought that everything went to its "natural resting place" in the center of the universe, which he believed to be at the center of the Earth. In reality, the shape of our planet (And all massive objects in space) is no coincidence. It is due to a peculiar force called gravity.

The idea of gravity was revised "only" about 300 years ago by Isaac Newton, who believed that the rock falls because of a pulling force between every particle within the Earth and every particle within the rock. He named the force gravity.

As a child, you "grew up" learning of Sir Isaac Newton's little incident with the apple falling from the tree and his realization of the effects of gravity. Gravity is one of the four fundamental forces that arose from the Big Bang over 14 billion years ago. Gravity gives weight to objects by accelerating them towards the center of a large, massive object. We know that the amount of gravity an object has depends on two things; the mass of the objects and how far apart they are. This is represented by the formula $F = G\frac{m_1 m_2}{r^2}$. Don't forget to keep in mind that the radius of the Earth is measured from its center (6378.1km), not from its surface.

In this equation, *r* is the distance between two objects and G is referred to as the universal gravitation constant (its value $G = 6.67 \times 10^{-11}\ \mathrm{N \cdot m^2/kg^2}$). In other words, the closer the objects are to each other, the greater the gravity. Likewise, the more massive an object, the greater the gravitational pull.

Due to gravity, during the formation of our solar system, dust began to accrete (attract and combine) to dust which became small rocks which then accreted with more and more material until it became larger and larger. When this big ball of rock and dust reached about 100km (60 miles) in diameter it began to have enough gravity to reshape itself into a sphere. Today, we readily accept that the Earth is a sphere and has gravity but these concepts have not always been accepted by all.

Question: What is Gravity?

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

Vocabulary:
Gravity
Mass
Accretion

Materials:
Styrofoam ball
Map of Earth
12 - 1" push-pins
Plastic dish (to support globes)
Light source
6 - 1"x1" cardboard pin supports

Procedure:
Answer the following questions before moving on in the lab.

1. Why did the ancient peoples think that the Earth was flat?

2. Pretend that the Earth is glass, which way would you point to if you were asked to point towards Australia? Which way is it to Europe?

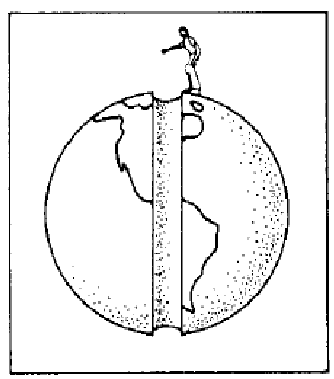
3. Given that the mass of the Earth is 5.9742×10^{24} kilograms, what is the force of gravity on a person who is 50 kg (about 110 pounds)? Be sure to show your work.

4. What was Aristotle's view on gravity and the shape of the Earth?

5. What was Newton's view on gravity and the shape of the Earth?

6. Why does the Earth appear to be flat from here on Earth but a sphere from space?

7. This drawing shows several people on different places on Earth dropping a rock all at the same time. Draw arrows to represent the path by which each rock will travel.



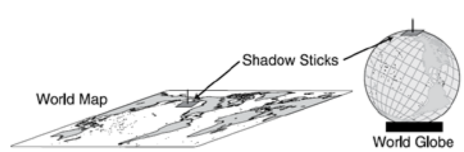
Follow these steps and answer the questions that follow:

a. Make 6 shadow sticks by pushing the pins through the centers of the 1" x 1" pieces of cardboard.

b. Set up the globe on a support with your location on "top" of the globe. Have a student place one shadow stick at your location, taping it in place with a loop of masking tape.

c. Place the flat map of the world on the lab station nearby. Have another student place a shadow stick at your location on the flat map and hold it in place with tape.

d. Ask a third student to use the ruler to measure and compare the lengths of the two shadows.



e. Place the remaining 5 pins pairs at locations on the map and their corresponding places on your "globe."

f. **Make sure your globe and map are equal distance from the light source**.

g. Measure the shadows and compare your data in the table below:

Pin location	Length of shadow cast on globe? *(in mm)*	Length of shadow on map? *(in mm)*

h. Remove all of the pins from your globe.

i. Place one pin in the globe so that it has the smallest shadow possible.

Analysis:

8. What is represented by the pin you placed in step i?

9. Looking back at Table 1, how do the shadows on the map vary with those from the globe?

10. Why do the shadows on the map vary with those from the globe?

11. How does the varying lengths of shadows on the globe demonstrate what is observed on the real Earth? (How does it demonstrate that the Earth is round?)

12. Where on Earth does the sun pass directly overhead on at least one day per year?

13. If you were to hear someone say that Columbus thought the world was flat, what evidence could you use to show that Columbus did indeed think that the world was a sphere?

14. How could you use the information from this lab to create a test to prove that the world is truly a sphere? (Be clear and specific - include steps!)

Shape and Dimensions of Earth

Introduction:
Often in Science we fall in the habit of stating results as facts. You've grown up with an image of the Earth as a planet, circling our sun, a star, and accounting for the daily motions of the Sun, Moon, and the stars with the Earth's rotation. That image- our internal model- has been shaped by countless pictures of Earth from space, from pictures in books, and from science classes.

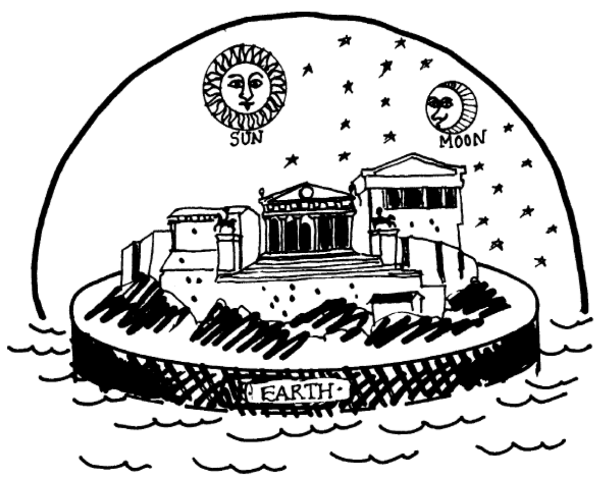
We might never stop to ask the question, "Where does the Sun go when it sets in the west?" People at different locations on Earth, with different cultures, might have answered with a completely different image of the Earth and Sun. Even from a high mountain, the Earth *looks* flat. So it is natural that most ancient models of the world did not portray the Earth as round.

