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A HISTORICAL APPROACH TO STUDYING ASTRONOMY

By

Bradley Charles Baryo

A Thesis

Submitted to
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Abstract

A Historical Approach To Studying Astronomy
by
Bradley Charles Baryo

This project was developed on the idea that most students need to have a better understanding of certain scientific concepts such as Astronomy. The idea was to increase their background and historical knowledge which intern would help them have a deeper understanding and better appreciation for the work that has already been done by scientists. This historical background knowledge would help with comprehension of future work in astronomy.

This goal was accomplished by taking information that most students could easily observe over the course of time with the naked eye, much like our ancient ancestors. I then built on these observations using activities such as demonstrations with discussions, labs, hands on activities and computer websites to teach students how scientist using experiments and better equipment, explained how the universe works. For each new lab or activity, I incorporated the background history that explained what scientists believed centuries ago and how we have progressed, over time, to the understanding of astronomy we have today.

Pre and post-test results were used as an indication of how many of the students knowledge increased over the course of this unit. I used an evaluation form to see what activities students liked and thought were helpful. The students needed to know not only how the universe works, but also what evidence scientists used to make their conclusions. The students also filled out evaluation forms that were useful in determining which activities were most beneficial.

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INTRODUCTION

STATEMENT OF RATIONALE

This unit was designed to help teachers and students alike overcome some of the major misconceptions about astronomy using historical facts and experiments. I chose this unit because of the eight staff members in my department, not one has ever taken an astronomy course in college. Most of my own knowledge about astronomy has come from my undergrad classes while attending the University of Michigan-Flint. I thought that developing and teaching this unit would be the best way to enhance my knowledge, which would allow me to help students and other teachers grasp all of the major concepts in astronomy. When instructors have a more throughrow understanding of the subject matter they can then make connections for the students that will increase the students' interest. I believe that most science teachers would love to integrate the history of science into their lessons. I think that most do not know where to start and do not have time to gather all of the information (Monk and Osborne, 1997) (Howe and Rudge, Forthcoming). This will make connections to other topics and create more interest for their students. Most of the instruction in high school has not changed significantly over the last 40 years and "much of science instruction proceeds as if it had no history and is not guided by any discipline."(Paldy, 2003) I believe that if you incorporate other subject areas, such as history, into the science curriculum this will engage more students. "The use of history can potentially humanize science and help students refine their critical thinking skills, promote a deeper understanding of scientific concepts, and address common student misconceptions that often resemble those of past scientists" (Matthews, 1994). One of the benefits of using this strategy is that it helps students that may be struggling academically and could help them to become more excited about science. This may cause them to become more passionate about looking for other science related information in the subject area that they truly love. Another benefit is that using the history of science is closely aligned with the constructivist teaching theory. The constructivist learning theory states that students are active learners that construct a framework to understand new ideas or concepts (Sewell, 2002, Haney, Lumpe, and Czerniak, 2003 and Lowery, 1997). This allows students to put together their own understanding of science and nature of science concepts (Howe and Rudge, 2004).

Astronomy is one of the several units that I teach my freshman and sophomore students in Earth/ Physical science class. The course is supposed to build on the concepts of astronomy covered in sixth, seventh and eight grades. While doing my research I discovered that the benchmarks at the middle school were not being covered. The Middle school teachers informed me that astronomy was the last topic on their agenda to cover each year. For the past few years they have run out of time and had not covered this topic. Due to this, I needed to cover all the middle school topics in addition to these to be taught in high school. These included: compare the earth to planets in terms of supporting life; describe, compare, and explain the motions of the solar system objects, and describe and explain common observations of the night skies. The high school topics included: compare our sun to other stars, motion of our solar system in the galaxy; scale, structure and age of the universe; explain how stars and planetary systems form and produce energy; and explain how technology and scientific inquiry have helped us learn about the universe.

Astronomy is an extremely important topic to understand and has helped shape our culture and religious beliefs throughout the centuries. Many high school students can answer some questions dealing with the simple concepts associated with astronomy, but when asked how scientists determined whether a theory is correct and to show the proof, students fail miserably. Over the years, after each unit, I have asked students to answer questions using scientific evidence to support scientific theories. To my dismay most students have a hard time making the connection between laboratory facts, class discussion and using scientific information to prove the theories correct. When the students finish this unit, I expect that they will have the necessary background knowledge to explain any of the theories using facts and figures. Approximately eight to nine weeks are devoted to covering this unit.

There are a few parameters that I felt like I needed to address before I could present any of this unit to the students. First, I needed to make sure that all of the student activities were aligned with the state of Michigan standards. The second was to make sure that multiple teaching strategies are used to help all students master the unit. The third was, to make sure that all of the common student misconceptions are discussed and rebutted. Finally, the most important feature was to incorporate as much history as possible into the curriculum, believing that the students would benefit and have a better understanding if they understood how science progressed slowly, step-by step, over the course of centuries(East Lansing Public School, 2004).

COMMUNITY PROFILE

The community of East Lansing is located about four miles from the city of Lansing, Michigan. It is a community of about 45,000 full time citizens and the population increases to about 90,000 during the academic year when students are attending classes at MSU. The individuals are middle to upper class socioeconomically. The community is well educated with many parents working as doctors, lawyers, university professors, and many other prestigious professional fields. The proportion of residents living in the community with at least a bachelor's degree is estimated to be 71.2% with the state average being 22.4%. The community is very supportive of its schools and has high expectations for teachers and students. The emphasis on a quality education is extremely high. The median household income is only $26,791, which is below the state average of $45,839. Statewide, only 5.2% of Michigan's schools have lower median household incomes. The reason for the lower household income is that most university students do not have full-time jobs and they are factored into this average. Very few households in the community consist of a lone-parent with child, about 5.5%, which is below the state average of 9.8%. The resident property owners pay on average $2,152 in school taxes on $100,000 of residential property value, which is higher than the State average. East Lansing's property taxes have increased an average of 4% per year. This shows a greater increase than the statewide average, which has shown little change (East Lansing Public School, 2004).

SCHOOL/DISTRICT PROFILE

The East Lansing Public Schools are located in a medium-sized suburban district. The district covers about 12.5 square miles which includes most of the city of East Lansing, small portions of Lansing, Lansing Township and Meridian Township. The district also has close ties to the City of East Lansing and Michigan State University, and benefits from the 2,000 parent volunteers. The population for 2003-2004 was approximately 3,556 students. Of the 3,556 students, 9.0% receive special education instruction. On a full-time basis, the district's special education enrollment is 3.1% of total enrollment, which is average with other schools of the same size in the state. The number of students who are classified as economically disadvantage and receive free or reduced-price lunch is about 17.3%, which is well below the state average. Due to the district's vicinity to Michigan State University, the district is proud to boast a rich diversity of students from over 50 different countries. The student-teacher ratio is 18 to 1. The teaching staff consists of 244 employees with 68% of them having advanced degrees from a wide array of colleges and universities. Most staff members have well over 15 years of experience in the teaching field. Many staff members have achieved state and national recognition in their field.

The district's total administrative expenditures are well above the state average with 57.3% allocated to school administration, compared to the state average of 48.3%. Transportation and food services expenditures are both below their peer group and state average. The average teacher salary expenditures are moderately above the state average $49,379 to $54,285, but the district has shown little net change compared to the state and peer trends, which show annual increases over the last few years (East Lansing Public Schools, 2004).

The High School is a comprehensive four-year preparatory school serving on average 1,213 students. Approximately 85% of the student body will attend post-secondary colleges or universities. The retention rate for the High School over the past three years has continuously been over 99%. The teaching staff at the high school totals about 70 teachers with 58% of them having advanced degrees. The high school has 18 advanced placement courses available to the student body. In 2003-2004, 166 students took AP exams with a mean score of 3.8. In that year the high school also boasted an average of 12 National Merit Scholarship Finalists, was winner of the annual physics competition at the University of Michigan, and *best of show* at the Journalism Education Association/National School Publishers Association's National Convention for the school yearbook. In addition to these academic honors, the student body has the opportunity to participate in over 37 student clubs, societies, or organizations, as well as athletics.

CLASS PROFILE

The counseling department determines the actual composition for the individual classes. The actual composition of the school for the 2004 school year is ≈73% of the students are Caucasian, ≈14% are African Americans, ≈7% are Asian, ≈5% Hispanic and ≈<1% Native American. Most students have been raised and educated in the East Lansing school system their entire lives. Approximately 2% of the students in this study have English as their second language. Many of these students have been in the United States only for a few years. The Earth/Physical Science classes consist of half freshman (Class of 2008) and half sophomore (Class of 2007). A total of 80 students out of 130 consented for this project (Appendix A-1). I could only use data for 69 of the students. The 11 students that consented, and whose information I could not use, either dropped the course or had not completed the required paperwork. Of the 69 students, 28 were males and 41 were females. The students in the freshman class, for whatever reason, are struggling at the high school. After the first semester, half of the freshman student body failed one or more of their classes. I have not experienced much of a problem in my classes. I did not see much of a difference in student performance this year compared to previous years and have actually experienced a lower failure rate this year compared to prior years.

SCIENCE BACKGROUND

Astronomy is the science or study of the universe in which the stars, planets and other objects in space are studied. Astronomy is probably the oldest of the natural sciences, dating back to the dawn of man. Astronomy can be broken into four main time periods which include: Prehistoric, Classical, Renaissance, and Modern.

The Prehistoric period has been practiced for as long as humans have been looking at the sky. Early civilizations, like the Mayans and Chinese, used astronomy to keep track of time, orient their cities, and predict the future. These early cultures associated celestial bodies with gods and spirits. The calendars of the world had been set to the Sun and Moon and were of great importance to ancient agricultural societies. These agricultural societies needed to use this information to know when to plant and harvest crops. A failure to know this information could have meant death to the entire society.(http://www.sir-ray.com/Ancient%20Astronomy.htm)

During the Classical period, the Greek civilization made some great contributions to the development of astronomy. They named many of the stars and were able to plot their exact position in the night sky. They proposed many astronomical ideas which included: planets were spheres, the sun was the center of the solar system, the explanation of how eclipses occurred, and the earth rotates on its axis, and calculated the size of and distance to the moon. They also were the first to attempt to determine the distance to the sun. The Arab civilization became highly cultured and translated many of the ancient Greek works into Arabic and started storing them in libraries. In the 10th century a huge observation facility was constructed which allowed Arabs to calculate the obliquity of the ecliptic, or the tilt of the earth's axis relative to the sun. Meanwhile, the progress was mostly stagnant in Europe as they moved through the Dark ages. The Europeans continued to use the Greek's geocentric model, in which the Earth was the center of the universe.(http://www.astro.virginia.edu/class/hawley/astr121/history.html)(http://www-groups.dcs.st-and.ac.uk/~history/HistTopics/Greek_astronomy.html)

The Renaissance period came along on the back of one Nicholas Copernicus, who reintroduced the Greek heliocentric model of the solar system. His work was then expanded upon by Tycho Brahe and Johannes Kepler. Kepler, being a mathematical genius, used the information that Tycho gathered from years of careful observation to calculate the orbits of the known planets. He then used the information to predict the planetary positions and created his three laws of planetary motions. Galileo, early in the 17th century, invented a telescope and was the first to observe four moons orbiting the planet Jupiter. He also noted that Venus exhibited phases similar to the phases of the moon. This information was necessary to disprove that the sun was the center of the solar system and supported Copernicus' heliocentric theory. This new observation was incompatible with the teaching of the Roman Catholic Church. These findings created many problems for Galileo and many of the scientists of the day. The Catholic Church's influence caused the advancement of astronomy, and other sciences, to be inhibited for hundreds of years.(Strobel, 2004)(http://www.infoplease.com/ce6/sci/A0856746.html)

Finally, Modern astronomy came about in the end of the 17th century when Sir Isaac Newton helped to merge physics and astronomy by discovered the law of gravity. He also discovered the laws of motion and that these external forces were strong enough to cause planets to have elliptical orbits thus, explaining Kepler's laws. He also discovered that visible white light from the sun could be decomposed into smaller fundamental units or component colors. Scientists then later discovered a multitude of spectral lines and used further experiments to show that hot gases produced the same spectral lines, and that each individual element has its own unique spectral pattern. (http://www.astro.virginia.edu/class/hawley/astr121/history.html)

Review of Pedagogical Literature

Michigan Standards

All of the student activities and lessons needed to be associated or connected to the state of Michigan benchmark standards. These standards are used to help school districts and teachers implement strategies that allow students to meet or exceed certain educational standards on the Michigan Educational Assessment Program (MEAP) test (http://www.miclimb.net). The state uses this test to gauge the academic competency of students in five basic subject areas: mathematics, reading, science, social studies and writing. This is especially important because currently the test is the one tool that measures the public school districts in the state of Michigan to determine if the students are receiving the same education and are mastering the same subject matter. This type of test did not exist in the past. The intent of the Michigan Educational Assessment Program (MEAP) is to measure the academic achievement of all students and to require all teachers to have instructional materials that will help students master all curriculums (Watkins, 2000) (Bybee, 2003).

Multiple Strategies

The second parameter was to make sure that I used a multiple intelligence approach to teaching that would give students the opportunity to express their ideas in an appropriate manner. This multiple intelligence approach was developed in 1983 by Dr. Howard Gardner who proposed that humans have eight different and unique intelligences (Gardner, 1983). These intelligences include:

- Linguistic
- Logical-Mathematical
- Spatial
- Bodily-Kinesthetic
- Musical
- Interpersonal
- Intrapersonal
- Naturalist

According to Dr. Gardner, schools and cultures focus most of their attention on Linguistic and Logical-mathematical intelligences (Gardner, 1983). Focusing solely on these types of learning strategies has encouraged memory teaching tools that promoted little to no association to material, low motivation, and inadequate performance. Not much valve is placed on learning, remembering or understanding the material. This leaves many students at a disadvantage of how to express their knowledge in a certain subject area. Much of the classroom instruction by nature tends to only use these two intelligences to get across the major points in a lesson. Many inexperienced teachers who are not comfortable with teaching a new lesson or unit will revert back to this style of teaching. All teachers need to recognize that if all students are to learn, they need to use the appropriate area of intelligence's to reach all students. They must create a science curriculum that is meaningful, relevant and personalized for all students. Students understanding and utilizing their intelligences will help them to be more successful in gaining knowledge that will help them become life long learners (Goodnough, 2001).

Helping students understand how to incorporate this information into their lives is the job of every teacher and/or parent.

My intelligence styles are very strong in Logical-Mathematical, Spatial, Bodily-Kinesthetic, Interpersonal, Intrapersonal and Naturalist which allows me too easily to incorporate lessons based around these styles of learning. Most people are multifaceted learners. I incorporated activities for the Linguistic learners by having students, using outline provided by the teacher, take chapter notes and allow time for the students to read the new information. Also, I encouraged the students to make songs about the different topics throughout the year. We went as far as to have singing days in class. Everyone in the class had to sing if they had a question or comment.

Misconceptions

The third parameter that I needed to work on was the fact that students often bring concepts that are scientifically incorrect into the classroom (Howren and Kang, 2004 Sewell, 2004). Using the Know, want to know and learned (KWL) lesson at the beginning of the unit I probed students to find their major misconceptions to help design many of the lessons for this unit. The following are some of the more common misconceptions that students have about astronomy (Annie Hapkiewicz MSTA Journal, 1992).

