Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
2005 Volume IV: The Sun and Its Effects on Earth

Sun and Earth

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Introduction

The focus of this unit will be on the Sun and Earth. Hopefully the material that is offered will be used to help students complete a Science Fair Project. My main objective is to provide basic information on various topics enabling the student to decide which area he/she would like to investigate to complete a meaningful Science Fair Project. Once a topic has been identified, the first step, if possible is to get the student a mentor. It has been proven that the one-to-one nature of this process results in a better project. If one cannot find a mentor, your guidance and suggestions, to the student(s), will be critical to the Science Fair process and the completion of a quality project.

We do not need to reinvent the wheel, there are many well-developed activities for us to use. This unit will give you some suggestions on where find useful hands-on activities.

Content Standards

This unit can satisfy Performance Standards in Science by performing science inquiry investigations for their project, we can satisfy the standards in Math by using measurement concepts to show data, and in Social Studies by the appropriate historical & chronological thinking to show how the discovery of new information changed understanding of science phenomena. Language Arts standards may be met by demonstrating reading and writing skills with the research paper.

More information for the New Haven Public School standards can be found at:

http://www.nhps.net/curriculum/documents.asp

Sun

The Sun is an object in the sky that we have observed from infancy. It seemed very large to us and it gave us heat and light. As we grew older, we began to ask questions about the Sun and were given answers that may have been right or wrong, but they helped to satisfy our curiosity. What are some of the questions we may have asked at these earlier ages and how would we answer them today?

How was the Sun formed?

The presently believed theory on the origin of the Sun, is that it formed from a large rotating inter-stellar gas cloud that condensed into the spherical object we call the Sun. To help them understand why and how it became a star, and to explain how this mass of gas and dust contracted and became hot enough to allow nuclear fusion to begin, go to the following website: http://www.owlnet.rice.edu/~esci101/Lecture?ESC1101.02.SolarSystem.pdf ESCI 101: Lecture 2. Origin of the Sun and Planets, January 14, 2005.

This website shows with diagrams and explanations how the Sun was formed.

If you have access to the website: http://www.brainpop.com, you may want to look at the short movie entitled "Lifecycle of Stars" for the younger students. This movie shows the development of a star beginning with the clouds of dust to the "death" of the star. They explain that the mass of the star determines what will happen to that star at the end of the lifecycle. There is also a ten-question quiz, at the end, you may use to evaluate the students grasp of the "Lifecycle of Stars."

Another source of information on the life history of the Sun is found at: http://unitedstreaming.com, "The Death of the Sun and the Solar System."

How big is the Sun?

After they have found this information by reading assigned material, it might be fun to do the activity found at: http://www.cse.ssl.Berkeley.edu/AtHomeAstronomy/activity_03.html, "Finding the Size of the Sun and Moon." This website takes you step-by-step from the constructing the device used to measure the diameter of the Sun, how to use this device and how to calculate the diameter of the Sun. If you have them do this activity, it is fun doing a percent error comparing their results with the assigned reading figures.

Correct Value - Experimental Value

% Error = Correct Value X 100%

How far away is the Sun?

Because the Sun is so large compared to the other objects in our solar system, it appears to be very close to Earth. When we talk about this distance, we usually use the average distance of 93 million miles. Students usually want to know how we arrived at this figure.

A successful activity I have used is having them do triangulation activities. I have them do this activity at two different distances. After I give them the real measured distances, I have them compare the results of their scale drawing to the measured distance.

A good website for this activity is: http://motivate.maths.org/conferences/conf46/c46_parallax.shtml

This website also shows how parallax is used to find this distance.

Structure of the Sun

When we (middle school) talk about the structure of the Sun, we generally refer to the core, photosphere, chromosphere and corona.. A good overview for the student is to view the brainpop film "Sun." This gives some basic information about the Sun and again has questions at the end of the viewing that you may use for evaluation purposes.

Brainpop is a website that cost $134.95/yr for "Teacher Access." This allows you 35 logins per day. This website not only has information for Science but for Math, Social Studies, Technology and English.

The Sun in relation to other stars in our universe is considered an average size star. However, more stars are smaller than larger compared to the Sun. The composition of the Sun, by mass, is hydrogen 74% and helium 24%. These two elements, as a result of nuclear fusion, form the energy we receive from the Sun. Basically what happens is four hydrogen nuclei are fused to form one helium nuclei. This energy works its way to the surface of the Sun, after about one million years, and radiates energy we see as visible light as well as forms we cannot see but can detect with special instruments.