In about 300 B.C.E., only about 50 years after the Greek astronomer Aristotle described the evidence that supported the idea that the Earth is shaped like a sphere, Eratosthenes, a librarian in Alexandria, Egypt, figured out how to measure its circumference. This is widely considered one of the most astounding achievements of ancient Science.

In Part 1 of this assignment, you will compare four early models of the Earth

In part 2 of this assignment you will learn about the dimensions of the Earth that were calculated as early as Ancient Greece.

In part 3 of this assignment, you will have the opportunity to learn the math behind the dimensions of the Earth, as proven by ancient and modern measurements.



Thales' idea of the world in 500 B.C. "The earth is like a cork bobbing in the sea."

Question:
How did the ancients come to know that the Earth was a sphere and how large it was?

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

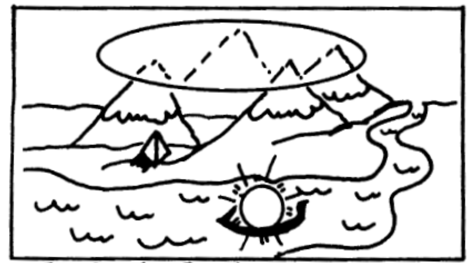
Materials:
These assignment sheets

Part 1 - The Early Models of the Earth
Vocabulary
Model
Phenomenonw

Procedure:
Read the following descriptions of how the ancient people in different parts of the world viewed the world.

EGYPT

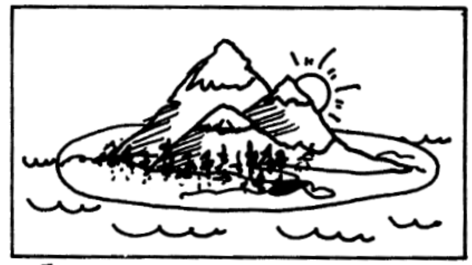
The Earth is flat. The sky is like a flat plate, supported at four places by mountains. The sun is carried across the sky in a boat, from east to west. At night, the sun is carried back to the east through the Underworld.



E G Y P T

INDIA

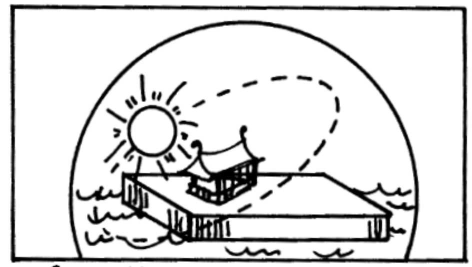
The Earth is a circular disk, surrounded by the ocean. In the center of the world is a great mountain. The sun goes around the mountain once a day. In the evening, the sun goes behind the western side of the mountain. It travels behind the mountain at night, and comes out on the eastern side in the morning.



I N D I A

CHINA

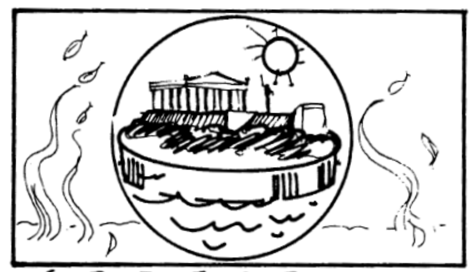
The sky is a round dome, surrounding a flat square-shaped Earth. The ocean goes all around the Earth. The sun travels in a big tilted circle. At night the sun is not under the Earth, but rather on the side of the Earth.



C H I N A

GREECE

Most ancient Greeks believed that the Earth floated in the ocean like a cork in water. One person, named Anaximander, thought that the Earth was a cylinder with a rounded top, floating in the air. The sky surrounded the Earth, and beyond the sky was a region of fire. The sun, moon, and stars were holes in the sky, through which the fire could be seen.



G R E E C E

Analysis:

Answer the following questions

1. Describe the motion of the Sun in the sky. How does it vary throughout the year?

2. After the Sun sets in the west, how does it get all the way over to the east before it rises the next morning?

3. How might different explanations and approaches to the same phenomenon-the daily movement of the Sun from east to west have evolved?

4. How do the explanations reflect the surroundings and environment of the people who created them?

   Egypt
   India
   China
   Greece

5. Imagine you were teleported back in time to ancient Greece. (For simplification, let's say they could understand English and welcomed you). Describe what you would do to convince them that the Earth really is a sphere.

Part 2 - Dimensions of the Earth

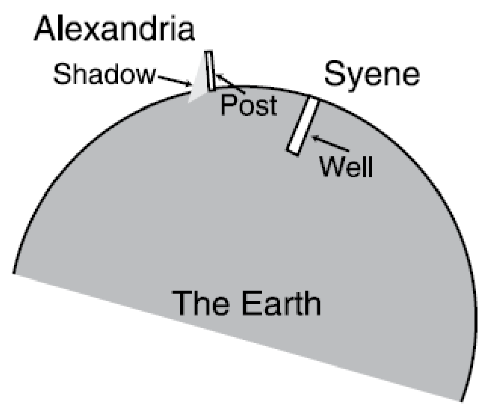
Vocabulary
Eratosthenes-
Christopher Columbus-

Procedure:
Read the following passage on how the shape and dimensions of the Earth were accurately calculated.

Greece was a center of trade routes, in addition to moving goods, people from different countries met and exchanged stories about the Earth, sky, and technologies. Some ancient Greeks listened to these stories and wondered how they could all be true. These people tried to invent models that provided the best explanations for what they saw in the sky. The sphere-shaped Earth was one of these ideas, probably suggested by Pythagoras or one of his followers, over 2,500 years ago!

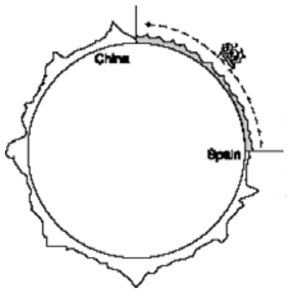
By the time Columbus set sail in 1492, many educated people believed in a ball-shaped Earth. Their biggest disagreement was about its size. Most people thought the Earth was so big that Columbus and his crew would run out of food before they reached land again. In fact, were it not for their unexpected encounter with the Americas, they would have!

Nonetheless, a very intelligent librarian was able to figure out how large the Earth was. Eratosthenes was a librarian at the Great Library at Alexandria, now regarded as one of the 7 wonders of the Ancient World. He had read that on the longest day of the year, the Sun shines directly down a well in Syene, a city several hundred miles to the south. When he looked at a vertical post in Alexandria on the same day, the sun's rays cast a shadow of 1/8 the length of the post.