- The Earth is flat.
- The sun is a perfect sphere that never changes.
- The Earth is in the center of the solar system.
- The Sun revolves around the Earth.
- All stars are yellow in color.
- Stars and constellations appear in the same place in the night sky every night.
- The sun follows the same path across the sky every day.
- Changing distance between the earth and the sun causes seasonal changes.
- All stars are the same distance from the earth.
- The solar system and galaxies are very "crowded".

- The surface of the sun does not have any visible features.
- All stars in a particular constellation are near each other.
- Stars are fixed spots in the night sky.
- The moon is larger than the sun.
- Planets orbit the sun in circular orbits.
- The only source of electromagnetic radiation coming from the sun is visible light.
- The atom is the source for all radiation.

I also wanted to make sure that the students understood the reasons why these misconceptions are incorrect. My strategy was to use questions like; "What is the shape of the Earth?", "What is the center of our solar system?" and "Does the Earth spin on its axis?" Most high school students could answer these questions so I went further by asking the students to tell me the proof used by scientists to explain the answers. This is where students failed to grasp the major ideas. The problem with a misconception is the fact that people tend to believe what they see and do not use the evidence to back-up their ideas.

I feel that the best way to break these misconceptions is to have students engage in activities that show them the evidence and they will then "see" for themselves what is correct. If the students actively participate they will then recognize the evidence and prove, or in our case disprove, their own misconceptions. These activities should help students overcome these major misconceptions since once students have incorrect ideas they are very difficult to change (Mestre and Touger, 1989, Salder, 1992, Trumper, 2001).

History

Finally, I believe and the research shows that history can be a valuable tool to help students understand the concepts of science (Matthews, 1992, 1994; Hills, 1992: Lentz and Winchester, 1997: Bevilaqua and Giannetto, 1999). Other research also shows that the lecture method of teaching is not an effective way to teach students science and have them retain the new knowledge (Leonard 1992, 2000). I think that the hardest thing for teachers to overcome when trying to incorporate history into the teaching of science is the time constraints needed to tell the stories, finding supporting activities and high quality resources (Howe and Rudge, 2004). Telling stories about the scientists' lives, culture of the time, philosophy, sociology and psychology will add a texture, richness and better understanding of how science has progressed over the years, and is very helpful to many students (Michalovic and McKinney, 2004).

There are many hazards that teachers must learn to avoid when presenting lessons using a historical perspective. History can be used to distort the facts. Teachers need to prioritize and include the correct information, but at the same time the students do not need to have a complete historical account to get the correct idea that is being presented (Allchin 2000, 2004). Stories are great, but students can not be expected to learn about science by simply exposing them to the historical information. The students will need to be led through the material and shown how each topic is connected to all of the others and put the historical stories into contexts. (Abd-El-Khalick, 1998).

I feel that the research that I did at Michigan State University to support the four parameters (Michigan Benchmarks, misconceptions, multiple intelligences, and history) will be beneficial to myself and my students. By having a better understanding of the Michigan Benchmarks and student misconceptions of Astronomy, I will be better able to incorporate lessons using multiple intelligences and historical background information. Hopefully using these four parameters will allow the students to better appreciate and understand the topics associated with astronomy.

Implementation of Unit

I believe that background content knowledge plays a critical role in helping students learn new material. I wanted the students to start with the simplest aspect of astronomy and build up from that point. I wanted them to start with their own observations, similar to what the prehistoric and ancient peoples would have done, and learn from that point forward. From this I could introduce step-by-step the more complex higher thinking skills that they need to know to understand and master the concepts of modern astronomy.

To start this unit I needed to know where the students stood with their background knowledge of astronomy. I have found that in previous years the students have come in with a wide range of knowledge in the area of astronomy. The fact is that in previous years very few students knew that "Changing distance between the earth and sun cause's seasonal changes" was a false statement. An even smaller percentage of students knew the true reason for the seasonal changes. On the other hand, many of the students knew that the "The Earth is flat" was a false statement, but almost no one could tell me the scientific evidence that makes this a false statement. I was quite shocked at how little the students actually knew about astronomy. After doing my research I discovered that the middle school teachers have not been covering their astronomy unit for the last few years. The sixth grade teachers informed the seventh and eighth grade teachers that they have not been getting to the astronomy unit due to time constraints. This oversight, I believe, has now been corrected and units have been shuffled around at all levels. Students in future classes will have an easier time handling this unit. The following table

(1) is an overview of the activities and benchmarks that were discussed over the course of this unit.

Table 1: **OVERVIEW OF ASTRONOMY UNIT FALL 2004**

BOLD PRINT denotes new or improved learning activities

Day/ Date	Daily Plans	Benchmark
Tuesday 10/5	•Go over test on Atoms/Matter/ Density •Talk about consent forms •KWL about astronomy	
Wednesday 10/6	**•Pre-test**	
Thursday 10/7	**•Notes Covering** **Prehistoric Cosmology** **Classical Astronomy**	Science/Strand II & V Standard 1 & 4/ High School Benchmark 2, 4 & 6
Friday 10/8	•Finish Notes **•Indirect Evidence Lab** **Tube-n-rope activity** **Think Boxes** •Turn-in activities	Science/Strand I &V Standard 1 & 4 / High School Benchmark 1 & 4
Monday 10/11	•Evaluation of Indirect Evidence Lab **•Pass out Space terms** **•Notes/Pictures** **Sun Motion** **Circumference** **Equatorial Bulge** **Ptolemaic System**	Science/Strand II & V Standard 1 & 4/ High School Benchmark 2, 4 & 6
Tuesday 10/12	**•Eratosthenes Circumference Lab** **•Homework Retrograde Motion**	Science/Strand V Standard 4/ High School Benchmark 2 & 7
Wednesday 10/13 **½ day** 5th and 6th hours **Parents night**	•Quiz Circumference **•Paper Moon Lab**	Science/Strand V Standard 4/ High School Benchmark 2
Thursday 10/14	•Movie "The Standard Deviants Astronomy part 1"	Science/Strand V Standard 4/ High School Benchmark 2
Friday 10/15 **½ day** 1st-3rd hours	**•Quiz Circumference** **•Paper Moon Lab**	Science/Strand I & V Standard 1 & 4/ High School Benchmark 1 & 2
Monday 10/18	•Evaluation Circumference of a circle •Paper Moon Lab Due	Science/Strand V Standard 4/ High School Benchmark
Tuesday 10/19	**•Notes** **Measuring a parallax** **Rotation Earth**	Science/Strand V Standard 4/ High School Benchmark 2

Wednesday 10/20	•**Measuring Parallax Lab**	Science/Strand V Standard 4/ High School Benchmark 2
Thursday10/21 **Fire drill**	•**Foucault Pendulum**	Science/Strand II & V Standard 1 & 4/ High School Benchmark 4
Friday 10/22	•**Movie "Galileo" PBS**	Science/Strand II & V Standard 1 & 4/ High School Benchmarks 4 & 6
Monday 10/25	• Finish **Movie "Galileo" PBS**	
Tuesday 10/26	•**Renaissance Notes** •Standard Deviants "Movie Tycho" •Evaluation Measuring Parallax	
Wednesday 10/27 **½ day** 1st-3rd hours	•**Space terms Quiz** •Evaluation Foucault Pendulum	
Thursday 10/28 **½ day** 5th-6th hours	•Space Terms Quiz •Evaluation Foucault Pendulum	
Friday 10/29 **Fire drill**	•**Kepler's laws Part I Lab**	Science/Strand V Standard 4/ High School Benchmark 4
Monday 11/1	•**Kepler's Law Part II** •Homework Telescope Website	Science/Strand V Standard 4/ High School Benchmark 4
Tuesday 11/2	•NO SCHOOL	
Wednesday 11/3	•**Kepler's Law Part III** Turn-in Telescope Homework	Science/Strand V Standard 4/ High School Benchmark 4
Thursday 11/4	•**Quiz Space Terms** •Finish Kepler's law packet	Science/Strand V Standard 4/ High School Benchmark
Friday 11/5 **Fire drill**	•**Electromagnetic Notes** •**Kepler's laws Quiz**	Science/Strand V Standard 4/ High School Benchmark 1
Monday 11/8 **Fire drill**	•Evaluation of Kepler's laws •**Ultraviolet Experiment**	Science/Strand II & V Standard 1 & 4/ High School Benchmark 1 & 4
Tuesday 11/9	•Turn-in Ultraviolet Lab •**Observing Wave properties of a slinky**	
Wednesday 11/10	•Evaluation Ultraviolet Lab •Talk About Slinky Lab/Turn-in •**Notes Emission Lines**	Science/Strand IV & V Standard 4/ High School Benchmark1 & 2
Thursday 11/11	•**Notes Absorption Lines** •**Start Fingerprinting the Stars**	Science/Strand IV & V Standard 4/ High School Benchmark 1 &2
Friday 11/12 **SUNNY DAY**	•**Herschel Infrared Experiment**	Science/Strand II & V Standard1 & 4/ High School Benchmark 1 & 4

Monday11/15	•Finish Fingerprinting a Star •Turn-in Herschel Infrared	
Tuesday 11/16	•Evaluation Herschel Infrared experiment **•Quiz Emission Lines** •Chapter 24 Notes •Notes dues Tuesday	Science/Strand V Standard 4/ High School Benchmark 2
Wednesday 11/17 **Fire drill**	•Evaluation Fingerprinting a Star **•Quiz on Fusion** •Sun's Interior Structure	Science/Strand II &V Standard 1 & 4/ High School Benchmark 1 & 6
Thursday 11/18	**•Electromagnetic Quiz** •Work on Sun's Interior Structure •Evaluation Fingerprinting a Star	
Friday 11/19 **PREP RALLY**	**•Space Term Quiz** •Turn-in Sun's Interior Structure	
Monday 11/22	**•Quiz Electromagnetic II** **•Hertzsprang-Russell Diagram**	Science/Strand V Standard 4/ High School Benchmark 1& 6
Tuesday 11/23	•Movie "BlackHole" •Turn-in H-R Diagram	Science/Strand V Standard 4/ High School Benchmark 4 & 6
Wednesday 11/24 **½ day**	**•Quiz H/R Diagram** •Finish Movie	
Monday 11/29	**•Expanding Universe**	Science/Strand V Standard 4/ High School Benchmark 3
Tuesday 11/30	Movie "Stargazer" Movie Questions about Hubble and Lowell	Science/Strand II & V Standard 1 & 4/ High School Benchmarks 4 & 6
Wednesday 12/1	**•Apparent/Absolute Magnitude Lab**	Science/Strand V Standard 4/ High School Benchmark 1
Thursday 12/2	•Finish Apparent/Absolute Magnitude Lab •Evaluation H-R diagram **•Life Cycle of a Star**	Science/Strand V Standard 4/ High School Benchmark 1
Friday 12/3	• Review	
Monday 12/6	**•Post-Test** •Turn-in Life Cycle of a Star	

My new unit started with a KWL activity. I used this activity to tell me what they know or think they know about astronomy. I spent about ten minutes of class time letting the students write down everything they could think of relating to astronomy. We went around the room and each student or group shared what they knew, or in some cases, what they thought they knew. The next day I administered the pre-test Appendix A-2). The test consisted of multiple choice and true/false. The pre-test and the KWL were both used to help me establish the areas that needed only brief review and the areas that would be treated as new concepts. I decided to break the unit into four sections, Prehistoric, Classical, Renaissance and Modern astronomy.

The Prehistoric portion, I thought, was going to be the easiest section because the students should have covered most of this in middle school or could draw from their own personal experience. After looking at the KWL and Pre-test I realized that most students did not have the basic observational knowledge of things such as: motions of the sun and stars, daily or diurnal motion, annual motion of the zodiac, annual motion of planets, solstices and equinoxes, the moon, constellations and eclipses. I spent two class periods showing pictures and website photographs of different objects that I thought would be most beneficial to the students in terms of getting them up to speed. In this portion of the unit I was trying to get the students to prove any belief they had about the solar system and universe using observations even if the beliefs were incorrect. This would be similar to what was done by ancient humans. The observations that were the most fascinating were the ones that students had no ideas about how to disprove them, even when they knew the observation was incorrect. One example is: how can you disprove that the sun is not moving across the daytime sky and that instead the earth is spinning on its axis. I felt that I had to cut the section shorter than I would have if I had not been pressed for time. I continued incorporating some of this prehistoric information and observations as we moved into the following sections.

In the second section, Classical astronomy, I discussed the shape and size of the earth, measure the distance from earth to sun and moon, measure the diameter of astronomical objects, discuss the motion of planets, and Ptolemy models of the solar system and finally discuss the earth's rotation and revolution. This section began with scientists use indirect evidence to prove that things exist or explain how things work. This is a major concept of the field of astronomy and many other science classes. At the start of every activity the students read the background or history associated with the lab to help them of understand the difficult concepts of modern astronomy. I had the students work on the tube-n-rope activity (Appendix B-1) in which they were to determine what was inside of a box and how a series of ropes were connected inside of a tube. They were instructed that they could use any means necessary to come up with their conclusion. After each activity the students would evaluate that activity, see evaluation (AppendixA-3). We studied how Pythagoras, Anaxagoras, and Aristotle all tried to explain the shape and size of the earth. Their ideas were unable to stand the test of time because they were based on faulty models and/or religious beliefs. Eratosthenes was the first to prove the size and shape based on mathematical calculation. We studied how this was done and then did a lab (Appendix B-3) calculating the diameter of small table top globes. Students found this lab to be exceptionally difficult because, the shadow that was casted by the toothpick was extremely small and hard to determine. I incorporated more observational evidence into the student's background knowledge by having them do the Retrograde Motion Lab (Appendix B-4) as homework. The retrograde motion lab used observation data collected on the movement of Mars over the course of time and graph the movement. We then used this information from this assignment to introduce Ptolemy and his explanation of the epicyclic behavior of planets.

Next, we tackled the idea of indirect measurement of an object. We used the angular diameter measurement technique to calculate the diameter of a large circle that is placed on the chalkboard, four meters from the students (Appendix B-5). The students then looked at how the parallax shift works (Appendix B-6). The student placed a toothpick a certain distance from a scale and by opening and closing each eye they could determine how much the toothpick moves. I also wanted them to realize that Aristarchus developed the idea of a sun-centered universe in 200 BC and that Aristotle's influence stopped scientific growth for some 2000 years. Aristotle's "common sense" views, such as

1. If the Earth spins then why don't objects fly off the spinning Earth?
2. If the earth is moving then why don't birds in the sky get left behind?
3. If the Earth is revolving around the sun why is there no parallax?

caused scientific innovation at least in the astronomical sciences to be stymied for thousand of years.

Finally, we needed to prove that the earth rotates on its axis. The Foucault pendulum lab (Appendix B-7) was a simple experiment that helped demonstrate to students that the earth does rotate. Student made a pendulum and rotated the base to see what the affects would be on the moving pendulum. We also used this movement to explain how scientists can determine the latitude Based on the rotation per day of the pendulum. The students felt that this lab was a quick and easy way of showing how the earth moves. They like the fact that we were using hands-on activities and some wished that they could see the movement over the course of a full twenty-four hour period.