Core

The core is located in the center of the Sun and is the location of the above mentioned fusion reaction. Both the temperature and the density of the Sun decrease as you move away from the core.

Photosphere

The photosphere (light) is what we see as the visible surface of the Sun. Granules cover the entire surface of the Sun, except where there are sunspots. Granules are convection cells that constantly rise to the surface, cool and after about 10-20 minutes are replaced by new granules.

The sunspots are dark areas that are cooler than the rest of the surrounding surface and may last for several days to weeks. Sunspot activity seems to peak in an eleven-year cycle allowing their magnetic fields to cause the most havoc with communications on earth. Tracking sunspot activity has helped us to learn that all areas on the sun do not rotate at the same speed, rotation being faster at the equator than at the poles.

It takes light approximately 81/2 minutes to travel the 93 million miles to Earth. There are other forms of energy the Sun sends to Earth. We cannot see these forms, but can detect their presence. These other forms of energy come as magnetic fields, ultraviolet rays, radio waves, infrared wave, x-rays, and gamma rays.

Chromosphere

The chromosphere(color –sphere) is located above the photosphere. The temperature rises from 6,000º C to 20,000º C in this region. The activities that can be observed in the chromosphere are solar flares, prominences and filament eruptions, and post-flare loops.

A solar flare is a tremendous release of energy that occur in the neutral area between opposing magnetic fields. The energy released is as much a billion megatons of TNT. Prominences and filaments are both dense clouds material that are pushed above the surface by loops of magnetic field. Prominences are seen near at the edge of the Sun and can be seen during an eclipse. Post-flare loops are seen after a solar flare event. They are loops that condense from the hot corona and move back to the surface of the Sun.

Corona

The corona is the outer atmosphere of the Sun and can be seen during a total eclipse. During the early observations, astronomers were puzzled by the composition of the corona and believed that it was made of a new element which they named "coronium." Later investigations proved that it was composed of superheated hydrogen and helium that were stripped of their electrons.

Scientist have been puzzled by the high temperatures in the corona. The currently held view is that magnetic fields transfer energy from the photosphere to the corona. The temperature in the corona ranges from 1,000,000 to 2,000,000 degrees K. An interesting fact is that very little heat is transferred to other materials because of the very low densities.

Sunlight and Earth

We all know that life on Earth depends upon sunlight. Without this light there would be no plants to supply food and oxygen for our use. We can now appreciate that the study of the Sun-Earth relationship involves more than just curiosity. We will now investigate how we learn facts about the Earth by studying Earth-Sun relationship.

Because we wanted to get the maximum use of the Sun, communities originally had their own solar time. As railway transportation developed, much confusion was encountered reading a time schedule, as each location had a different time. Sir Sanford Fleming developed a system for Standard Time setting-up time zones that will be explained later in this unit. In some areas, we created daylight savings time to maximize daylight hours and now we are trying to use solar energy to help use with our energy problems.

Sun-Earth Movements

Most of us, at one time, probably thought that the Sun revolved around the Earth. At such early ages, we never knew the difference between the Sun and Moon and never thought about the tides unless we lived near an ocean.

As we grew older and gained more knowledge about these things, we gained an appreciation for those who made and proved the behaviors of the Sun and Earth.

A good starting point would be to perform 3 investigations on Sun-Earth relationships. After completing these investigations, they appreciate how new information proves or disproves previous beliefs. One investigation will give the best explanations for Sun-Earth movements based on our present day knowledge.

If you have access to the book "Earth Science for Secondary Schools" by Bob Swift(see bibliography) or an earlier version entitled "Interactions of Earth and Time, these three investigations showing possible Sun-Earth movements may be used as a demonstration or a hands-on activity for the student. We begin by using the changing lengths of days as a means of determining the proper Sun-Earth relationship.

Investigation 1 has the Sun in a fixed location. The Earth is in another fixed location and rotating on its axis. To satisfy the changing hours of daylight, they have the Earth rocking back and forth toward and away from the Sun. This model satisfies the criteria for the changing length of days.