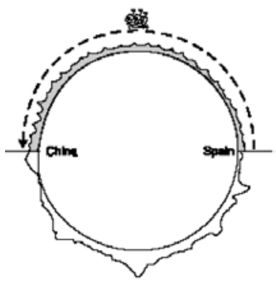
Eratosthenes used geometric calculations written about by a Greek named Euclid to find that the angle formed was 1/50th the distance around the Earth. From this he was able to calculate the diameter and then the circumference of the Earth to an accuracy that astounds modern scientists.

Fast forward 2000 years to 1486. Christopher Columbus is asking Queen Isabella and King Ferdinand of Spain for supplies and money to fund a water-based trip to the East Indies (modern day China and India). Queen Isabella called on a few of her trusted advisors from Spain's University of Salamanca, one of the four best Universities of Europe. After much deliberation, they could not convie Queen Isabella that Columbus' calculations were wrong. The Queen gave Columbus the funding he asked for. You will find out on the following page why this was a "Fail" of epic proportions.



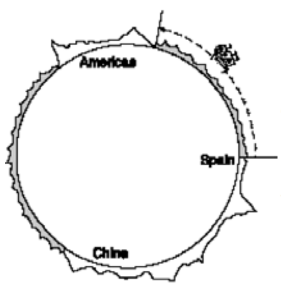
Columbus claimed that the Earth is only 18,800 miles in circumference, and the land route from Spain to China is about 15,000 miles. How far did he think it would be to sail westward from Spain across the Ocean Sea to the Indies?

_________________ miles



The professors at Salamanca disagreed. They thought the distance around the Earth was at least 20,000 miles as measured by Ptolemy (A.D. 150), and that the land route from Spain to China was no more than about 10,000 miles. How far did the professors at Salamanca think it would be to sail westward to the Indies?

_________________ miles



The modern view is that the distance around the Earth is about 24,900 miles, and the land route from Spain to the Indies is about 8,000 miles. How far would Columbus have had to sail to reach the Indies?

_________________ miles

Analysis:

6. Why did Columbus think he reached the Indies, even though he made landfall in the Americas?

7. If you were the King and Queen, would you have went against the advice of the professors and given the funding to Columbus?

8. Columbus' voyage, although not to the Indies is said to have unintended consequences. What is meant by this? What are a few of the unintended consequences of his voyage?

A look at the math behind it all.

speed of light (c) = $3x10^5$ km/s (km per <u>second</u>) *5280 ft=1 mile* *Cir = $2\Pi r$* *1km=1000m*

astronomical unit (AU) = 1.5×10^8km (150,000,000km) *year = 365.25 days*

Remember to answer the following questions IN COMPLETE SENTENCES when appropriate!!!!

9. What evidence did people over 2,000 years ago have that the Earth is shaped like a sphere. (Remember that in ancient times it was not possible to travel all the way around the Earth or into space.)
10. If you see a vertical post in Syene at the same moment as the Sun shines directly down the well, does the post cast a shadow? Why so?

11. Why do we see a shadow cast by the post at noon in Alexandria at the same time we see no shadow in Syene? What does this tell me about the shape of the Earth?

12. If 493 miles (793 km) is 1/ 50 of the way around the world, how many miles is it all the way around the world? Show your calculations.>

13. The circumference of the world by modern measurements in 24,900 miles. How close was Eratosthenes' calculated measurement to the modern measurement?

14. What is the largest dimension (measurement) you have personal knowledge of or are personally familiar with?

*Be sure to **show your work** when solving the following problems - answers without work shown will not receive credit:*

15. If the diameter of earth is 7928 miles, what is the diameter in feet?

16. Using the answer you got above, figure out the diameter of the earth in inches.

17. If the diameter of the earth is 12,756km, what is the diameter in meters?

18. Using the answer you got in the last question, figure out the diameter of the earth in centimeters.

19. About how many miles are there in one AU?

20. How many seconds are in a day? How many seconds are in a year?

21. The nearest galaxy to our own is about 2 million light years away? How many kilometers is that?

22. How many earths laid edge to edge, flat would it take to get to the nearest galaxy?

23. An astronomical unit is the average distance between the Earth and the Sun. Why is it more convenient to use an astronomical unit than it is to use a mile or kilometer?

24. What is a light year (definition, not numbers)? Why is it more convenient to use a light year than an astronomical unit in some case?

Earth & Sun Relationship

Introduction:

(excerpts from http://learn.greenlux.org/packages/clear/thermal/climate/sun/relationship.html)

The earth receives almost all its energy from the Sun's radiation. Sun also has the most dominating influence on the changing climate of various locations on Earth at different times of the year.

The Earth rotates about on a fixed plane that is tilted at an axis of 23.5° with respect to its vertical axis around the sun. The Earth needs 23hrs 56mins to complete one true rotation, or one sidereal period, around the sun. The solar day, on the other hand, is the time needed for a point on earth pointing towards a particular point on the sun to complete one rotation and return to the same point. It is defined as the time taken for the sun to move from the zenith on one day to the zenith of the next day, or from noon today to noon tomorrow. The length of a solar day varies, and thus on the average is calculated to be 24hrs.

For simplicity, we averaged out that the Earth will complete one rotation every 24hrs (based on a solar day) and thus moves at a rate of 15° per hour (one full rotation is 360°). Because of this, the sun appears to move proportionately at a constant speed across the sky in what is called the solar arc, the apparent path of the sun's motion across the sky. At different latitudes north and south of the equator, the sun will travel across the sky at different angles each day.

The rotation of the earth about its axis also causes the day and night phenomenon. The length of the day and night depends on the time of the year and the latitude of the location. For places in the northern hemisphere, the shortest solar day occurs around December 21 (winter solstice) and the longest solar day occurs around June 21 (summer solstice). In theory, during the time of the equinox, the length of the day should be equal to the length of the night.

The average time the earth takes to move around the sun in approximately 365.25 days. This path that the earth takes to revolve around the sun is called the elliptical path.

Equinoxes & Solstices

Equinoxes happen twice per year. The Spring (Vernal) Equinox occurs on approximately March 21st and Fall (Autumnal) Equinox occurs on approximately September 21st. During the equinoxes, all parts of the Earth experiences 12 hours of day and night and that is how equinox gets it name as equinox means equal night.