In the third section, Renaissance astronomy, the discussion shifted to individuals such as Copernicus, Tycho, Kepler and Galileo, and how they contributed to astronomy and brought about the enlightenment of science and astronomy. I familiarized the students with Copernicus and how he revived Aristarchus' heliocentric model of the universe using his seven key points:

1. Earth rotates on its axis
2. Earth revolves yearly on its axis
3. Planets circle the sun
4. Earth precesses as it rotates
5. Solid, planets-bearing retained
6. Sphere containing fixed stars stationary
7. Planets ordered according to their periods of revolution

In this section I used some historically correct movies that enabled students to get an accurate assessment of what the Renaissance period was truly like, and how religious leaders influenced the scientific community and mandated its own agenda by any means necessary. The students watched a movie about each one of the four scientists and examined their lives. The follow-up assignment after the movie about Kepler was to look at each of his three laws (Appendix B-8).

1. Planets travel on elliptical orbits.
2. $P^2 = A^3$.
3. Planets sweep out equal areas in equal times.

The first activity was to have the students draw the orbits and show them that the orbits of planets are elliptical and explain eccentricity. The second and third activities were to explain the formula $P^2=R^3$ and show how all planet or moon's orbits can be expressed using this formula. We used Galileo's observations of Jupiter's moons to explain how the moons obey the third law. After watching the Galileo movie, the students had to answer questions from the telescope website that related to the development of the telescope (Appendix B-9). I really liked using the websites (Strobel, 2004) as homework and many students have asked for me to include more website lessons.

In the final section we took a look at modern astronomy. We took a glimpse at the history of electromagnetic radiation and used its physical properties to learn more about our universe. I feel that this section still needs to have more history included. I started by looking at the physical properties of using polarized lens to show the students how light rays can be blocked. We then observed the wave properties by doing the slinky lab (appendix B-11). They got to experience how waves reflected back when they strike a solid object or what happens if they run into each other. The slinkies helped the students visualize the waves. This part of the activity brought about questions pertaining to wave pools and the waves on the Great Lakes that sink ships. Building on conversations with the students, I felt the need to integrate some music to help the students who are musically inclined. We listened to the song "The Sinking of the Edmund Fitzgerald" by Gordon Lightfoot and I enlightened the students on how waves caused the demise of the mighty freighter.

As a group, the students were asked to name the seven types of electromagnetic waves and what is the proof that they exist. Every class was able to come up with all seven and most had some proof such as: the use of X-rays in hospitals, microwaves for heating of food and radio wave being received by radios. Other than gamma rays, the two that seemed to cause the most difficulty were the proofs for ultraviolet and infrared rays. So we did Johann Wilhelm Ritter and the William Herschel experiments to prove that they do exist (Appendix B-10 and 13). The labs both used prisms to separate the individual wavelengths of light and then the students could use CBL to determine which area of the spectrum produces heat and which area causes blueprint paper to go through a chemical reaction. The kids again liked these experiments because we went outside and they got to work with the CBLs.

After learning about the discovery of the electromagnetic spectrum we used this information to study the chemical composition of the sun, fingerprinting a star activity, (Appendix B-12) and built the sun's interior structure. (Appendix B-15) The fingerprinting of the star activity used spectroscopes to look at the emission lines created by hot gases and burning chemicals. Then the students built a model of the sun, I made models to represent the earth and the planet Jupiter for the students to compare the size. I integrated the uses of Wien's law of black body radiation to determine the temperature of hot objects and the apparent and absolute magnitude (Appendix B-19) of stars to create the Hertzsprung-Russell diagram. (Appendix B-16) We looked at how the wave's physical properties seemed to change depending if the light is moving away or toward the viewer. (Appendix B-17) I explained that this change was called the Doppler shift and that Edward Hubble used this shift to explain that the universe is still expanding, and also proposed evidence for the theory of the big bang. The students then made a poster explaining the life cycle of stars (Appendix B-20) and we discussed how larger elements are produced from Hydrogen and Helium when a star dies. The final part of modern astronomy that we discussed was the complex ideas of black holes, quantum physics, and the theory of time space continuum. Only a few days were set aside for these topics and in the future I will need to a lot more time to address all of the student's questions.

Assessment Tools

Throughout this unit, I randomly used subjective and objective assignments to gauge the student's learning. The subjective assessments consisted of comparing the pre and post-test scores. The pre-test was useful to determine the knowledge and misconceptions that students were bring in to the classroom and the post–test was given one day after a review session to establish how much information the students were able to retain over the course of the unit. The students needed to clearly include evidence to explain almost any of the questions on the test. I also looked at the scores on individual assignments and pop quizzes to make sure that the students were studying and following the material. The subjective assessments included the students answers on many of the in class assignments and the evaluation at the end of each activity.

Results/Evaluation

Evaluation of Laboratory/Activity Assignments

When trying to assess the student's knowledge of this unit I felt that having objective and subjective tools would be very helpful. The assessments were designed to determine if the students were retaining the knowledge accumulated from the new teaching style. The technique that I used for subjective assessment was to have the students fill out an evaluation at the end of each assignment. For the objective assessment I used the pre and post-test over the entire unit and applied a paired T-test to determine if the difference were significant.

The subjective evaluation usually occurred one or two days after the assignment which I felt made the students revisit the activity and truly think about what had occurred. The evaluation was then used to determine if the main idea was interpreted correctly.

The students had three questions on each evaluation to answer. The first question was to briefly describe the individual activity. Most of the students, about ninety-nine percent, had no problem coming up with an explanation of the activity, therefore no responses are recorded. I consider this question very helpful because having the students reflect and explain the activities, in their own words, increases the students reasoning ability (McKinnon and Renner, 1971).

The second question was more difficult for the students because they needed to elaborate on the activity. They were told to think of an example where the information from this activity could be applied. I was expecting that the students would" think outside of the box," or in other fields of science or mathematics, and come up with another example. Most of the students just reapplied the information to a topic closely related to astronomy. A few students did come up with some very good ideas.
Table two indicates the responses of students, randomly chosen, for the second question on the evaluation form for each assignment.

The final question was a subjective question about what they liked and disliked about each activity and why. This question gives the students an outlet to express their feelings about the assignments. Most students were very good about giving constructive criticism about each activity. Table three indicates the responses of students, randomly chosen, this question.

One of the objective assessments that I thought would be useful was to look at the average scores for each of the assignments/quizzes over the course of the unit. I could determine if the students were preparing and working hard on all of their assignments. Hopefully, their final post-test score should show marked improvement. Each assignment was based on a total point scale. Table four, listed below, shows each of the individual assignments and the average point score.

Table 2: **Evaluation Responses to Question #2**

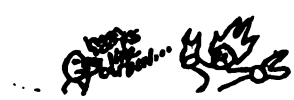
Activity	Responses
TUBE-N-ROPE and THINK BOXES	•"If I were a scientist and I had to tell you what was in the center of the earth." •"When your parents put Christmas presents under the tree." •Figuring out what chemicals the sun is made of." •"When trying to solve what is in the nucleus of an atom of what the su is made of." •"Solving math problems that cannot be solved directly."
ERATOSTHENES LAB	•"To determine the circumference of various spherical objects." •"This can be used to measure a giant boulder."
MOON LAB	•"This activity could be applied when trying to measure anything. You could measure a tree, a basketball hoop." •"If we want(ed) to know the diameter of the sun, you can't fly to it." •"If we wanted to know the height of a landmark."
PARALLAX SHIFT	• "If looking at two trees that are far away and you're not sure which one is farther, you can look at them from both eyes and see which one has the smaller parallax shift, so you know that one is farther. •"Maybe when shooting a gun."
FOUCAULT PENDULUM	•"We can find the latitude at any point and helps us understand the movement of the earth at different locations."
KEPLER LAWS	•"Ice skaters tuck their limbs tight in order to spin faster." •"We can better understand pendulums and metronomes." •"Merry-go-around."
FINGERPRINTING A STAR	•"Identifying the chemical composition of burning things." 
SLINKY LAB	•"If you were designing a wave pool at a theme park- you want to know how to make the shape of the pool in order to create the best waves." •"In making acoustically good speakers/concert halls."
ULTRAVIOLET and INFRARED LAB	•"This is useful because it shows that UV light can be present even when there is no visible light. This can explain sunburn on a cloudy day." •"Dermatology" "Radio Station" "If you were using infrared goggles." •"Being able to use different wavelengths of light in medicine, Like laser surgery." •"If you wear black it absorbs heat If you wear light colors it reflects the light."
SUN'S INTERIOR STRUCTURE	•"If you know the inner structure of the sun then you can find the inner structure of other stars since the sun is a star." •"It can be applied when learning about fusion and trying to scale down objects too large to copy at full size."

Table 3: **Evaluation Responses to Question #3**

Activity	Responses
TUBE-N-ROPE and THINK BOXES	•"I liked the fact that we had to figure out what was inside without looking because it is a new way to think about how scientists find things out. I didn't like that the things inside the boxes were so complex." •"I liked it because it had me really thinking (outside) the box" •"I liked that we could consult with friends. I disliked nothing. It was fun and interesting. It was great to consult with friends."
ERATOSTHENES LAB	•"I really liked that we needed to use our brains for this activity." •"I liked the fact that if given the degree and a measurement of an object you can find the circumference." •"I liked this activity because we had to think about it." •"I liked the challenge of having to figure out something in a way more interesting than just using a ruler."
MOON LAB	•"I liked this activity because it was challenging and fun." •"That it was not very difficult and the skill we learned could actually be used in the real world."
PARALLAX SHIFT	•"Liked this activity because when I was a little kid I would open both eyes then shut my left eye and be amazed at how the object moved….now I know what it is."
FOUCAULT PENDULUM	•"I could really see the proof, and really felt like I learned something." •"It was fun and I actually understood it!!" •"I discovered something new-pendulums always move in the same direction."
KEPLER LAWS	•"Liked easy to relate the activity to earth's orbit." •"Liked doing numerous calculations helped prove the third law." •"I liked spinning the stopper around- it was fun and hands –on." •"I liked seeing how all the planets have a constant K, and all of Jupiter's moons are constant."
FINGERPRINTING A STAR	•"I liked learning about how each element has unique emission lines." •"This activity was actually exciting and interesting."
SLINKY LAB	•"Liked playing with the slinky and watching the wave bounce off each other." •"Slinkies!!!...It helped visualize the waves and how they behave."
ULTRAVIOLET and INFRARED LAB	•"I liked seeing the paper change color that was really amazing." •"I liked this project because I learned about the color spectrum." •"Very simple, with very dramatic results to easily prove a point." •"I liked that you could see (how) each color actually heated up the probe
SUN"S INTERIOR STRUCTURE	•"I liked the visual display however some parts of the activity I did not find worthwhile however in the end it was nice to see the compassion between the earth and the sun." •"I liked making it and putting it together."

Table 4: **Quiz and Activities Scores (Quizzes are in Bold)**

AVERAGE ASSIGNMENT SCORES	GROUP AVERAGE SCORE
Tube-n-Rope/Think box	5 out of 5
Eratosthenes Lab	5 out of 10
Circumference Quiz	3 out of 5
Retrograde Homework	4 out of 5
Paper Moon Lab	8 out of 10
Measuring Parallax Lab	7 out of 10
Foucault Pendulum	7 out of 10
Space Term Quiz	6 out of 10
Kepler's Laws	21 out of 25
Telescope Website	8 out of 10
Kepler's Laws Quiz	1 out of 3
Ultraviolet Lab	5 out of 10
Space Term Quiz II	5 out of 10
Infrared Lab	9 out of 10
Observing Wave properties of a slinky	8 out of 10
Fingerprinting a Star	9 out of 10
Chapter 24 Notes	24 out of 25
Fusion Quiz	2 out of 5
Electromagnetic Quiz	3 out of 5
Sun's Interior Structure	9 out of 10
Space Term Quiz III	8 out of 10
Electromagnetic Quiz II	7 out of 10
Hertzsprang/Russell Diagram	7 out of 10
"Black Hole" movie questions	10 out of 10
H/R Diagram	2 out of 5
Expanding Universe	8 out of 10
Apparent/Absolute Magnitude Lab	7 out of 10
Life Cycle of a Star	11 out of 15

I feel that the students' assignment scores shows how hard they actually worked. Some of the quiz scores (table 4) were lower than I had expected, but I think students used the quizzes to help them focus on the major topics.

Pre and Post-Test

I used the pre-test to determine the student's background knowledge and to learn about misconceptions students may have brought with them from lower grades. I also needed to have a good baseline from which to work from so I could determine student gains.

Rubrics for grading the pre and post-test were as follows. Multiple choice questions were graded for correct responses and were worth one point each on both the pre and post-test. True and false questions were analyzed from two points of view. First, I needed to know if the students could answer the question correctly. Second, was to determine if the students could explain why each answer was correct. All true and false questions were worth one point. The questions were graded occurring to the students having the correct response and then based on the students' giving the correct reasoning for each answer. The same questions were used on both the pre and post-test. Figures one and two which show the scores for every student that participated in this study. Figures three and four show the test scores based on whether the students could explain each answer.