Investigation 2 has the Earth in a fixed location with a tilted axis and the Sun is revolving around the Earth. This also satisfies the changing lengths of day and night.

Investigation 3 has the Sun in a fixed position and the Earth, rotating with its axis tilted, revolving around the Sun. Again this satisfies the changing lengths of days.

These investigations make the students realize that they must start using other information to eliminate some or all of the models investigated. The first piece of evidence they use is Polaris. They know that they can go our on any night, face north, raise their arm at about a 45° angle and Polaris is always in the same spot. This knowledge eliminates investigation 1.

Investigation 2 & 3 are still accurate at this point. They use the analogy of a moving car in a rainstorm with spotting meteors. They tell the students that more raindrops hit the front windshield of the car than the rear windshield because the front of the car is moving into the rain while the back of the car is moving away. They then say we see more meteors in the morning than at night. If the Earth were stationary, you would see the same number of meteors throughout the night. This eliminates investigation 2.

Remind the student that we now have more definitive proof of Earth revolution using Cosmic Microwave background radiation.

Now that we have determined the Earth revolves around the Sun and the axis of the Earth is tilted, causing the hours of daylight to vary during the year what else might we want to investigate? We may want to investigate the direction of Earth rotation, how we maximize the hours of daylight and how we determine our location on Earth. We can use shadows to help us understand some of these questions.

From an early age we noticed that our shadow changed in size and direction. However, most of us were more interested in having fun chasing the shadow and not really thinking about what caused it. When we observe our shadow during the day, we notice it not only changes direction but also its size. In the morning we notice that it points in the direction opposite the Sun and is larger than the object that causes the shadow. At noon, its direction has changed and the shadow is shorter. In the evening, the shadow is longer again but points in the opposite direction from the morning shadow as the position of the sun has changed due to the rotation of the Earth. If we construct a gnomon, we can use the shadows from a gnomon to determine the season of the year and also our longitude. You can make your own gnomon by using a board, sheet of unlined paper and a paper clip. This is an advantage over using your shadow because you will have a written record of time of day, length and direction of the shadow. If you have access to the textbook "Earth Science for Secondary Schools" or Interaction of Earth and Time" the activities with the gnomon are set-up for you to follow. The lesson entitle "The Gnomon" shows you how to construct your gnomon, record and construct a shadow line.

The next lesson is entitled "Interpreting a Shadow Line." From this lesson you can determine the difference between solar noon and clock noon. You can also determine the difference between true north and magnetic north.

You may find your longitude using your gnomon records, knowing what the central meridian is for your time zone and the time correction in minutes:seconds.

Speed of Earth's Rotation

We know that the Earth rotates on it's axis once in about every twenty-four hours. But just how fast is this? Is it the same for all places on the Earth? If we look at a model for the Earth, we see that it is a sphere and so not all places travel at the same speed during a rotation. If we divide the circumference of the equator by 24 hours, we find that places on the equator are traveling at about 1,000 mph. To find out how fast you are traveling at your latitude, you multiply the speed at the equator by the cosine of your latitude.

Most calculators make this possible. You may look up your latitude on line or construct an instrument called an astrolabe and measure the altitude of the North Star.

Earth's Revolution

One revolution around the Sun is referred as a year. Special things happen on Earth during this revolution around the Sun. Our astronomical winter, spring, summer and fall begin with these special events. The first day of winter begins on the winter solstice. This is when we have least number of daylight hours in the northern hemisphere (Dec.), after this date, we begin to have more daylight hours. Spring begins on the spring equinox (March) and all places on Earth have twelve hours of daylight and twelve hours of darkness. The days continue to get longer, more hours of daylight, until June when we have the summer solstice, the longest day of the year. After the summer solstice, the days begin to get shorter and when we reach the month of September, we have the fall equinox, equal hours of daylight and darkness. The hours of daylight continue to decrease until we reach the winter solstice and we start the whole cycle again.

During these changes of seasons, we notice a change in temperature as well as changing hours of daylight. These changes are due to the tilt of the Earth's axis. In the winter, the axis is pointed away from the Sun causing us not only to receive less hours of daylight but the angle at which sunlight reaches us. As we move from winter to summer, the hours of daylight increase and slowly we notice a temperature increase. Just the opposite happens from summer to winter. What some people fail to realize is that we are closer to the Sun in the month of March than we are in summer.