On approximately December 21st, the winter solstice occurs. On the winter solstice, the North Pole is angled directly away from the sun. 3 months later, the earth will reach the date point of the March equinox and that the sun's angle will be 0°. 3 months later, the earth will reach the date point of the summer solstice. At this point it will be at an angle of -23.5°. This cycle will carry on, creating the seasons that we experience on earth.

Change of Seasons

Seasons are caused by the Earth axis which is tilted by 23.5°. When the northern axis is pointing to the direction of the Sun, it will be winter in the southern hemisphere and summer in the northern hemisphere. Northern hemisphere will experience summer because the Sun's ray reached that part of the surface directly and more concentrated hence enabling that area to heat up more quickly. The southern hemisphere will receive the same amount of light ray at a more glancing angle, hence spreading out the light ray therefore is less concentrated and colder. The converse holds true when the Earth southern axis is pointing towards the Sun.

Question: How does the angle of the Sun's light effect the Earth's temperature and seasons?

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

Vocabulary:
Axis
Rotate
Revolve
Orbit
Sidereal period
Solar day
Solar arc

Materials:
1 Sticker (or piece of tape)
1 Miniglobe
1 flash light (or other "direct" light source)

Activity 1: What causes day and night?
Procedure:
1. First place a sticker anywhere on the northern hemisphere.
2. Stand about 1ft. away and shine the light on the sticker.
3. Rotate the earth and observe what happens.

Analysis:
1. What does the light represent?
2. In relationship to the light, when is it day where the sticker is located? When is it night where the sticker is located?
3. Which way should the earth be rotating for the sun to rise in the east and set in the west?
4. Is there any part of the earth that is receiving no light when the northern hemisphere is tilted toward the sun?
5. Think about (or try) what would happen if the northern hemisphere was tilted away from the sun. Do you think there would be any area of the earth receiving no light when this happens?
6. Why is daylight longer in the summer and not as long in the winter?

Activity 2: What causes the seasons?
Procedure:
1. Hold the flashlight directly perpendicular to a piece of paper about 1ft. above it. Draw a circle around the part of the paper that is lit up.
2. Now, hold the flashlight at an angle (at the same height as Step 1). Draw a circle around the part of the paper that is lit up.

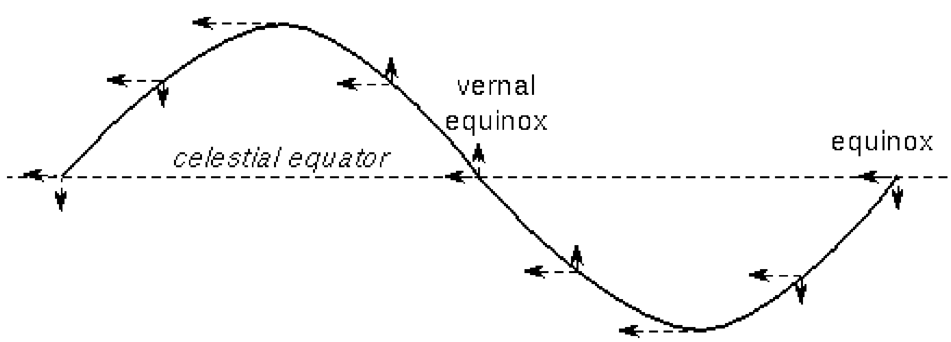
Analysis:
7. Which light beam appears to be less intense (more spread out)?
8. If the flashlight represents the sun and the paper represents the earth, in which case (directly perpendicular or at an angle) do you think the amount of heat absorbed by the earth be greater? Why?

Procedure:

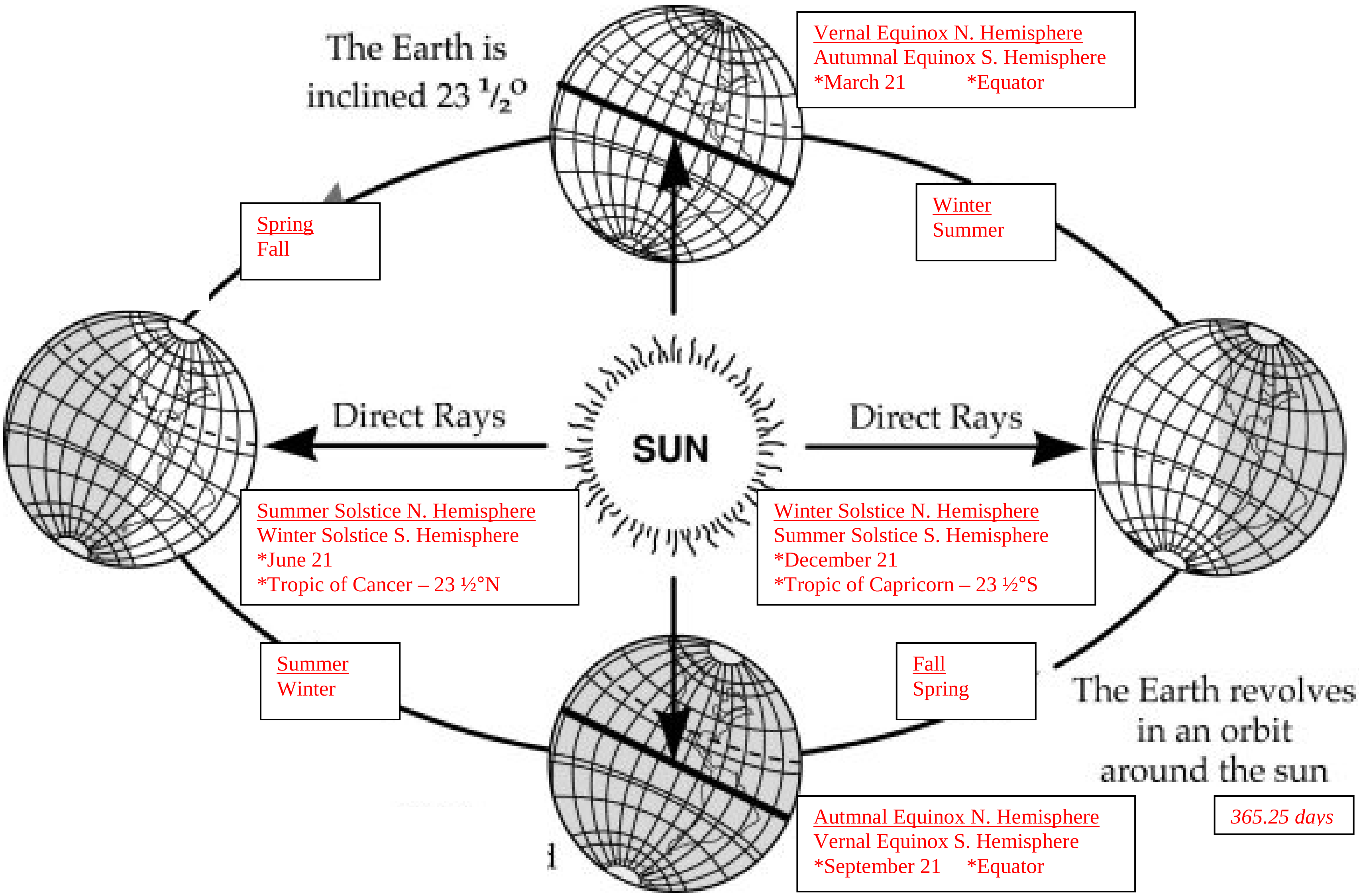
1. Place light bulb in the center of your table.
2. Point the axis of your earth toward North House, which is going to represent the North Star.
3. Place the earth so your sticker (the northern hemisphere) is tilted toward the sun and, of course, tilted to the North Star.
4. Observe what season this is and the specific location on earth the sun is shining at. SEE QUESTION 11!
5. Move the earth ¼ of the way in its orbit around the sun. REMEMBER: the tilt of the earth does not change, it should still be titled toward the North star (North House). Observe what season this is and the specific location on earth the sun is shining at. SEE QUESTION 12!
6. Repeat Step 5. SEE QUESTION 13!
7. Repeat Step 6. SEE QUESTION 14!