Figure 1: **Correct Answers for Students 1-35**

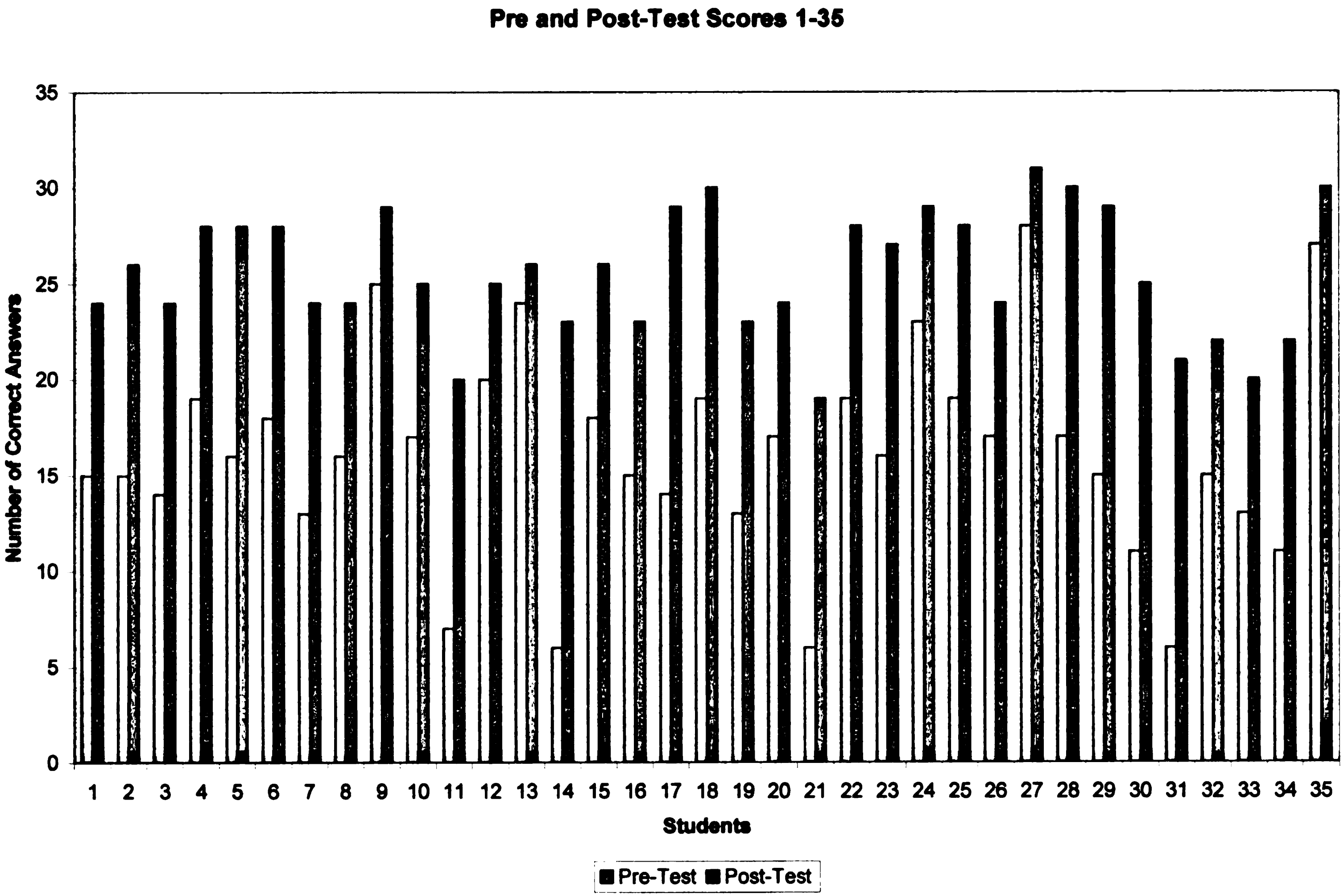


Figure 2: **Correct Answer of Students 36-69**

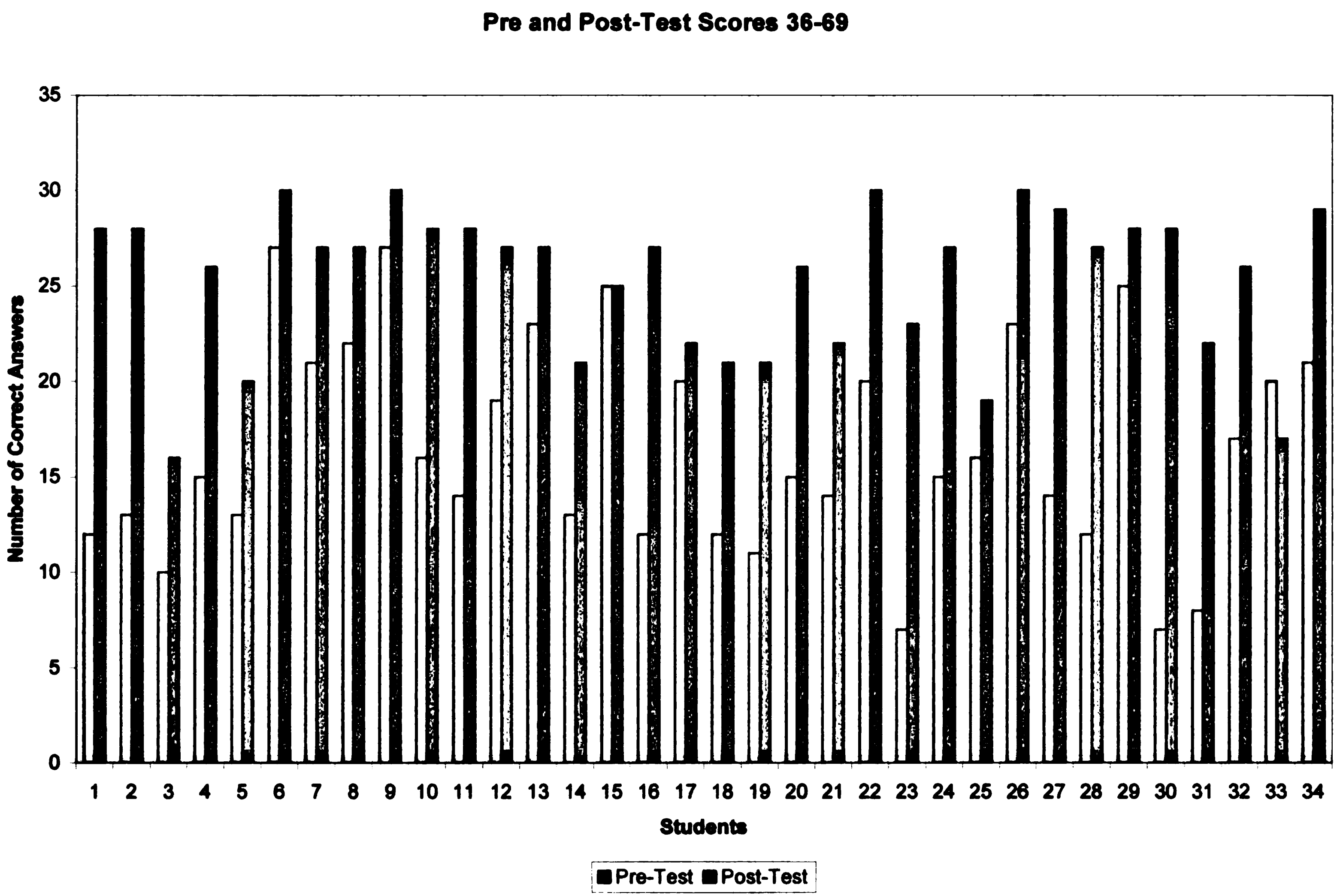


Figure 3: **Correct Answers Reasons for Students 1-35**

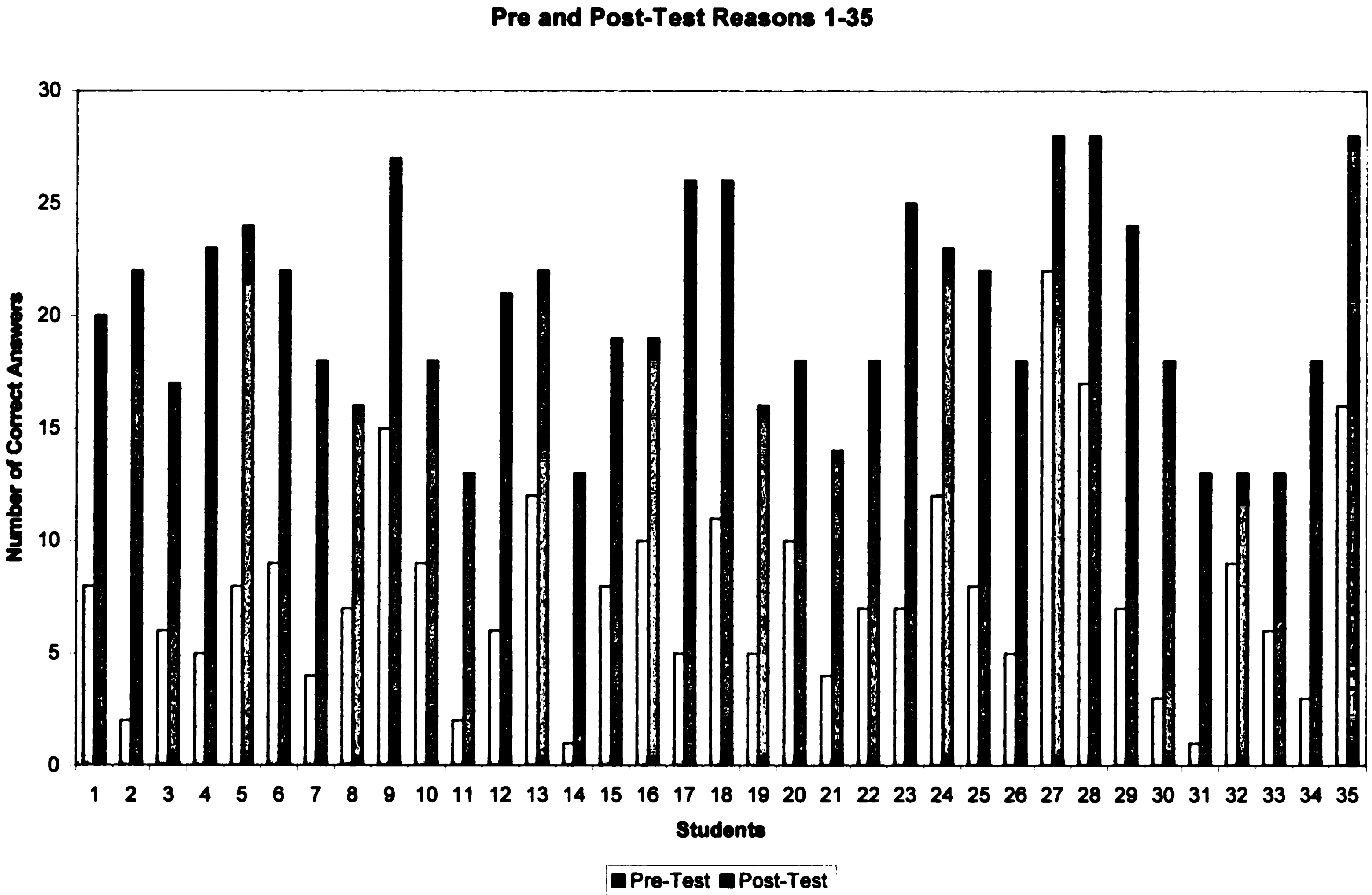
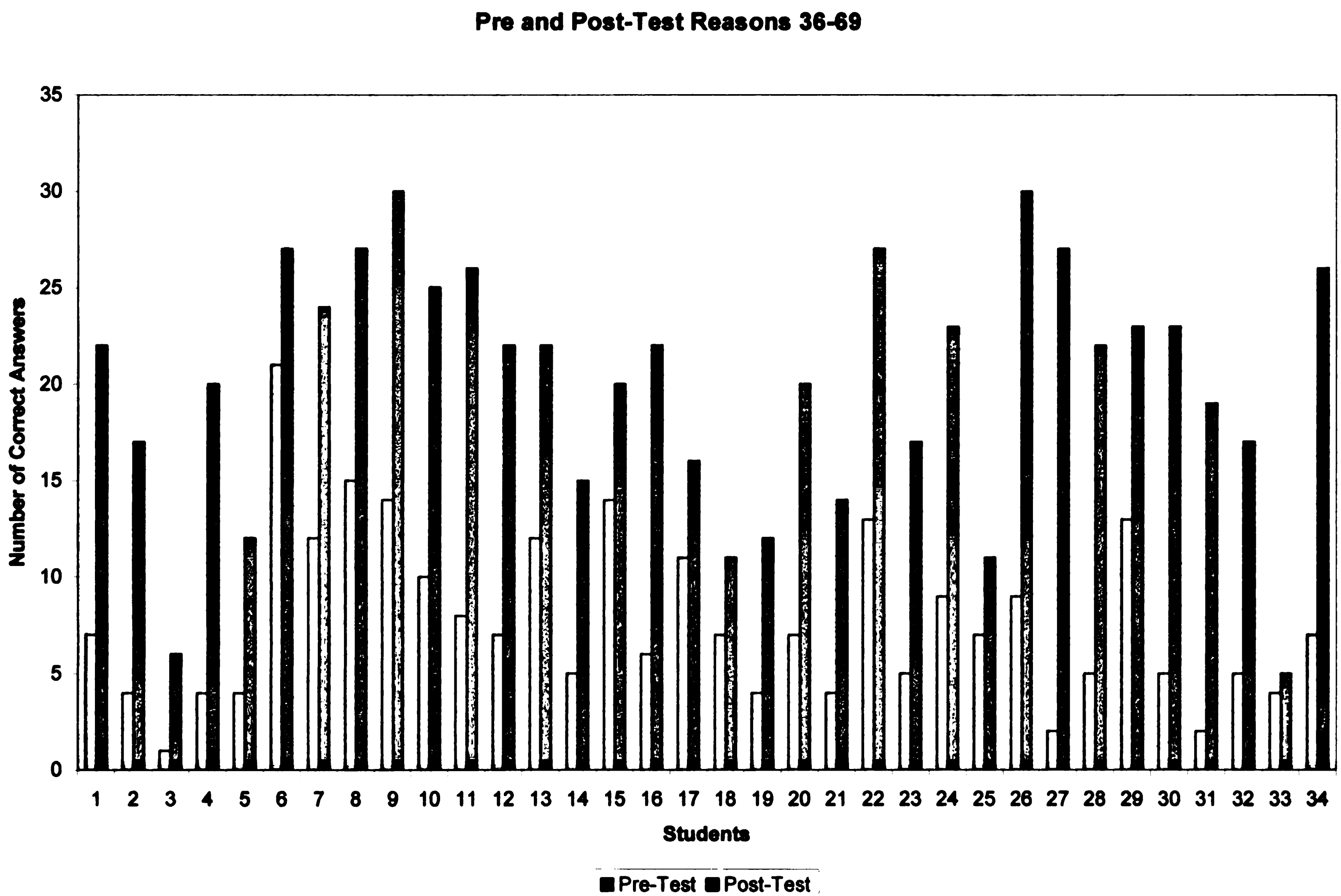


Figure 4: **Correct Answers Reasons for Students 36-69**



The students showed great improvement in their knowledge of astronomy over the course of the unit. The class-mean score for the pre-test was 16.3 out of 30 possible points and improved to 25.5 out of 30. If we looked at making the students incorporate the reasons into their answer, their scored increased even more. The class-mean score on this assessment went from 7.72 out of 30 to 20.1 out of 30. The paired T-test calculated the standard deviation between the pre and post –test scores for just correctness of the answers to be 4.59 and based on reasoning to be 5.13 with the t-value been 11.8 and 14.2. The probability of both samples was lass than 0.0001. This indicates that we reject the null hypothesis and that there is no difference between the pre and post-test. One fact is that 68 out of the 69 students increased their score.

Comparing Multiple Choice on Pre and Post-Test

I looked at the test questions to see if different types of concepts were harder for the students to answer and then provide the correct reason. First, I looked at the multiple choice questions. Figures five thru nine correspond to each of the thirteen multiple choice questions, according to each class. I took the data for each question and applied a paired t-test and questions seven, nine, ten and thirteen had probabilities that exceed 0.1. The t-value for each question in order was 0.711, 2.02, 1.87 and 0.392. The probability for each of the questions was 0.497, 0.078, 0.098 and 0.705 respectively. This indicates that the pre and post-test scores for these four questions are relatively close and they are not significantly different. Question seven dealt with spectral lines and question nine dealt with formation of stars. Question thirteen dealt with reading and interrupting the H/R Diagram and question ten dealt with the death of stars. The four topics are very closely related and were all part of the modern astronomy section. I will need to cover these topics in a little more detail next year. With more instructional time I think that these responses four questions can be easily improved.