Because we want to use sunlight to our best advantage, we have time zones and in some areas, we use daylight savings time. If we divide the number of degrees in a circle (360°) by the number of hours in a day (24hrs.) we find that the Earth rotates about 15° per hour. As a result of this, our time zones are 15° in most places except where it might adversely affect the working environment of towns and cities close to one another. Daylight savings time is used in some areas in order to get the maximum use of sunlight and for safety reasons. Daylight Savings Time has communities setting their clocks ahead one hour starting in April and ending in October. We basically change the clocks so we may have an additional hour of daylight in the evening thus saving energy by maximizing sunlight.

Solar Energy and Weather

Weather is generally defined as the condition of the atmosphere at a particular time and a particular place. The main factors for these conditions are the amount and angle of the sunlight that reach the earth. These factors cause a global wind pattern. At the equator we have what are called the Trade Winds. These exist between 0° and 30° north and south of the equator. At 30° to 60° north or south of the equator we have the

Prevailing Westerlies and the final loops are called the Polar Easterlies that are located from 60° to 90° north or south of the equator.

One of the most important effects of the Sun on the Earth is the water cycle. This cycle constantly moves water from the atmosphere to earth and back into the atmosphere making it a renewable resource. If we did not have this cycle, we would not have life, as we know it. We should review or introduce the water cycle at this time. Remember a cycle is something that keeps happening over and over, so it really does not matter where you start. Basically the cycle is precipitation, run-off, evaporation, and condensation. A good website for this explanation with a great diagram is:

http://ga.water.usgs.gov/edu/watercycle.html

When we talk about weather, the condition of the atmosphere, we generally concern ourselves with seven basic weather elements. We now will spend some time on how to measure these basic weather elements and see their importance in a weather forecast. If weather is a class project, you may divide the class into groups with each investigating one basic weather element and constructing an instrument to measure that element. The construction of the instrument(s) helps them to understand the basic principle of the measuring device we use to measure that element.

These elements are:

Precipitation : Moisture that falls to the earth in the form of rain, snow, sleet or hail.

The form of precipitation that eventually falls to earth depends on the temperature of the atmospheric layers as it travels to earth. All precipitation begins as snow.

There are different ways to construct a precipitation gauge. You can go online to find one that you prefer to construct.

One online source is: http://www.miamisci.org/hurricane/moisture.html

Air Pressure : The pressure of the atmosphere on people and objects at the surface of the earth.

The barometer is the instrument we use to measure air pressure. Normal air pressure is 14.7 psi (pounds per square inch.) This means that on every square inch our body, a pressure of 14.7 psi is acting on it. A change in air pressure is an indicator of a change in weather. If the air pressure rises, it generally means good weather. If the air pressure falls, poor weather conditions can be expected.

When the air descends, it becomes warmer making the spaces between the molecules greater and room for more water vapor molecules. This downward movement also increases the pressure on the earth's surface causing an increase in air pressure readings.

Just the opposite occurs when the air ascends. The air becomes cooler causing the molecules to come closer together that force water vapor molecules to combine. When they combine, clouds form and precipitation may fall. The upward movement takes pressure off the earth's surface and the barometer readings fall.

Again, you can go online and find a way to construct a barometer of your choice.

One source is: http://www.miamisci.org/hurrican/airpressure.html

Air Temperature : Molecular activity of air molecules.

Air temperature is an important element. It determines when crops will grow, what crops will grow, what we will wear and what activities we can perform on a particular day.

We read a thermometer by the rising and falling of a liquid in a tube that air has been removed. This vacuum allows the liquid to move up and down without resistance. As stated earlier, temperature is the measure of molecular activity. The warmer the liquid, the greater the molecular motion and expansion occurs. Just the opposite occurs with the cooling of the liquid.

A good way to show what happens in a thermometer is to build a water thermometer. If you have access to an Interaction of Earth and Time textbook, there is a good demonstration activity showing the principle of the thermometer.

You should make sure your students have knowledge of the Celsius and Fahrenheit scales. A good website is: http://miamisci.org/hurricane/temperature.html

Relative Humidity : Amount of moisture in the air compared to what it can hold at

that temperature and pressure.