Analysis:

9. Draw and label a picture of the earth's trip around the sun. This should be a sun with four earths drawn around it. Make sure to indicate the tilt of the earth relative to the sun in your picture.
10. In step 4, the first position of the earth, what season was that for the Northern Hemisphere? What season was this in the Southern Hemisphere?
11. What specific location on earth was the sun pointing to in Step 4? What specific date is this?
12. What specific location on earth was the sun pointing to in Step 5? What specific date is this?
13. What specific location on earth was the sun pointing to in Step 6? What specific date is this?
14. What specific location on earth was the sun pointing to in Step 7? What specific date is this?
15. Draw and label the following diagram with the dates June 21, September 21, December 21, and March 21. This diagram indicates the sun's apparent position in the sky throughout the year.



16. What is the difference between winter and the winter solstice?
17. What is the difference between summer and the summer solstice?
18. What is the difference between spring and the vernal equinox?
19. What is the difference between fall and the autumnal equinox?
20. Why is the Earth said to have an orbit of 365.25 days? What is done in the calendar year to correct this?



The Earth is inclined 23 ½°
Vernal Equinox N. Hemisphere
Autumnal Equinox S. Hemisphere
*March 21 *Equator
Spring
Fall
Winter
Summer
Direct Rays
SUN
Direct Rays
Summer Solstice N. Hemisphere
Winter Solstice S. Hemisphere
*June 21
*Tropic of Cancer – 23 ½°N
Winter Solstice N. Hemisphere
Summer Solstice S. Hemisphere
*December 21
*Tropic of Capricorn – 23 ½°S
Summer
Winter
Fall
Spring
The Earth revolves in an orbit around the sun
365.25 days
Autmnal Equinox N. Hemisphere
Vernal Equinox S. Hemisphere
*September 21 *Equator

Graphing Earth-Sun Relationships

Question: What are climate graphs and what information can be obtained from them?

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

Vocabulary:
Temperature range

Materials:
4 data tables

Procedure:

Analyze the data on the following pages.

1. Use the data in the boxes labeled "Temperatures around the World" to make a multiple line graph for the Months vs. Average Temperatures on the attached graph.
2. Use the data in the boxes labeled "Seasonal Changes in Number of Hours of Daylight" to make a multiple line graph for the Months vs. Day Length on the attached graph.
3. Use the graphs to answer the following questions – make sure you answer in complete sentences!

Analysis:
Answer the following questions on lined paper.

Temperatures Graph

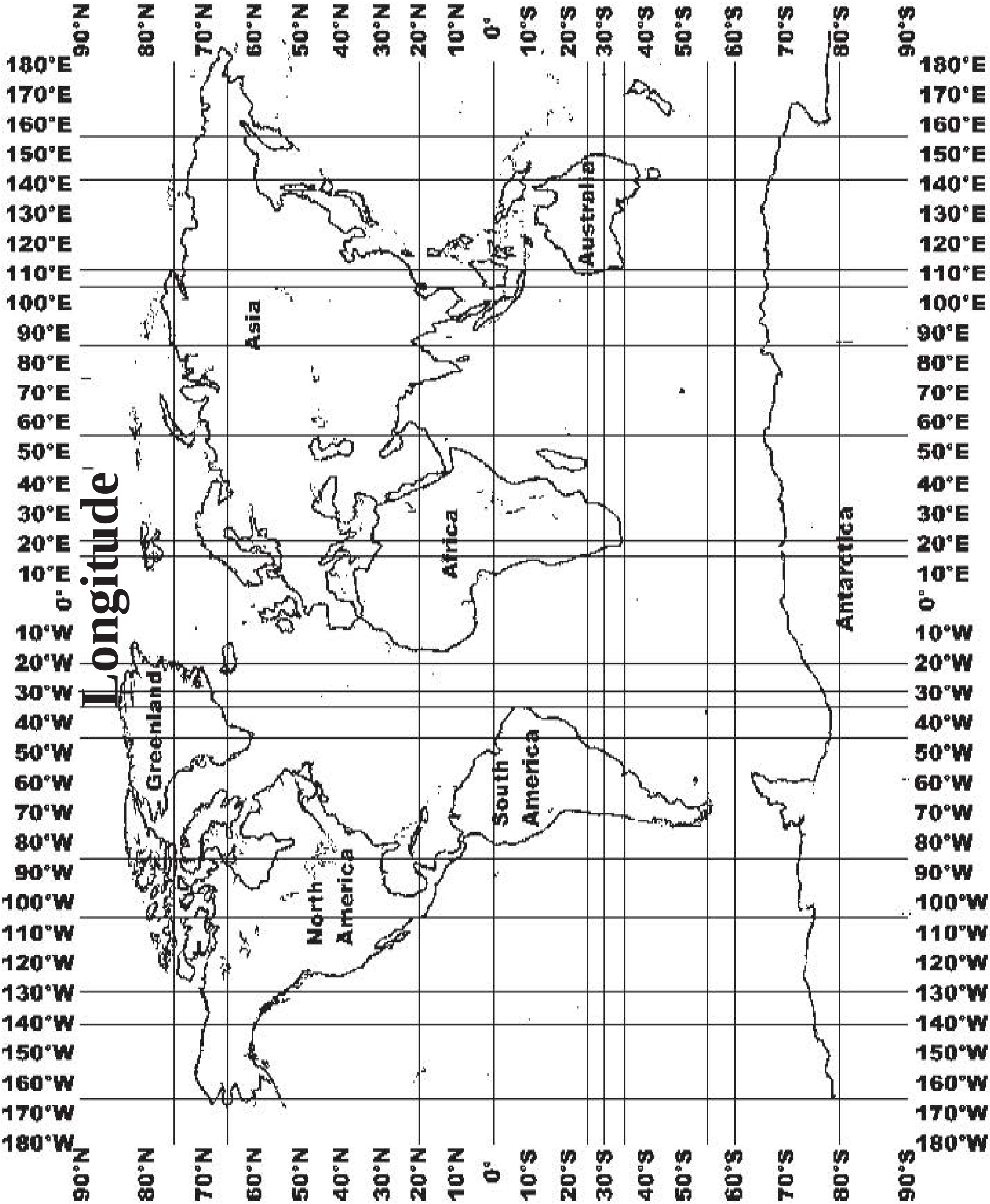
1. Describe the range in Minnesota's temperature. What is Minnesota's latitude?
2. Describe the range in Ecuador's temperature. What is Ecuador's latitude?
3. Why is Minnesota's temperature range so different than Ecuador's temperature range?
4. When does Australia reach its lowest temperature? When does Minnesota reach its lowest temperature?
5. Why do Minnesota and Australia reach their temperature lows at such different times throughout the year?