Figure 5: **Correct Multiple Choice Answers First Hour**

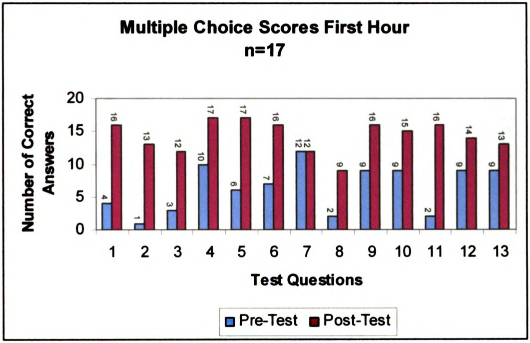


Figure 6: **Correct Multiple Choice Answers Second Hour**

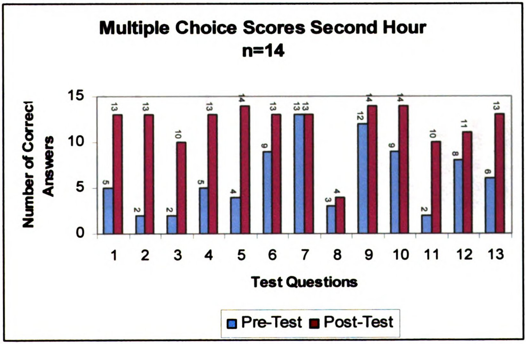


Figure 7: **Correct Multiple Choice Answers Third Hour**

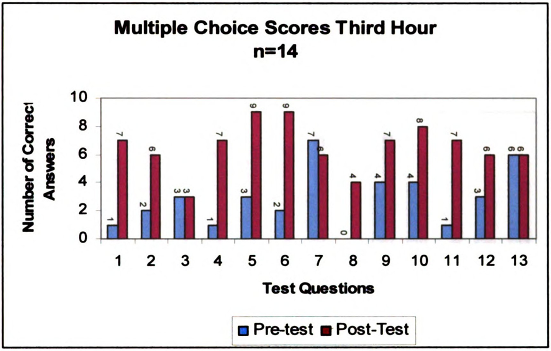


Figure 8: **Correct Multiple Choice Answers Fifth Hour**

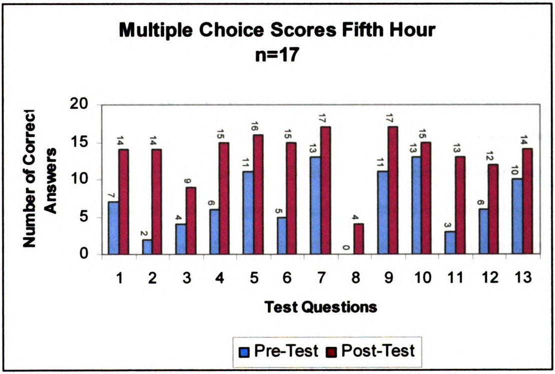
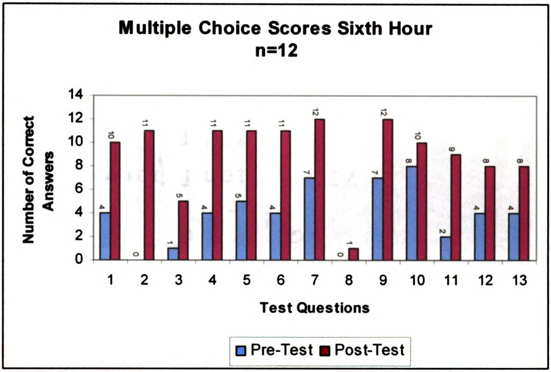


Figure 9: **Correct Multiple Choice Answers Sixth Hour**



Finally, I looked at the True/False questions which reflected the major misconceptions students have about astronomy (MSTA 1992). Figure ten corresponds to how many of the students got each question correct. I took the data for each question and applied a paired T-test and questions eleven, twelve, fifteen and sixteen were significant. The reason that this section scored low is that the students scored very high on the pre-test and did not have much room for improvement, despite little to no middle school instruction. The t-value for each of the questions that were statistically significant, are in order 2.96, 2.20, 2.52 and 2.22. The probability for each of the questions is 0.018, 0.050, 0.036 and 0.050 respectively. This indicates that the scores for these four questions are not close and are significantly different

Figure 10: Correct Answers for True/False Questions

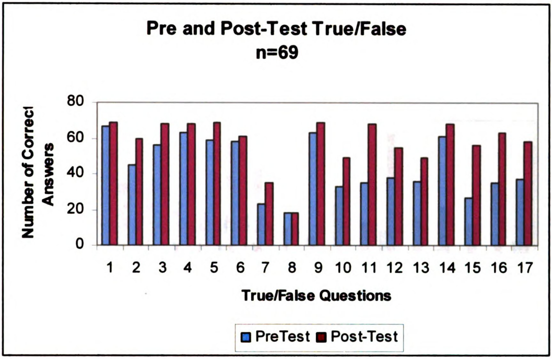
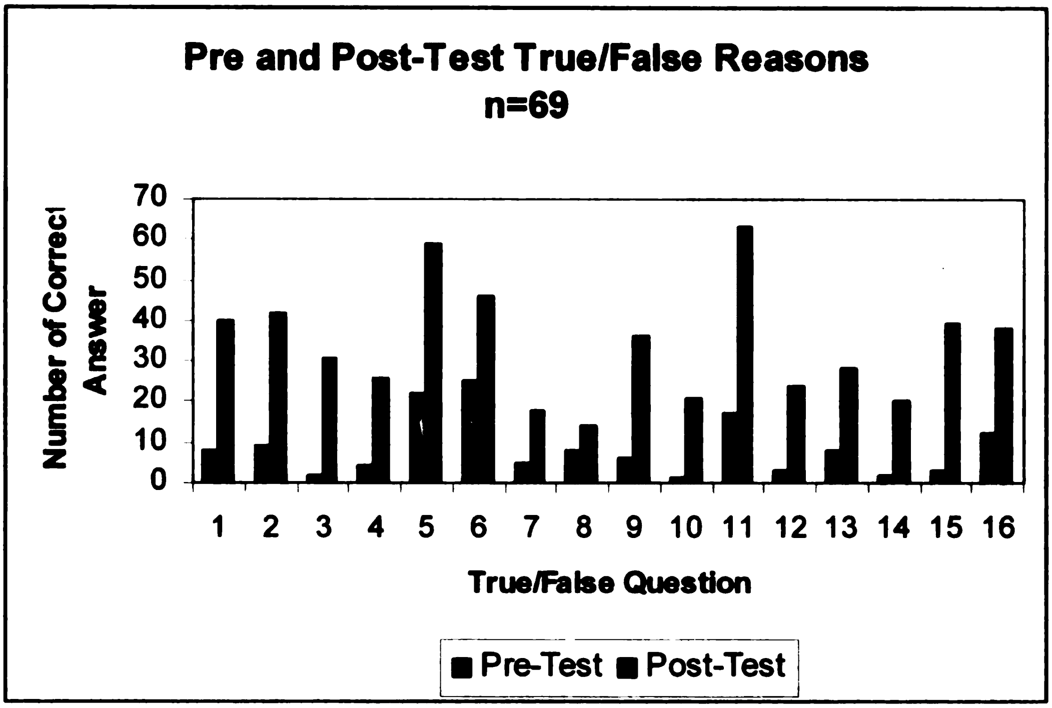


Figure eleven was to see if students could explain the reasoning behind misconceptions. If the question was false, the student then needed to give the evidence to prove the misconception wrong in order to get the answer correct. Only one question, number 6, "stars and constellations appear in the same place in the night sky every night" had a low t-test score. The t-value was 2.17 and the probability was 0.062 all of the rest are significantly different.

Figure 11: Correct Answers for Reason on True/False Questions



Looking over the data, I noticed that question seven, "the sun follows the same path across the sky every day" and question eight, "changing distance from the earth and the sun causes seasonal changes" had very few students correctly answer the questions and scored what seemed to be extremely low. The probability of both of these questions was just above the 0.050 cut-off point. The students really have a hard time breaking these two misconceptions. The first misconceptions, in particular, because they are so accustomed to seeing the sun move across the sky in what seems to be the same path. Without careful observation and detailed records, this idea may go unnoticed. Question eight is just as complicated because the students are familiar with moving objects closer to the heat source if you want them to become warm. It just seems as if teachers will have an extremely challenging time changing these misconceptions.

CONCLUSION

This project was used to address the four main parameters that I thought would be beneficial to the students that take Earth Science at East Lansing. These topics included the alignment of the Michigan benchmarks, multiple teaching strategies, misconceptions of astronomy and explaining the significant historical achievements in astronomy.

The alignment of the benchmarks was a big improvement over what existed before I started this unit. My data suggests that the students will do very well on the MEAP test which is the goal for all teachers. One of my students was actually quizzed, by an eighth grade teacher who was observing the science classes at the high school, on Kepler's laws about 2 months after the astronomy unit. The student was able to explain all three laws without a problem. As a result of developing this unit, I really focused more on the benchmarks. I tried to maintain the focus and objectives at the forefront of each lesson. With an endless supply of information to consider, I really felt comfortable with the way I kept the lessons simple and to the point. Many students expressed in the evaluations that they really enjoyed how each activity was approached and handled in a simple manner.

Using multiple teaching strategies was the second goal. I have always tried to use multiple strategies when teaching any lesson over the course of my career. This was accomplished by using both oral and written notes, which helps the students who are strong linguistic learners. I used labs like the *tube-n-rope* and *paper moon* that are more logical-mathematical and spatial based, which helps the classical students. Many of the movies had some sort of song or jingle that were directed toward the musically inclined students. One day the students suggested that we have a singing day. Everyone in the class had to ask questions and answer them by singing. Some of the students really had fun and asked to have other days later in the school year become singing days. Because the students work alone or in groups, depending on the lab or activity, this helped the interpersonal and intrapersonal learners. The bodily-kinesthetic learners were targeted with the *ultraviolet* and *infrared* labs where we went outside to get them stimulated and interested in astronomy. All of the labs and activities, because they are science related, tilt toward the naturalist learners. In the past I have been told by groups of students how they hated or loved the exact same assignment. The more strategies that are used, the more opportunities students will have to reach and surpass the State of Michigan standards.

Overall, I feel that the students' misconceptions were changed quite significantly. On the pre-test, on average, 44 of the students were able to answer all of the questions correctly. On the post-test 58 out of the 69 students answered all of the questions correctly. If we look at the students' ability to explain the evidence, the change is remarkable. On the pre-test, on average, only 8 students could answer all the questions correctly. The post-test scores showed that 34 out of 69 students could answer all of the questions. I noticed that many of the misconceptions are difficult to change even if the students are given the information and shown that their ideas are incorrect. Working with the middle school teachers, we should be able to negate all of the misconceptions. I think that this new information will help me explain to the middle school teachers what needs to be done at their level so I can cover the higher level astronomy concepts. The High school and Middle school teachers plan on meeting in the summer to discuss ideas and to go over problem areas related to student learning. One idea I have, to help stop the misconception about the seasons being caused by the distance to the sun, is to use incline planes at different angles and have the students determine the temperature difference in relation to the angle. This will show students that when the incline plane is at a ninety degree angle to the sun this temperature change is what causes the seasons.

The historical approach took way too much time. I need to cut this down and streamline this information. If the middle school teachers can touch on some of the Prehistoric information when they are covering the benchmarks that include describe, compare and explain the motions of the solar system and describe and explain common observation of the night skies, this would help out dramatically. Our meeting in the summer months should help alleviate some of the problems. The students were really amazed at how scientists used evidence to explain all of the their theories. Most of the students, by looking at their pre-test and true/false reasoning scores, either do not understand, realize or make that the connections that scientists use and need evidence to prove their theories.

The hardest labs were the *ultraviolet* and *infrared*. By the time we got to the point where we looked at the electromagnetic spectrum, we were into November. The sun was very low in the sky. Most days in November are cloudy and cold which makes it harder for the kids to use the prisms. In the future I will try to have the astronomy unit at the very beginning of the school year. The best lab, according to the students evaluation and the in-class discussion, was fingerprinting the stars. The students loved this lab and I think that I may try to have the students look at each chemical or gas tube at a different lab station next year instead of doing it from the teacher's station as a demonstration. The students found the Kepler activities to be very educational and very useful in explaining each of the three laws. In previous years the students had problems understanding the nature behind the three laws. The students, explained in their evaluations, how the hands-on activities help simplify the more difficult ideas.

I expected that when we started this unit the students would enjoy all of the new labs and activities. I did not expect that the process of introducing the background history would be such an extensive endeavor. The time requirement to implement the new information almost doubled the time needed from previous years. However not having the students fill-out evaluation forms after each assignment next year will allow for more instructional time.

Most of the students who participated in the project really enjoyed their time and learned many new things. I felt like the struggling, average and advanced students all benefited from this unit. I feel that the data, for the pre and post-test showed that the students made great intellectual strides and, with some minor changes, this unit can help many other students in the future.

Appendix A-1

Parent/ Student Consent Form
A Historical Approach To Studying Astronomy

Date: September 11, 2005
To: Students/Parents/Guardians
From: Mr. Brad Baryo
Re: Collection of Data for Master's Thesis

Dear Students/Parents/Guardians,

I wanted to take a moment of your time to welcome you back to school and thank you for all of your involvement with us here at East Lansing High School.

For the past few summers I have been working on my Master's degree at Michigan State and this summer I designed an Astronomy unit that I believe will help my students better understand the concepts associated with this topic. The students will be looking at the Astronomy unit from a historical perspective. I have gathered many of the experiments done over the last 600 years and incorporated new technology which will help increase students' interest and help students retain this information and increase their knowledge of astronomy.

In order to evaluate the effectiveness of this unit, I will be collecting data on how well the different experiments and how well each student retains information. I will use pre and post-tests, inquiry and reflection questions, homework, writing assessments, student interviews and in class discussions. This work is a requirement of all students and is not based solely on my thesis. Only an adviser from MSU and myself will review any materials collected. All materials will be stored in a locked cabinet in an alarmed secured office. **Your child's privacy will be protected to the maximum extent allowable by law.**

I would like your permission to use any of the data mentioned above in my Master's thesis. **At no time will the students' name be attached to or in the thesis paper.** At any time during the course of the school year you may request for your student's work not to be used. There is no penalty for not signing this consent or for revoking consent in the future. Participation in this project is voluntary, you may choose not to participate at all, or may refuse to participate in certain procedures of answer certain question or discontinue your participation at any time without penalty or loss of benefits.