We are most comfortable when the relative humidity is about 45%. As the temperature changes, so can the relative humidity. The warmer the air, the more spaces between air molecules for water vapor. The cooler the air, the less space for water vapor. When we reach a relative humidity of 100%, we will have some type of precipitation.

We can use an instrument called a sling psychrometer to measure relative humidity.

Again you can find how to construct this instrument in a textbook or online.

One online source is: http://www.miamisci.org/hurricane/moisture.html

Wind (Speed & Direction): Horizontal movement of air.

Wind is caused by the difference in pressure. The greater the pressure difference, the stronger the wind. The direction the wind is coming from is how it is named.

Wind direction is measured by a wind vane and wind speed by an anemometer. There are different ways to construct and calibrate these instruments. The type you choose will depend on the grade level of your students.

One website is: http://www.miamisci.org/hurricane/wind.html

Clouds : Formed when moisture in the air condenses around solid particles in the atmosphere. There are four basic cloud types with a Latin root. Cummulus (heap), stratus(layer), cirrus(curl) and nimbus(rain).

Clouds are classified as high-level, mid-level, low-level and clouds with vertical development. To go into greater detail with clouds, go to the website:
http://ww2010.atmos.uiuc.edu/(GH)/guides/mtr/cld/cldtyp/home.rxml

If you would like to make a cloud in the classroom, go to website:
http://www.ucar.edu/educ_outreach/webweather/cloudact2.html

"Create a Portable Cloud"

Dew Point : The temperature at which air is saturated and condenses to a liquid.

A good way to start their understanding of dew point is to ask students what happen on the outside of a cold can of soda when you take it out of the refrigerator in the summer. Most will say moisture appears on the out side. Ask them if they know why this happens. Most probably will not know. You can explain to them that the air is cooled when it touches the can causing the water vapor molecules to come closer together and condense on the outside of the can. Tell them the same thing happens in the atmosphere when the air is cooled to the dew point.

One way for them to find dew point is to fill a glass ¾ full of water. Add ice to the water and stir carefully with a thermometer. Take the thermometer reading when moisture begins to form on the container. This is the dew point.

Weather Station Model

If you would like your students to be able to plot and read information on a weather station model, go to:
http://cimss.ssec.wisc.edu/wxwise/station/page2.html

Solar Energy Past and Present

We in the United States are the biggest energy users in the world. Presently one of our main concerns is the use of fossil fuels that appear to have a negative effect on our environment and occasionally the economy. Because the Sun will be around about another 4.5 billion years, it may be to our benefit to learn how to use this form of energy effectively and efficiently.

History of Solar Energy Development

The concern about alternative means of energy began during the Industrial Revolution not during the "energy crisis" of the 1970's. During the Industrial Revolution, people thought there was an inexhaustible supply of fossil fuels. However, there were a few engineers that did not agree with this way of thought and began exploring renewable energy options. Most decided to focus on solar power even though they knew many technical barriers had to hurdled.

Because there appeared to be no crisis with the fossil fuels, all the work they had done with solar thermal conversion was ignored. Presently the cost of a solar cell is very high compared to its efficiency so again more emphasis is being placed on other forms of renewable energy.

The amount of solar energy is not equal on all parts of the world as we noticed while doing earlier investigation with night/day and seasons. For this reason the areas that can maximize solar energy are used to test new solar technologies such as collecting solar energy by the use of mirrors. These mirrors track the sun and focus their rays on a single broiler system. This system is used only at midday when there is a peak of electrical usage. If it should be a cloudy day, a back-up thermal system filled with oil is used.

Students and the Solar Cell

If your school is a CPEP school(Connecticut Pre-Engineering Program,) each year they hold a competition where students make solar cars and solar boats. They then race their car or boat against other Connecticut schools. This would be an opportunity for the student(s) to show how the energy of the cell is measured with the varying amount and angle of the Sun.

They could also explain briefly how a solar cell produces energy. If one goes to "How Stuff Works," they can go to http://science.howstuffworks.com/solar-cell2.htm and learn how a solar cell operates.

Many schools have the K' NEX Solar Power Kit. The kit supplies two solar cells, motor, gears &connectors and an instruction booklet for many solar energy projects.

If you should need information about these kits, the address is:

K'NEX Industries, Inc.