Day Length Graph

6. What do you notice about Ecuador's day length throughout the year? What does that tell you about day length along that latitude?
7. When does Alaska reach its peak amount of daylight? What is special about this time of year?
8. When does Alaska reach its low in amount of daylight? What is special about this time of year?
9. What do you notice about South Africa, at 26° S, and Mexico, at 26°N? What does this tell you about the relationship between hemispheres?
10. Make a conclusion about the relationship between distance from the equator (0°) and the variation in the amount of daylight.

Temperatures Around the World
Latitude and Longitude Data

Latitudes, Longitudes, and Elevations	
Escuela Antarctica, Esperanza; Provincial #38 Julio Argentina Roca Latitude: 63°S Longitude: 57°W Elevation: 10 m	Guangzhou, China Guangdong Guangya MS Latitude: 23°N Longitude: 113°E Elevation: 20 m
Sandy Bay,Australia Fahan School Latitude: 43°S Longitude: 147°E Elevation: 20 m	Kyoto, Japan Koryu JrHS Latitude: 36°N Longitude: 135° E Elevation: 8 m
Carltonville, S Africa; Tsitsiboga Primary School Lat:26°S Long:27°E Elevation : 1524 m	Minnesota USA Detroit Lakes Mid Sch Lat:47°N Long:96°W Elevation: 1431 m
Quito, Ecuador; Colegio Albert Einstein Lat:0°N Long:78°W Elevation: 2890 m	Kodiak, Alaska, USA Kodiak HS Latitude: 58°N Longitude: 152°W Elevation : 35 m
Chalatenango, El Salvador; Escuela Rural Mixta Latitude: 14°N Longitude: 89°W Elevation: 1700 m	


Longitude
90°N
80°N
70°N
60°N
50°N
40°N
30°N
20°N
10°N
0°
10°S
20°S
30°S
40°S
50°S
60°S
70°S
80°S
90°S
180°E
170°E
160°E
150°E
140°E
130°E
120°E
110°E
100°E
90°E
80°E
70°E
60°E
50°E
40°E
30°E
20°E
10°E
0°
10°W
20°W
30°W
40°W
50°W
60°W
70°W
80°W
90°W
100°W
110°W
120°W
130°W
140°W
150°W
160°W
170°W
180°W
Asia
Australia
Africa
Antarctica
Greenland
North America
South America

Latitude

Temperatures Around the World

Average Temperatures: 1996-1998 Data from GLOBE Schools Around the World

Data is in Degrees Celsius (°C)

Below are Celsius to Fahrenheit Temperature Conversions

°C	°F
-40	-40.0
-18	-0.4
-16	3.2
-14	6.8
-12	10.4
-10	14.0
-8	17.6
-6	21.2
-4	24.8
-2	28.4
0	32.0
2	35.6
4	39.2
6	42.8
8	46.4
10	50.0
12	53.6
14	57.2
16	60.8
18	64.4
20	68.0
22	71.6
24	75.2
26	78.8
28	82.4
30	86.0
32	89.6
34	93.2
36	96.8
38	100.4
40	104.0
100	212.0

$°F = (°C \times 9/5) + 32$

Escuela Antarctica, Esperanza; Provincial #38 Julio Argentina Roca
Latitude: 63°S
Longitude: 57°W
Elevation: 10 m

Month	Year	Avg Temp
Apr	1998	-3.8
May	1998	-3.9
Jun	1998	-4.2
Jul	1998	-12.5
Aug	1998	-11.5
Sep	1998	-9.7
Oct	1998	-6.3
Nov	1998	0.6
Dec	1998	1.2

Quito, Ecuador; Colegio Albert Einstein
Lat:0°N Long:78°W
Elevation: 2890 m

Month	Year	Avg Temp
Jan	1998	18.8
Feb	1998	18.4
Mar	1998	17.6
Apr	1998	16.0
May	1998	19.7
Jun	1998	17.1
{Aug	1997	17.6}
{Sep	1997	18.4}
{Oct	1997	18.0}
Nov	1997	18.3
Dec	1997	16.7

Kyoto, Japan
Koryu JrHS
Latitude: 36°N
Longitude: 135° E
Elevation: 8 m

Month	Year	Avg Temp
Jan	1996	4.4
Feb	1996	2.9
Mar	1996	6.9
Apr	1996	9.5
May	1996	16.4
Jun	1996	21.2
Jul	1996	24.3
Aug	1996	25.5
Sep	1996	20.2
Oct	1996	15.7
Nov	1995	10.3
Dec	1995	5.8