In addition to collecting data, I may take photographs of the students working on activities and use these in a power point presentation. This would be used only to help defend my thesis and may possibly be shown to other science teachers in the area to help them incorporate this information into their classes. Again, **at no time will the students' name be attached to any of this work.**

Please complete the lower portion of this form and return this letter within the next three to five days. **If you have any questions regarding your rights as a study participant, or are dissatisfied at any time with any aspect of this study, you may contact anonymously, if you wish-Peter Vasilenko, Ph. D., Chair of the University Committee of Research Involving Human Subjects (UCRIHS) by phone: (517) 355-2180, Fax (517) 432-4503, or e-mail** ucrihs@msu.edu, **or regular mail: 202 Olds Hall, East Lansing, MI 48824. If you have questions about the study, please contact Brad Baryo by e-mail baryo_bc.elps.k12.mi.us or by phone (517) 622-4328.**

Thank You,

Brad Baryo

_____ I give Mr. Baryo permission to use my son/daughter's data and picture in his thesis project.

_____ I give Mr. Baryo permission to use my son/daughter's data only in his thesis project.

_____ I **do not** give permission for my child's data to be used in this study.

Parent/Guardian Signature______________________________ Date______________
Student Signature ______________________________ Date ______________

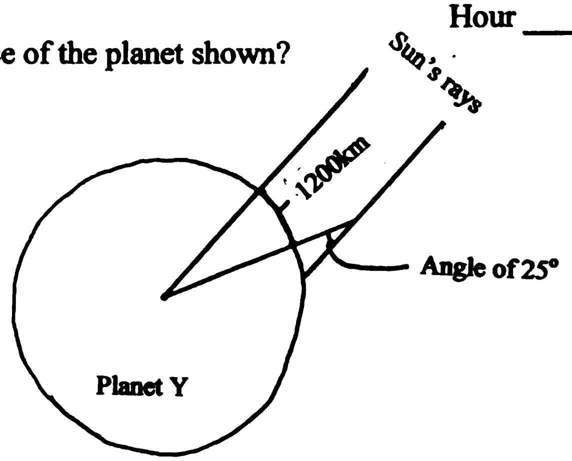
Appendix A-2

Pre-Test

Physical Science
Astronomy Unit

Name____________
Date ____________
Hour _____

1. What is the circumference of the planet shown?
    a. 18,300 Km
    b. 17,280 Km
    c. 13,600 Km
    d. 19,540 Km



2. Which of these is **NOT** an example of electromagnetic waves?
    a. Ultrasound b. Microwaves c. Infrared d. Visible Light

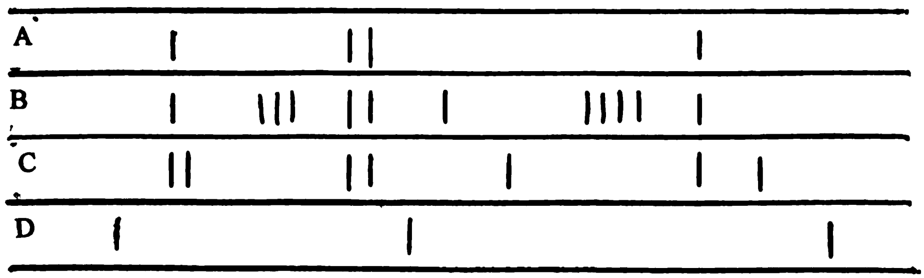
3. If the distance between Earth and the Sun were increased, which change would occur?
    a. The apparent diameter of the sun would decrease.
    b. The amount of radiation received by Earth would increase.
    c. The time for one Earth rotation would increase.
    d. The time for one Earth revolution would decrease.

4. The orbits in which planets move around the sun are ______.
    a. Parabolic b. Circular c. Elliptical d. Spherical

5. The distances to nearby stars can be measured by using ______.
    a. Parallax c. Temperature
    b. Nebula d. Color

6. Which of the following is not a type of galaxy?
    a. Circular c. Barred Spiral
    b. Spiral d. Irregular

7. The following spectral patterns were obtained from stars with the same spectroscope filters. Which combination of stars has at least one element in common?
   a. All four
   b. A, B, C
   c. A, B, D
   d. A, D



8. As the wavelength of energy increases from ultraviolet to infrared, the speed at which this energy travels _________.
   a. Increases
   b. Decreases
   c. Remains the same
   d. Cannot by determined

9. A star begins as a _________, a large cloud of gas and dust.
   a. Nebula
   b. Giant
   c. Dwarf
   d. Black hole

10. Which of the following is associated with the death of a star?
   a. Nebulas
   b. Coronas
   c. Sunspots
   d. Supernovas

11. The best evidence that the universe is expanding is supplied by ____________.
   a. A red shift of spectral lines
   b. Pulsars or quasars
   c. Hertzsprung-Russell diagrams
   d. Neutron stars

12. What makes Sirius the brightest star in the night sky?
   a. Absolute magnitude
   b. Temperature
   c. Apparent Temperature
   d. Apparent magnitude

13. The distances to nearby stars can be measure by using __________.
    a. Parallax
    b. Nebula
    c. Temperature
    d. Color

Please indicate whether the following statements are true or false. If false, explain how scientists know that they are incorrect.

14. The Earth is flat.

15. The sun is perfect sphere that never changes.

16. The Earth is in the center of the solar system.

17. The Sun revolves around the Earth.

18. All stars are yellow in color.

19. Stars and constellations appear in the same place in the night sky every night.

20. The sun follows the same path across the sky every day.

21. Changing distance between the earth and the sun cause seasonal changes.

22. All stars are the same distance from the earth.

23. The solar system and galaxies are very "crowded".

24. The surface of the sun does not have any visible features.

25. All stars in a particular constellation are near each other.

26. Stars are fixed spots in the night sky.

27. The moon is larger than the sun.

28. Planets orbit the sun in circular orbits.

29. The only source of electromagnetic radiation coming from the sun is visible light.

30. The atom is the source for all radiation.

31. Stars on the left half of the diagram shown above are?

a. More luminous
b. Larger
c. Farther away
d. Hotter

Appendix A-3

Evaluation

Please use the following space to tell me what you remember from the following activity.

Statement #1

Briefly describe the activity in your own words.

Statement #2

Think of an example where the information from this activity can be applied.

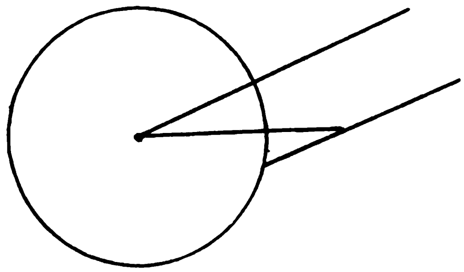
Statement #3

Tell me what you LIKED and DISLIKED about this activity.

Appendix A-4

Circumference Quiz

1. Use the following information to calculate the circumference of the circle.



Kepler's Law Quiz

1. In your own words explain Kepler's three laws.

Electromagnetic Quiz I

1. Name the seven electromagnetic waves in order for smallest to largest.

Electromagnetic Quiz II

1. Explain how Emission lines are produced.

Fusion Quiz

1. Explain the process of fusion.

H/R Diagram Quiz

1. The region of the H/R diagram occupied by the most star is called?

2. What are the two axes on the H/R Diagram?

Appendix A-5

Air and Space Term Quiz

1. The shifting, glowing lights seen over the Polar Regions caused when energized particles from the sun react with particles in the Earth's upper atmosphere; the energized particles come from solar flares.

2. The magnitude a star would have if viewed from 10 parsecs, 32.6 light years

3. The unobstructed diameter of the mirror or objective in a telescope or in a pair of binoculars

4. The study of the universe beyond Earth's atmosphere

5. The outer layer of soil on a planet or moon

6. The force of attraction between two objects

7. A nuclear reaction in which nuclei join together to form a larger nucleus

8. The proportion of mass to volume

9. The angular distance between a celestial object and the celestial equator

10. An assemblage of millions to hundreds of billions of stars, nebulae, gas and dust; largest known structures in the universe.

Appendix A-6

Air and Space Term Quiz

1. Man-made object that is placed in orbit about a natural object in space.

2. Massive white dwarf star tat has consumed its fuel and no longer gives off any light.

3. Weather instrument that measures atmosphere pressure.

4. Visible form of electromagnetic radiation.

5. The lines of magnetic force around a planet or moon caused by magnetic deposits on the planet or moon.

6. An enormous cloud of interstellar dust and gases.

7. A star which suddenly flares up to 100,000 times its brilliance before fading away over a period of months or years.

8. The reflectivity of brightness of a celestial object such as a planet of moon.

9. The angular distance between a celestial object and the celestial equator.

10. Natural satellites that orbit plants.

Appendix A-7

Air and Space Term Quiz III

1. Visible form of electromagnetic radiation

2. The reflectivity of brightness of a celestial object such as a planet or moon

3. The outer layer of soil on a planet or moon

4. A nuclear reaction in which nuclei join together to form a larger nucleus

5. Rapidly-spinning neutron star, which gives off regular bursts of radiation

6. An eruption of the surface of the sun

7. The stream of energized particles given off by the sun

8. The bands of colors of wavelengths obtained when light passes through a prism of drop of moisture

9. The point in the sky directly above the observer

10. The explosion of a high-mass star

11. Everything that exists: Matter, radiation and space

12. The elliptical, closed path that one celestial body travels about another.

13. Small dense star that results from a massive star, which exploded as a supernova

14. Movement of energy in the form of rays and waves

15. Distant and luminous object probably about the size of a large star, which gives off energy equal to that of thousands of galaxies, believed to be at the core of active galaxies.

Appendix A-8

Post-test

Physical Science
Astronomy Unit

Name____________
Date ____________
Hour _____

1. The best evidence that the sun rotates on its axis from west to east is obtained through the study of
   a. Solar eclipses
   b. Radio telescope studies
   c. Solar probes
   d. Sunspot activity

2. The color of a star is mainly an indication of its
   a. Composition
   b. Surface temperature
   c. Distance from Earth
   d. Magnitude

3. An undisturbed atom, all electrons are in
   a. random orbits
   b. the lowest orbits with vacancies
   c. the emptiest orbit
   d. the nucleus

4. As the wavelength of energy increases from ultraviolet to infrared, the speed at which this the energy travels _____.
   a. Increases
   b. Decreases
   c. Remains the same
   d. Cannot be determined

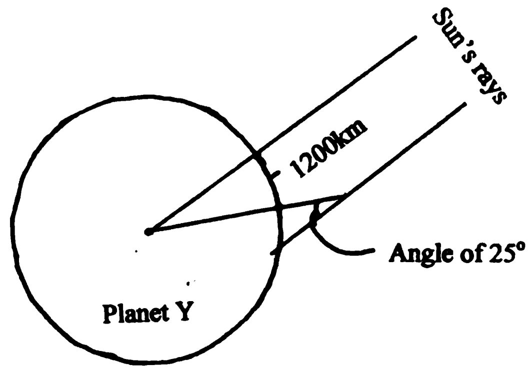
5. A star begins as a _______, a large cloud of gas and dust.
   a. Coronas b. Neutron stars c. Super Novas d. Nebulas

6. Most of the stars located in the Milky Way would be considered part of which group?
   a. Red Giants b. Main Sequence c. Quasars d. White dwarfs

7. The best evidence that the universe is expanding is supplied by _____.
   a. Black Holes b. Neutron stars c. Doppler shift of spectral lines
   d. HR Diagrams

8. An observer on Earth records the motion of Mars for three hours, starting at sunset. Mars would appear to…
   a. Move toward the Western horizon
   b. Move toward the Eastern horizon
   c. Move Northward
   d. Remain fixed in the same position

9. What is the circumference of the planet shown?
   a. 18,300 Km
   b. 17,280 Km
   c. 13,600 Km
   d. 19,540 Km



10. Which of these is **NOT** an example of electromagnetic waves?
   a. Ultrasound b. Microwaves c. Infrared d. Visible Light

11. The wavelength of a wave is calculated by________.
   a. Frequency times wave speed
   b. Amplitude times wave speed
   c. Wave speed divided by frequency
   d. Wave speed divided by amplitude

12. If the distance between Earth and the Sun were increased, which change would occur?
   a. The apparent diameter of the sun would decrease.
   b. The amount of insulation received by Earth would increase.
   c. The time for one Earth rotation would increase.
   d. The time for one Earth revolution stay the same.

13. The orbits in which planets move around the sun are ______.
   a. Parabolic b. Circular c. Elliptical d. Spherical

14. Most large observatories are built
   a. Close to populous areas for easy access
   b. On desert mountains for clear weather and dark skies
   c. In remote areas to keep tourists away
   d. No choice

15. Human senses limit our knowledge of the universe. One source of limitation is that humans
    a. Cannot perceive electromagnetic radiation.
    b. Perceive only the lowest frequencies of electromagnetic radiation.
    c. Perceive only the highest frequencies of electromagnetic radiation.
    d. Perceive only a small portion of the electromagnetic radiation.

16. Stars on the left half of the diagram shown above are?
    a. More luminous   b. Larger   c. Farther away   d. Hotter

17. Where are the smallest stars found on an HR diagram?
    a. The upper left end of the main sequence.
    b. The lower right end of the main sequence.
    c. The upper right corner of the HR diagram.
    d. The lower left corer of the HR diagram.

18. Vampire bats can detect heat from victims through their noses. What type of electromagnetic energy is detected by the bat's nose?
    a. Ultraviolet B
    b. Gamma
    c. Infrared
    d. Visible Light

19. The microwaves have longer wavelengths than those detected by the light detector. This means that microwaves, when compared to the waves detected by the detector, have which of the following?
    a. Higher pitch
    b. Higher energy
    c. Lower velocity
    d. Lower frequencies

20. Each element emits specific wavelengths of light when burned. Wavelength emitted from which of the following elements are most often seen by astronomers when observing stars?
    a. Xenon/Krypton
    b. Nitrogen/Oxygen
    c. Hydrogen/Helium
    d. Sodium /Potassium

21. What makes Sirius the brightest star in the night sky?
    a. Absolute magnitude
    b. Temperature
    c. Apparent Temperature
    d. Apparent magnitude

22. The distances to nearby stars can be measured by using ______.
    a. Parallax
    b. Nebula
    c. Temperature
    d. Color

23. The hottest stars in space are ____ in color.
    a. Yellow
    b. White
    c. Green
    d. Blue

24. Which of the following is not a type of galaxy?
    a. Circular
    b. Spiral
    c. Barred Spiral
    d. Irregular

25. Dark, cooler areas of the Sun's surface and called ______.
    a. Solar Flares
    b. Prominences
    c. Coronal Holes
    d. Sunspots

Please indicate whether the following statements are true or false. If false, explain how scientists know that they are incorrect. (Questions 26-42)

26. The Earth is flat.

27. The sun is perfect sphere that never changes.

28. The Earth is in the center of the solar system.

29. The Sun revolves around the Earth.

30. All stars are yellow in color.

31. Stars and constellations appear in the same place in the night sky every night.

32. The sun follows the same path across the sky every day.

33. Changing distance between the earth and the sun causes seasonal changes.

34. All stars are the same distance from the earth.

35. The solar system and galaxies are very "crowded".

36. The surface of the sun does not have any visible features.

37. All stars in a particular constellation are near each other.

38. Stars are fixed spots in the light sky.

39. The moon is larger than the sun.

40. Planets orbit the sun in circular orbits.

41. The only source of electromagnetic radiation coming from the sun is visible light.

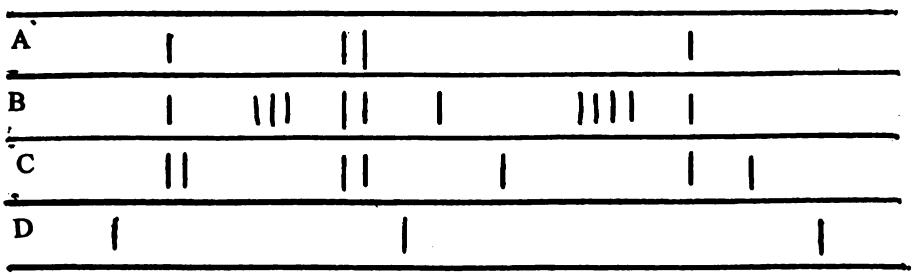
42. The atom is the source for all radiation.