Hatfield, PA 19440-0700

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Observing the Sun: http://solar-center.stamford.edu/observe/observe.html

Classroom Activities: http://pwg.gsfc.nasa.gov/istp/outreach/sunobserve1.pdf

SPA web resources: http://www.windows.ucar.edu/openhouse/activities.html

Lesson Plan Outline: http://www.kidseclipse.com/pages/a1b1c0d0.htm

Sun: http://www.oulu.fi/~spaceweb/textbook/

Zoom Astronomy: http://www.enchantedlearning.com/subjects/astronomy/

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Solar Physics – The Photosphere: http://science.msfc.nasa.gov/ssl/pad/solar/surface.htm

Our Amazing Sun – http://www.unitedstreaming.com

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Lesson 1

Purpose: To provide an activity for a Science Fair Project investigating how the angle of the Sun's rays affects temperature change during the year.

Objective: Upon completion of the investigation, the student will be able to explain why the temperatures ranges are different at different latitudes and why they vary at the same latitudes during a year.

Materials: Light Source, Solar Panel, Motor and/or Voltmeter,

Procedure:

1. Place your light source at approximately a 15° angle to the solar panel and measure the energy produced.
2. Place your light source at approximately a 45° angle to the solar panel and measure the energy produced.
3. Place your light source at approximately a 90° angle to the solar panel and measure the energy produced.

Observation:

(table available in print form)

Conclusion: The light source perpendicular to the solar cell produces the most energy.

Lesson 2

Purpose: To provide an activity for a Science Fair Project to measure the size of the Sun.

Objective: To construct a pinhole viewer and gather data to effectively use the formula

for finding the diameter of the Sun.

Materials: Sun, Cardboard, tape, ruler, plain white paper, tin foil, pushpin, scissors

Procedure: 1) Construct a pinhole viewer.

a. Cut a 2x2 centimeter square in a piece of cardboard.
b. Tape a piece of tin foil over the opening.
c. Use a pushpin and puncture a hole in the tin foil.

2) Use your pinhole viewer to project the image of the Sun on a plain sheet of

white paper. Make the distance between the pinhole and paper as large as

possible and still have a sharp image.

3) Measure the diameter of the image of the Sun.

4) Measure the distance from the pinhole to the paper.

Observation: Diameter of the image of the Sun = ______

Distance from pinhole to paper = ______

Diameter of the image of the Sun X Distance from Earth to the Sun = Diameter of the Sun

Distance of pinhole to paper

%error = Correct Value – Experimental Value X 100%

Correct Value

Conclusion: The diameter of the Sun can be calculated from using a pinhole viewer and using the above formula.

Lesson 3

Purpose: To provide an activity for a Science Fair Project distinguishing Solar Noon from

Clock Noon.

Objective: Upon completion of this investigation, the student will be able to use a

gnomon record to explain the difference between Solar Noon and Clock Noon

for their longitude.

Materials: Gnomon and gnomon board, Plain white paper (8 ½" X 11"), magnetic

compass, ruler, masking tape, watch or clock, drafting compass

Procedure:

1. At the middle of the long side of the paper, measure in about 2 ½ inches and make a small hole for the gnomon.

2. Place the gnomon through the hole and tape the paper to the board. (I found using a paper clip and bending a part of it straight up for the gnomon worked very well.)

3. Write your name and date in the lower right hand corner of the paper.

4. Place your gnomon outdoors where sunlight will not be interfered with for your observation period.

5. Make sure the gnomon is level and using your magnetic compass, draw a line showing the direction for magnetic north.

6. Make a small dot at the end of the gnomon shadow line every 15 minutes between the hours of 10:00 A. M. and 2:00 P.M.

7. Using a Plastic ruler, connect the dots using a smooth curved line.

8. Using your drafting compass, place the pivot point in the gnomon hole.

9. Open the compass so that it will cross the shadow line at two points.

10. Make an arc on each side of the shadow line.

11. Open your compass so that is a little more than half way between the twoarcs.

12. From each arc on the shadow line, place the pivot point of the compass and construct two new arcs that

will intersect each other.

13. Using your ruler, draw a straight line from the gnomon hole to the place where the two arcs intersect.

Observations: The straight line representing Solar Noon did not cross the shadow line at Clock Noon.

Conclusion: Places with different longitudes will have a different Solar Noon even though their Clock Noon is the same.