Sandy Bay,Australia
Fahan School
Latitude: 43°S
Longitude: 147°E
Elevation: 20 m

Month	Year	Avg Temp
{Jan	1998	18.0}
Feb	1998	17.5
Mar	1998	17.9
Apr	1998	14.7
May	1998	12.8
Jun	1998	10.1
Jul	1998	11.0
Aug	1998	10.6
Sep	1998	15.2
Oct	1998	13.7
Nov	1998	14.6

Chalatenango, El Salvador; Escuela Rural Mixta
Latitude: 14°N
Longitude: 89°W
Elevation: 1700 m

Month	Year	Avg Temp
Feb	1997	15.4
Mar	1997	15.5
Apr	1997	15.3
May	1997	16.0
Jun	1997	15.7
Jul	1997	15.7
Aug	1997	16.3
Sep	1997	16.5
Oct	1997	16.9
Dec	1996	15.1

Minnesota USA
Detroit Lakes Middle School
Lat:47°N Long:96°W
Elevation: 1431 m

Month	Year	Avg Temp
Jan	1997	-14.1
Feb	1997	-9.2
Mar	1997	-2.1
Apr	1997	2.8
May	1997	10.6
Jun	1997	20.3
Jul	1997	19.3
Aug	1997	18.9
Sep	1997	17.3
Oct	1997	3.8
Nov	1997	-5.5
Dec	1997	-4.5

Carltonville, S Africa; Tsitsiboga Primary School
Lat:26°S Long:27°E
Elevation : 1524 m

Month	Year	Avg Temp
Feb	1998	20.8
Mar	1998	25.2
Apr	1998	23.5
May	1998	18.9
Jun	1998	11.8
Jul	1998	13.9
Sep	1998	14.8
Oct	1998	18.8
Nov	1998	19.1

Guangzhou, China
Guangdong Guangya MS
Latitude: 23°N
Longitude: 113°E
Elevation: 20 m

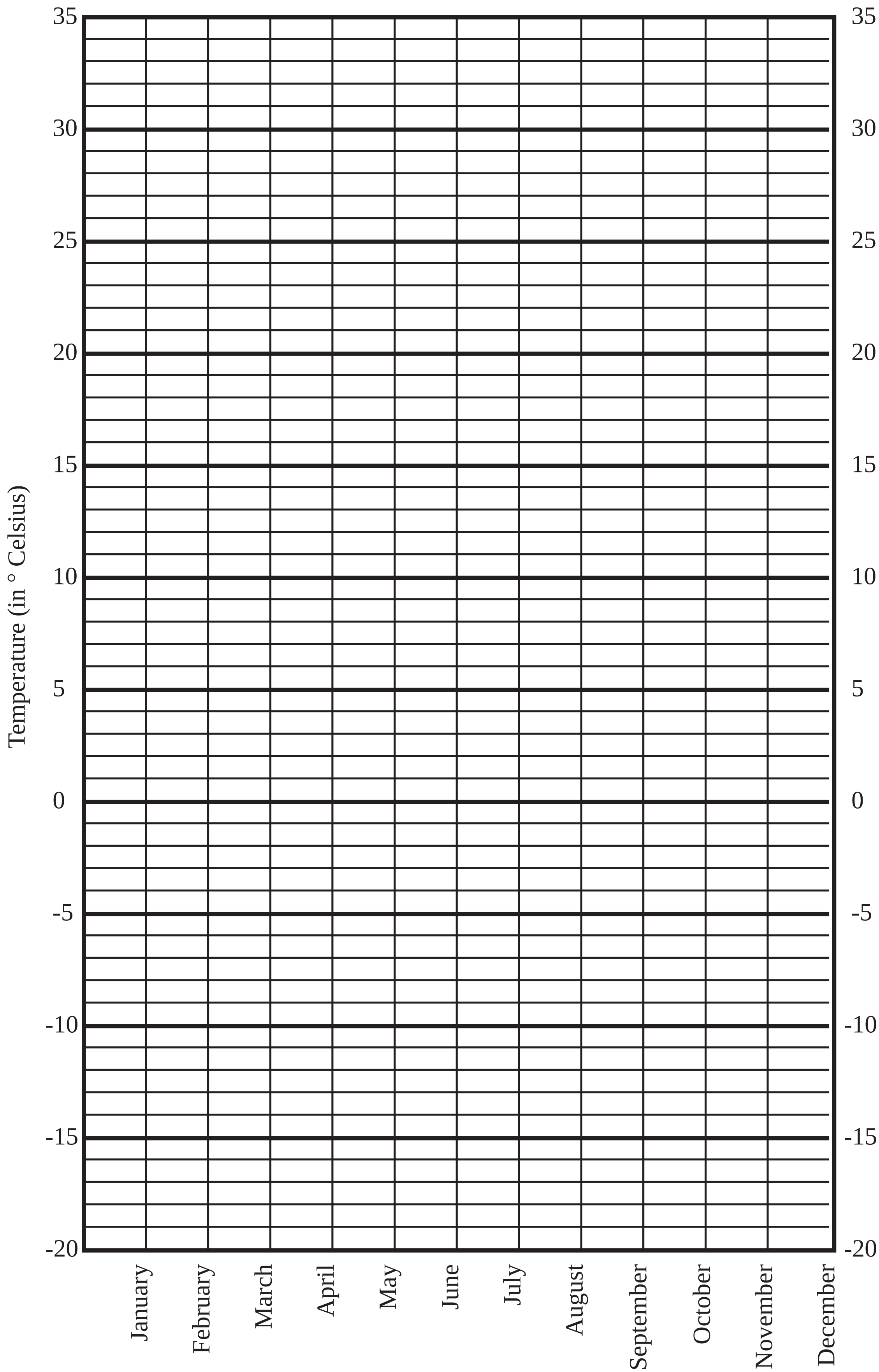
Month	Year	Avg Temp
Jan	1999	13.7
Feb	1998	18.4
Mar	1998	18.5
Apr	1998	23.6
May	1998	24.8
Jun	1998	27.2
Jul-Aug	{no data}	
Sep	1998	27.2
Oct	1998	23.1
Nov	1998	22.2
Dec	1998	18.0

Kodiak, Alaska, USA
Kodiak High School
Latitude: 58°N
Longitude: 152°W
Elevation : 35 m