43. Pick one of the following scientists and give a brief description of his or her work and explain how it impacted future work in astronomy.

a. Jonannes Kepler
b. Galileo Galilei
c. Tycho Brahe
d. Nicholas Copernicus
e. Eratosthenes
f. Pythagoras
g. Aristarchus
h. Claudius Ptolemaic
i. Henry Russell
j. Friedrich Wilhelm Bessel
k. Isaac Newton
l. Heraclides
m. Jean Foucault
n. William Herschel
o. Johann Wilhelm Ritter
p. Henrietta Swan Leavitt
q. Ejnar Hertzsprung

44. The following spectral patterns were obtained from stars with the same spectroscope filters. Which combination of stars has at least one element in common?

a. All four
b. A, B, and C
c. A and D
d. None of the above



45. Which of the following is associated with the death of a star?

a. Nebulas b. coronas c. sunspots d. supernovas

46. As the sun ages, the chemical composition of its core changes so that it contains a lower percentage of ______ and a greater percentage of ______.

a. helium, hydrogen
b. uranium, lead
c. hydrogen, helium
d. oxygen, carbon

Appendix B-1

Tube-n-ropes and Think Box

Physical Science
Astronomy Unit

Name ___________
Date ____________
Hour _____

History

On a cold winter night in 1930, the astronomer Clyde Tombaugh discovered Pluto, the smallest and most distant planet in our solar system. Since Tombaugh's discovery, we have learned that Pluto orbits the sun at an average distance of 5.9 billion kilometers (3.7 billion miles). Since it is so far from the sun, it takes a long time to orbit- 284.4 times as long as the Earth. Since Pluto is far away from the Sun, it is extremely cold. The Plutonian landscape has a layer of frozen methane the cover the surface. Pluto is very small and has little mass, only 1/500 that of Earth. Since gravity is proportional to mass, a truck that weighs 4,000 pounds of Earth would weigh only 8 pounds on Pluto.

Do you really believe this data? Who has ever watched to make sure the Pluto orbits the sun? Pluto was discovered only in 1930. So no one could possibly have watched to see how long it takes to complete an orbit. No probes have been to the surface of Pluto but astronomers tell us, with confident, that the surface is covered with methane.

There are many things that are either very difficult or impossible to measure directly. No one can weigh an electron directly and yet scientist report that it has a mass of 9.1083×10^{-28} .No one can see X-rays, but physics books report they have a wavelength of 10^{-10} meters.

Although it is impossible or impractical to measure many quantities directly, it is often possible to do so indirectly.

Objective

To systematically conduct research and explain how tube-n-ropes work and what is inside the think boxes.

Materials

1. One tube-n-rope
2. One think box
3. Paper and Pencil

Procedure

1. You may not remove the end caps or indo the knots at the ends of the ropes.
2. Take the tube-n-rope and determine how the strings are attached.
3. Explain what happens as each string is pulled and what evidence you used to determine the connection inside.
4. Take the think box and determine what is inside.
5. Explain what evidence you used to determine what is inside.

Data

Prediction	Answer
Think Box	
Tube-n-rope	

Results

Conclusion

Appendix B-2

Air and Space Terms

1. **Absolute magnitude**—The magnitude a star would have if viewed from 10 parsecs, 32.6 light years
2. **Albedo**—the reflectivity or brightness of a celestial object such as a planet or moon
3. **Apparent magnitude**—the apparent visual brightness of a celestial body
4. **Artificial satellite**—man-made object that is placed in orbit about a natural object in space
5. **Asteroids**—chunks of rock, metal and ice that orbit our sun, found mostly between Mars and Jupiter, varying in size from boulders to small moons; also called planetestial of minor planets
6. **Astronaut**—a space explorer
7. **Astronomical unit**—unit for measuring distances in space, based on the distance from the earth to the sun, equal to 93 million miles abbreviated AU
8. **Astronomy**—the study of the universe beyond Earth's atmosphere
9. **Axis**—imaginary line about which an object spins
10. **Binary star**—a pair of stars that orbit about a common center of gravity; also called double stars
11. **Black dwarf**—massive white dwarf star that has consumed its fuel and no longer gives off light
12. **Black hole**—a region of highly warped space time, around a collapsed massive star, in which the gravitational field is so strong that not even light can escape
13. **Comet**—an object made of ice, dust and gas which orbits the sun with its tail of dust pointing away from the sun
14. **Constellation**—a group of stars that gives the appearance of a pattern when viewed from earth
15. **Crust**—the outermost layer of soil on a planet or moon
16. **Declination**—the angular distance between a celestial object and the celestial equator

17. **Eclipse**—when one celestial body blocks the view of another, such as when the moon blocks our view of the sun during a solar eclipse
18. **Elliptical galaxy**—a large group of stars that appears in the shape of an ellipse
19. **Fission**—a nuclear reaction in which nuclei are split, releasing enormous amounts of energy;
20. **Fusion**—a nuclear reaction in which nuclei join together to form a larger nucleus
21. **Galaxy**—an assemblage of millions to hundreds of billions of stars, nebulae, gas and dust
22. **Galilean satellites**—Jupiter's first four moo's discovered , by Galileo
23. **Gravity**—the force of attraction between objects
24. **Inner planets**—the four planets closest to the sun
25. **Light** –visible from of electromagnetic radiation
26. **Light year**—the distance light travels in a vacuum in one year
27. **Magnetic field**—the lines of magnetic force around a planet of moon caused by magnetic deposits on the planet or moon
28. **Moon**—Natural satellites that orbit planets
29. **Meteor**—a streak of light seen in the sky caused by the fiery, atmospheric friction from entry of a meteoroid through Earth's atmosphere
30. **Meteorite**—the portion of a meteoroid that has survived the atmospheric friction and crashed into the Earth
31. **Meteoroid**—small particles of interplanetary objects in space
32. **Milky way**—light from thousands of stars that are located along the main plane of our galaxy
33. **Nebula**—an enormous cloud of interstellar dust and gases
34. **Neutron star**—small dense star that resulted from a massive star which exploded as a supernova
35. **Nova**—a star which suddenly flares up to 100,000 times its brilliance before fading away over a period of months or years
36. **Orbit**—the elliptical, closed path that one celestial body travels about another
37. **Outer planets**—the five planets farthest from the sun
38. **Pulsar**—rapidly-spinning neutron star which gives off regular burst of radiation

39. **Quasar**—distant and luminous object probably about the size of a large star, which gives off energy equal to that of thousands of galaxies, believed to be the core of a active galaxies
40. **Radiation**—movement of energy in the form of rays and waves
41. **Radio telescope**—large dish-like instrument that gathers radio waves from distant objects in space
42. **Red giant**—after about 10 million years, a yellow star enlarges and cools down, forming a red giant star, thus red stars are older, larger, and cooler than yellow stars
43. **Revolution**—the movement of one body, in an elliptical path, around another
44. **Rotation**—the spin of an object about its center line
45. **Satellite**—any small body orbiting a larger one
46. **Solar flare**—an eruption on the surface of the sun
47. **Solar system**—a system of planets, comet, satellites and debris that orbits about a star
48. **Solar wind**—the stream of energized particles given off by the sun
49. **Space probe**—a spacecraft, without humans, which gathers data about object in space
50. **Space shuttle**—a spacecraft capable of carrying people and equipment into space and returning to Earth
51. **Space station**—a spacecraft that stays in space for long periods of time orbiting Earth of other heavenly bodies
52. **Spectroscope**—instrument used fro viewing the spectrum of a light source directly
53. **Spectroscopy**—the study of the spectra
54. **Spectrum**—the bands of colors of wavelengths obtained when light passes through a prism of drop of moisture
55. **Spiral galaxy**—galaxy that extends from a central region as it spins about its axis
56. **Star**—celestial object composed mostly of hydrogen and helium that shines by producing its own light through nuclear conversion of hydrogen to helium

57. **Sunspot**—magnetic storm on the sun; it appears as a dark region on the sun because it is cooler than the surrounding area
58. **Supernova**—the explosion of a high-mass star
59. **Telescope**—optical instrument composed of lenses, which makes objects appear closer and brighter, used for observing celestial bodies
60. **Terminator**—the division between the light and dark sides of a planet of satellite
61. **Universe**—everything that exists: matter, radiation, and space
62. **White dwarf**—an old, dense star that results after a red giant star consumes its fuel over a long period of time
63. **Zenith**—the point in the sky directly above the observer

Appendix B-3

Eratosthenes Lab

Physical Science
Astronomy Unit

Name ___________
Date ____________
Hour ____________

History

Eratosthenes, a Greek geographer (about 276 to 194 B.C.), made a surprisingly accurate estimate of the earth's circumference. Eratosthenes was director of the famous library in Alexandria, and is known for numerous important contributions to mathematics, geography, and astronomy. In the great library in Alexandria he read that a deep vertical well near Syene, in southern Egypt, was entirely lit up by the sun at noon once a year. Eratosthenes reasoned that at this time the sun must be directly overhead, with its rays shining directly into the well. In Alexandria, almost due north of Syene, he knew that the sun was not directly overhead at noon on the same day because a vertical object cast a shadow. Eratosthenes could now measure the circumference of the earth by making two assumptions - that the earth is round and that the sun's rays are essentially parallel.

He set up a vertical post at Alexandria and measured the angle of its shadow when the well at Syene was completely sunlit.

The formula Eratosthenes used is:

$$\frac{D}{d} = \frac{A}{a}$$

d=distance between Syene and Alexandria
A=360 degrees assumption of round earth
a=shadow angle of vertical stick
D=to be determined (circumference)

Objective

Students will be able to use Eratosthenes technique to calculate the circumference of a small sphere.

Materials

1. Paper
2. Pencil
3. Toothpicks
4. Clay
5. Flashlight
6. Globes

Procedure

1. Using small pieces of clay stick the toothpicks to the globe.
2. Make sure that the toothpicks, if extended would, go though the center of the globe.
3. Measure the distance between the two toothpicks
4. Turn off the classroom lights.
5. Place the flashlight over one of the toothpicks.
6. This toothpick should not cast a shadow.
7. The second toothpick will have a shadow.
8. Measure the angle created by the shadow.
9. Use Eratosthenes formula to calculate the diameter of the globe.

Results

Show your work! Grades will be given on percent error.

Appendix B-4

Retrograde Motion

Physical Science
Astronomy Unit

Name ________________
Date ________________
Hour _____

History

Ancient astronomers (astrologers) mapped the positions of planets moving gradually through zodiac constellations. They saw that planets moved across the sky from east to west each day. However, they also slipped eastward throughout the year. Since astronomers believed the planets were traveling around Earth, they assumed the paths would always move eastward, like the sun. What they observed was very different. The planets did move eastward, but from time to time they would slow down, stop, and then begin moving westward. Gradually, they would slow down again until they stopped and resumed their eastward motion again. Thus, they appeared to be making loops in their paths. The loops varied in size with each planet, and not every planet was looping at the same time. This was finally explained by the theory that the planets were traveling around Earth within their own circular orbits, called epicycles. Later, it was proved that the planets revolve around the sun, not Earth. Now, a different explanation for this backwards, or retrograde, motion was needed.

Objective

Students will plot the path of Mars though the constellations.

Materials

1. Paper
2. Pencil
3. Graph Paper

Procedure

1. Make transparencies of mars motion in 1971 and have students explain what is happening.
2. Have students graph the horizontal (x-axis) and the vertical position (y-axis) of Mars.
3. Each point on the graph should be represented by an open circle.
4. The higher the negative number the larger the circle.
5. When the students are done graphing show them the transparency of Explaining Retrograde Motion of Mars. Point out the orbits of Mars and Earth is not centered on the sun. Show that Mars takes longer than 12 months to make one complete trip around the sun. Place a finger from each hand on the position 1 for both planets. Rotate Earth's orbit, keeping your fingers moving to 2. As you do this for all positions, pause to analyze the distances and direction of Mars. Notice that Mars appears to lag behind Earth (retrograde) from 4 until 10, after which Mars begins to catch up with Earth again.

Data

Number	Month	Horizontal Position	Vertical Position	Distance from Earth	Apparent Magnitude
1	March	18.1	23.5	75 million miles	-0.4
2	April	19.5	22.8	64	-0.5
3	May	20.5	20.8	47	-0.7
4	June	21.5	19.0	36	-1.2
5	July	21.8	19.6	35	-2.1
6	August	21.4	22.6	36	-2.4
7	September	21.1	22.3	40	-2.6
8	October	21.5	18.1	48	-2.4
9	November	22.5	11.4	54	-1.6
10	December	23.4	3.5	63	-1.2
11	January	15.5	18.3	72	-0.6
12	February	16.9	22.2	80	-0.3

Questions

1. Have the students find where Mars appears brightest. Dimmest.

2. What is the direction of Mars from Position # 1 to position #6?

3. Describe what happened after position #6.

4. What happen to the appearance of Mars? Brightness?

5. Why would Mars change in size and brightness?

Note: portion of this lab were adapted from
http://www.teachercreated.com/lessons/020412cs.shtml
Cracolice, Mark S., & Deming, John C., Learning How to Think. The Science Teacher Vol. 71 n3 Mar 2004 pg 42-47.

Appendix B-5

Paper Moon Homework

FOR EACH QUESTION: Use a ratio of eye-to-finger distance to finger width of 60 to 1

1. You are standing in a park on a hill outside Boston, Massachusetts. At this position, the width of a little finger will just cover the height of the John Hancock building found in downtown Boston. The Visitor's guide to the city states the Hancock building is 245m tall. Estimate your distance from the building.

2. Another cluster in Taurus is the Hyades which forms the "face" of the bull. This cluster appears to be about 4 fingers wide. If you assume it to be about 10 light years in diameter, how many Light Years are the Hyades from us?

3. The only galaxy easily visible to people in the northern hemisphere is the andromeda galaxy in the constellation of Andromeda. The bright nucleus of the galaxy can be seen with the naked eye on a very clear and moonless night. This nucleus, which astronomers estimate to be about 35,000 light years in diameter, appears about two finger width wide. How light years is this galaxy from us?

4. The Pleiades, star cluster in the constellation of Taurus the bull, appears about one finger width big in the sky. If one assumes the cluster to be about 9 light years in diameter, how far away is the cluster?

5. You are on a boat entering New York Harbor. You observe that the towers of the world trade center appear about three little finger width tall. The guidebook to New York states that the towers are 465 m tall. What is the distance?

6. You attend the Launch of the space shuttle form Cape Canaveral. The observing site is 15km from the launching pad. The shuttle, with fuel tank, appears about one fourth of a little finger width tall. What is the height of the shuttle in meters?

Appendix B-6

Measuring Parallax

Physical Science
Astronomy Unit

Name _____________
Date ______________
Hour _____

History

When early astronomers observed the sky, they imagined the vast array of stars embedded in a giant "crystalline sphere" that encompassed the Earth and the Sun. They believed that the planets resided on a smaller transparent sphere concentric to the one on which the stars moved. Many astronomers surmised that if the Earth circled the Sun then the stars were not in a celestial sphere then they should move in relation to each other. This idea of a Sun-centered solar system had been proposed as early as 200B.C. by Aristarchus of Samos. His theories did not last long under the Aristotle's influence and "common sense":

1. If the Earth spins then why don't objects fly off the spinning Earth?
2. If the Earth is moving then why don't birds in the sky get left behind?
3. If the Earth is revolving around the sun why is there no parallax?

Thus, Aristotle's geocentric model would last for almost 2000 years until Friedrich Wilhelm Bessel in 1838 precisely measured the distance to the star 61 Cygni. This would put an end to the idea of a geocentric universe.

Objectives

Observe the effect of parallax and predict the effect of distance on parallax.