Month	Year	Avg Temp
Jan	1999	-0.9
May	1998	6.4
Jun	1998	10.8
Jul	1998	12.8
Aug	1998	12.9
Sep	1998	9.9
Oct	1998	5.3
Nov	1998	2.7
Dec	1998	-1.5

Temperatures Around the World

Label each plot line:
a. latitude and
b. state/country



Days and Nights Around the World: Seasonal Changes in Number of Hours of Daylight

All dates are the 21th day of the month

Latitude: 70° North

Date	Sunrise (AM)	Sunset (PM)	Day Length
Jan	NONE	NONE	0
Feb	8:14	4:34	8:20
Mar	6:04	6:32	12:28
Apr	3:35	8:46	17:11
May	NONE	NONE	24:00
Jun	NONE	NONE	24:00
Jul	NONE	NONE	24:00
Aug	3:36	8:46	17:10
Sep	5:46	6:17	12:31
Oct	7:49	3:58	8:09
Nov	NONE	NONE	0
Dec	NONE	NONE	0

Tromsö, NORWAY
Prudhoe Bay, ALASKA, USA
Clyde, Baffin Island, CANADA

Latitude: 57° North

Date	Sunrise (AM)	Sunset (PM)	Day Length
Jan	8:28	4:15	7:47
Feb	7:23	5:25	10:02
Mar	6:09	6:26	12:17
Apr	4:50	7:25	14:35
May	3:41	8:24	16:43
Jun	3:15	9:08	17:53
Jul	3:48	8:43	16:55
Aug	4:49	7:35	14:46
Sep	5:53	6:12	12:19
Oct	6:56	4:52	9:56
Nov	8:04	3:47	7:43
Dec	8:47	3:29	6:42

Kodiak, ALASKA, USA
Glasgow, SCOTLAND
Copenhagen, DENMARK
Moscow, RUSSIA

Latitude: 38° North

Date	Sunrise (AM)	Sunset (PM)	Day Length
Jan	7:22	5:21	9:59
Feb	6:52	5:55	11:03
Mar	6:12	6:23	12:11
Apr	5:26	6:51	13:25
May	4:55	7:18	14:23
Jun	4:47	7:36	14:49
Jul	5:04	7:28	14:24
Aug	5:30	6:55	13:25
Sep	5:57	6:08	12:11
Oct	6:24	5:24	11:00
Nov	6:57	4:54	9:57
Dec	7:22	4:54	9:32

USA: San Franci sco, CALIFORNIA
Charleston, W. VIRGINIA
Wichita, KANSAS
St. Louis, MISSOURI
Louisville, KENTUCKY
Pueblo, COLORADO
Richmond, VIRGINIA
Sendai, JAPAN
Tientsin, CHINA
Athens, GREECE
Cordoba, SPAIN
Seoul, S. KOREA
Izmir, TURKEY
Palermo, SICILY
Lisbon, PORTUGAL

Latitude: 26° North

Date	Sunrise (AM)	Sunset (PM)	Day Length
Jan	6:58	5:44	10:46
Feb	6:41	6:06	11:25
Mar	6:12	6:22	12:10
Apr	5:41	6:36	12:55
May	5:21	6:52	13:31
Jun	5:19	7:05	13:46
Jul	5:30	7:02	13:32
Aug	5:45	6:40	12:55
Sep	5:58	6:07	12:09
Oct	6:12	5:37	11:25
Nov	6:32	5:19	10:47
Dec	6:53	5:23	10:30

Monterey, MEXICO
Kunming CHINA
Karachi, PAKISTAN
Luxor, EGYPT
Taipei, TAIWAN
Patna, INDIA
Riyadh, SAUDI ARABIA
Wau El Kebir, LIBYA

Latitude: 0°

Date	Sunrise (AM)	Sunset (PM)	Day Length
Jan	6:18	6:25	12:07
Feb	6:20	6:27	12:07
Mar	6:14	6:20	12:06
Apr	6:05	6:12	12:07
May	6:03	6:10	12:07
Jun	6:08	6:15	12:07
Jul	6:13	6:20	12:07
Aug	6:09	6:16	12:07
Sep	6:00	6:06	12:06
Oct	5:51	5:58	12:07
Nov	5:52	5:59	12:07
Dec	6:04	6:12	12:08

Quito, ECUADOR; Nairobi, KENYA; Singapore, MALAYA

Latitude: 26° South

Date	Sunrise (AM)	Sunset (PM)	Day Length
Jan	5:36	7:06	13:30
Feb	5:59	6:48	12:49
Mar	6:14	6:20	12:06
Apr	6:28	5:48	11:20
May	6:44	5:29	10:45
Jun	6:56	5:27	10:31
Jul	6:54	5:38	10:44
Aug	6:33	5:53	11:20
Sep	6:00	6:05	12:05
Oct	5:29	6:20	12:51
Nov	5:11	6:41	13:30
Dec	5:15	7:01	13:46

Pretoria, SOUTH AFRICA
Curitiba, BRAZIL
Brisbane, AUSTRALIA
Asuncion, PARAGUAY

Latitude: 38° South

Date	Sunrise (AM)	Sunset (PM)	Day Length
Jan	5:11	7:31	14:20
Feb	5:46	7:00	13:14
Mar	6:14	6:20	12:06
Apr	6:42	5:34	10:52
May	7:09	5:04	9:55
Jun	7:26	4:47	9:21
Jul	7:19	5:13	9:54
Aug	6:47	5:39	10:52
Sep	6:01	6:05	12:04
Oct	5:16	6:33	13:17
Nov	4:45	7:07	14:22
Dec	4:44	7:32	14:48

Melbourne, AUSTRALIA
Auckland, NEW ZEALAND
Bahia Blanca, ARGENTINA
Curacautin, CHILE

Latitude: 70° South

Date	Sunrise (AM)	Sunset (PM)	Day Length
Jan	NONE	NONE	24:00
Feb	4:09	8:35	16:26
Mar	6:10	6:21	12:11
Apr	8:19	3:57	7:38
May	NONE	NONE	0
Jun	NONE	NONE	0
Jul	NONE	NONE	0
Aug	8:24	4:03	7:39
Sep	6:00	6:07	12:07
Oct	3:37	8:15	16:38
Nov	NONE	NONE	24:00
Dec	NONE	NONE	24:00

ANTARCTICA

Data generated with Voyager by Carina software, Hayward, California

Days and Nights Around the World:
Seasonal Changes in Number of Hours of Daylight

Label each plot line:
a. latitude and
b. state/country