Materials

1. Unlined paper 2. Meter ruler 3. Clay 4. Toothpick 5. Pencil

Procedure

1. Place the paper on the table in front of you. Draw a line across the paper 2 cm from the top. Using the metric scale, mark a centimeter scale along the line and number it from 0 to 20.
2. Draw a second line across the paper 5 cm from the top.
3. Draw a third line down the center of the paper and mark off 5 cm, 10 cm, 15 cm, and 20 cm.
4. Fold the paper along the second line so that the scale stands up on your table.

5. Place the paper in front of you along the edge of your desk. Stand the toothpick in a piece of clay and place it on the 5 cm mark.
6. Kneel down so that when you look at the toothpick, you see the scale behind it. Close your right eye. Line the toothpick up on the scale and record that number in the data table.
7. Without moving your head, open the other eye and close your left eye. Read the scale and record the number in the data table.
8. Subtract the first number from the second number to measure how much the apparent position has shifted. Record the difference in the data table.
9. Repeat step 6 thru 8 with the toothpick at 10 cm, 15 cm and 20 cm.
10. Now, move back 2 meters from the scale. The toothpick should still be on the 20 cm mark. Repeat steps 6 thru 8 and record data.

Data Table

Position of Toothpick	Scale Reading Right Eye	Scale Reading Left Eye	Parallax Shift
5 cm			
10 cm			
15cm			
20 cm			
20 cm (step 10)			

Results

1. In which position did the toothpick appear to change position the most and the least?

2. What happened as the toothpick moved farther away from the observer?

3. Is it possible that you could move so far away that there would be no parallax?

4. What would happen to the parallax if you:
    a. Increased baseline and decreased distance to the object?

    b. Decreased baseline and increased distance to the object?

    c. Increased baseline and increased distance to the object?

    d. Decreased baseline and decreased distance to the object?

5. Hold a pencil in each hand at arm's length and point them toward each other. With both eyes open touch the points of the pencils together. Now close one eye and try to touch the points again. Try the other eye!! What happened? Why?

6. Your teacher should have a large tube in the front of the classroom for you to look though. Close your left eye and look through the large tube. Determine the order of lights with number one being the closest and four being the farthest away. Now use the other eye to look though the tube. Determine the order. Now use both eyes.

Trial	Left Side	Middle Left	Middle Right	Right Side
Left Eye				
Right Eye				
Both Eyes				

Note: portion of this lab were adapted from
http://www.pbs.org/deepspace/classroom/activity3.html
Feather, Ralph M., Snyder, Susan, Earth Science Laboratory Investigation, Glencoe/McGraw-Hill, page 100-103.

Appendix B-7

Foucault Pendulum

Physical Science
Astronomy Unit

Name ____________________
Date ______________________
Hour______

History:

The first to explain that the apparent rotation of the heavens is brought about by the rotation of the earth on its axis rather than by the passage of stars around the Earth was the Greek scientist Heraclides (4^{th} century AD).

Jean Foucault(1819-1886) was adept at setting up and performing interesting and important physical-science investigations. One of his most intriguing demonstrations used a simple pendulum to demonstrate that the Earth rotates on its axis. Scientists before Foucault's time believed that the Earth rotated on its axis but could not actually demonstrate this rotation. Foucault's first demonstration of the Earth' rotation was in his cellar of his home. He then duplicated this experiment in the Paris Observatory using a pendulum 36 feet (11m) in length. His most spectacular demonstration was in 1851, in the dome of the Pantheon, a building in Paris, where a 220 foot (67 m) pendulum with a 60 pound (27 kg) metal bob was suspended from the center of the dome.

Part I

Objectives:

1. Observe the rotation of the Earth about its axis.
2. Compare the different scientific theories that evolved into our geocentric model of the solar.
3. Explain how the Earth's axial rotation affects life on earth.

Materials:

1. Classroom set of sinkers
2. Fishing line
3. Ring stand
4. Clamp with rod

Procedure:

1. Make the pendulum as shown in Figure 1.
2. Set the sinker in motion swinging back and forth.
3. Grasp the ring stand at the base and slowly rotate clockwise and then counterclockwise.
4. Observe the movement of the sinker.
5. Record observations.

Results:

Part II

Information:

The pendulum in part one does not turn with the ring stand, but rather continues to swing in the same plane in which it began swinging. You can watch the base of the ring stand turn under the swinging pendulum. Why does the pendulum continue to swing in the same plane? Answer is Newton's first law: "Every object continues in its state of rest or of uniform motion in a straight line unless compelled to change that state by forces impressed on it." Gravity is a force that acts on a pendulum and is external to it, but it cannot force the pendulum to rotate with the ring stand because it acts only in a downward direction. This downward is causes the pendulum to swing in an arc. Gravity does not act in a sideways direction. Consequently, there is no force to push the pendulum in a sideways direction. The pendulum continues to swing in a straight line as the base of the ring stand turns under it.

The turning of the base of the ring stand under the swinging pendulum is analogous to the turning of the floor under a Foucault pendulum. The building is attached to the Earth and thus rotates with it. The pendulum is attached to the building but does not rotate with it because there is no external force acting on the pendulum to change its lateral direction.

Let's consider three positions on the Earth's surface. At the north pole the pendulum will appear to turn 360° after one rotation of the Earth. Since one rotation of the Earth requires 24 hours, the apparent rotation of the pendulum will be 360°/ 24hours, or 15° per hour. Because the Earth rotates in a counterclockwise direction when viewed from above the North Pole, the apparent rotation of the pendulum is in a clockwise direction.

A pendulum at the equator will travel eastward along with its point of attachment but there will be no turning motion of the Earth under it. (See figure 2) Consequently, there will be no turning motion of the pendulum under its point of support, and the apparent rotation of the pendulum will be 0° per hour.

What about a pendulum at 45° north? This pendulum will travel eastward as does the pendulum on the equator, but there will also be some rotation of the Earth under the pendulum. How many degrees per hour will the pendulum appear to rotate? The answer to the question is not obvious because there is simultaneous "twisting" and "traveling" of the pendulum. The number of degrees of apparent rotation per hour ($Rot_{(h)}$) is given by the formula:

$$Rot_{(h)} = 15^\circ \text{ X } \sin(\text{latitude})$$

Remember that latitude is an angle. Multiplying by 24 gives the apparent rotation in 24 hours ($Rot_{(d)}$):

$$Rot_{(d)} = 15^\circ \text{ X } \sin(\text{latitude}) \text{ X } 24 = \sin(\text{latitude}) \text{ X } 360^\circ$$

If a Foucault pendulum is located in Paris, France (48° N), its apparent rotation in 24 hours will be:

$$Rot_{(d)} = \sin(48^\circ) \text{ X } 360^\circ = 0.743 \text{ X } 360^\circ = 268$$

We can use a Foucault pendulum to find the latitude of any place in the world by measuring the apparent rotation of the pendulum at that location for a 24 hour period and solving for sine of the latitude:

$$\text{Sin (latitude)} = Rot_{(d)}/360^\circ$$

Suppose we find that a pendulum located in a certain city has an apparent rotation of about 100° in 24 hours. What is the approximate latitude of this city?

$$\text{Sin (latitude)} = Rot_{(d)}/360^\circ = 100^\circ/360^\circ = 0.277$$

The angle with a $\sin^{-1}$ of 0.277 is 16.1°. Therefore, the latitude of this city is approximately 16.1°. The following table shows data shows data from Foucault pendulums at different locations around the world. Use a table of sine, and an almanac, map, or globe to complete the table.

Rot_d	$Rot_d/360^\circ$	Angle with this $\sin^{-1}$	Direction	Latitude	City or geographic feature at this location
360°			Clockwise		North Pole
360°			Counter		South Pole
222°			Clockwise		Athens, Greece
100°			Counter		
240°			Clockwise		
275°			Clockwise		
201°			Counter		
226°			clockwise		

Conclusion:

Note: portion of this lab were adapted from
www.cartage.org/lb/en/themes/Biographies/MainBiographies/F/Foucault/1.html
http://robeonplanetrium.freeyellow.com/grade6/06reasonpre.html

Appendix B-8
Kepler's Laws

Physical Science
Astronomy Unit

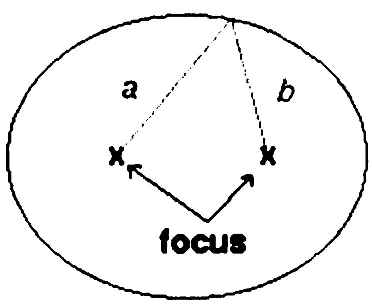
Name ________________
Date ________________
Hour _____

History

Kepler and Brahe did not get along well. Brahe apparently mistrusted Kepler, fearing that his bright young assistant might eclipse him as the premiere astronomer of his day. He therefore let Kepler see only part of his voluminous data. He set Kepler the task of understanding the orbit of the planet Mars, which was particularly troublesome. It is believed that part of the motivation for giving the Mars problem to Kepler was that it was difficult, and Brahe hoped it would occupy Kepler while Brahe worked on his theory of the Solar System. In a supreme irony, it was precisely the Martian data that allowed Kepler to formulate the correct laws of planetary motion, thus eventually achieving a place in the development of astronomy far surpassing that of Brahe.

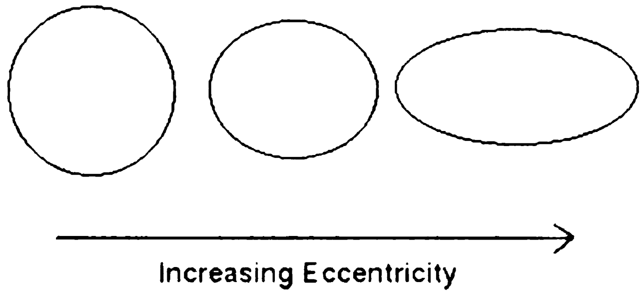
Unlike Brahe, Kepler believed firmly in the Copernican system. In retrospect, the reason that the orbit of Mars was particularly difficult was that Copernicus had correctly placed the Sun at the center of the Solar System, but had erred in assuming the orbits of the planets to be circles. Thus, in the Copernican theory epicycles were still required to explain the details of planetary motion. It fell to Kepler to provide the final piece of the puzzle: after a long struggle, in which he tried mightily to avoid his eventual conclusion, Kepler was forced finally to the realization that the orbits of the planets were not the circles demanded by Aristotle and assumed implicitly by Copernicus, but were instead the "flattened circles" that geometers call ellipses.

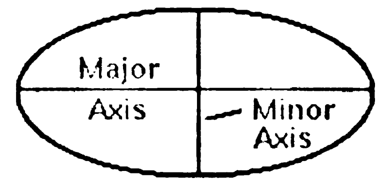
The irony noted above lies in the realization that the difficulties with the Martian orbit derive *precisely* from the fact that the orbit of Mars was the most elliptical of the planets for which Brahe had extensive data. Thus Brahe had unwittingly given Kepler the very part of his data that would allow Kepler to eventually formulate the correct theory of the Solar System and thereby to banish Brahe's own theory! Since the orbits of the planets are ellipses, let us review a few basic properties of ellipses.



1. For an ellipse there are two points called foci (singular: focus) such that the sum of the distances to the foci from any point on the ellipse is a constant. In terms of the diagram shown to the left, with "x" marking the location of the foci, we have the equation $a + b$ = constant that defines the ellipse in terms of the distances a and b

2. The amount of "flattening" of the ellipse is termed the *eccentricity*. Thus, in the following figure the ellipses become more eccentric from left to right. A circle may be viewed as a special case of an ellipse with zero eccentricity, while as the ellipse becomes more flattened the eccentricity approaches one. Thus, all ellipses have eccentricities lying between zero and one.





The orbits of the planets are ellipses but the eccentricities are so small for most of the planets that they look circular at first glance. For most of the planets one must measure the geometry carefully to determine that they are not circles, but ellipses of small eccentricity. Pluto and Mercury are exceptions: their orbits are sufficiently eccentric that they can be seen by inspection to not be circles.

3. The long axis of the ellipse is called the *major axis*, while the short axis is called the *minor axis* (adjacent figure). Half of the major axis is termed a *semi major axis*. The length of a semi major axis is often termed the size of the ellipse. It can be shown that the average separation of a planet from the Sun as it goes around its elliptical orbit is equal to the length of the semi major axis. Thus, by the "radius" of a planet's orbit one usually means the length of the semi major axis.

The Laws of Planetary Motion
Kepler obtained Brahe's data after his death despite the attempts by Brahe's family to keep the data from him in the hope of monetary gain. There is some evidence that Kepler obtained the data by less than legal means; it is fortunate for the development of modern astronomy that he was successful. Utilizing the voluminous and precise data of Brahe, Kepler was eventually able to build on the realization that the orbits of the planets were ellipses to formulate his *Three Laws of Planetary Motion.*

Kepler's First Law:
I. The orbits of the planets are ellipses, with the sun at one focus of the ellipse. Kepler's First Law is illustrated in the image shown above. The Sun is not at the center of the ellipse, but is instead at one focus (generally there is nothing at the other focus of the ellipse). The planet then follows the ellipse in its orbit, which means that the Earth-Sun distance is constantly changing as the planet goes around its orbit. For purpose of illustration we have shown the orbit as rather eccentric; remember that the actual orbits are much less eccentric than this.

Kepler's Second Law: II. The line joining the planets to the sun sweeps out equal areas in equal times as the planets travels around the ellipse. Kepler's second law is illustrated in the preceding figure. The line joining the Sun and planet sweeps out equal areas in equal times, so the planet moves faster when it is nearer the Sun. Thus, a planet executes elliptical motion with constantly changing angular speed as it moves about its orbit. The point of nearest approach of the planet to the Sun is termed *perihelion*; the point of greatest separation is termed *aphelion*. Hence, by Kepler's second law, the planet moves fastest when it is near perihelion and slowest when it is near aphelion.

Kepler's Third Law:

III. The ratio of the squares of the revolutionary periods for two planets is equal to the ratio of the cubes of their semi major axes: $P_1^2/P_2^2 = R_1^3/R_2^3$ In this equation P represents the period of revolution for a planet and R represents the length of its semi major axis. The subscripts "1" and "2" distinguish quantities for planet 1 and 2 respectively. The periods for the two planets are assumed to be in the same time units and the lengths of the semi major axes for the two planets are assumed to be in the same distance units. Kepler's Third Law implies that the period for a planet to orbit the Sun increases rapidly with the radius of its orbit. Thus, we find that Mercury, the innermost planet, takes only 88 days to orbit the Sun but the outermost planet (Pluto) requires 248 years to do the same.

Calculations Using Kepler's Third Law

A convenient unit of measurement for periods is in Earth years, and a convenient unit of measurement for distances is the average separation of the Earth from the Sun, which is termed an *astronomical unit* and is abbreviated as AU. If these units are used in Kepler's 3rd Law, the denominators in the preceding equation are numerically equal to unity and it may be written in the simple form

$$P(YEARS)^2 = A(AU)^3$$

This equation may then be solved for the period P of the planet, given the length of the semi major axis,

$$P(YEARS) = A(AU)^{3/2}$$

or for the length of the semi major axis, given the period of the planet,

$$P(AU) = A(AU)^{3/2}$$

As an example of using Kepler's 3rd Law, let's calculate the "radius" of the orbit of Mars (that is, the length of the semi major axis of the orbit) from the orbital period. The time for Mars to orbit the Sun is observed to be 1.88 Earth years. Thus, by Kepler's 3rd Law the length of the semi major axis for the Martian orbit is

$$A = P^{2/3} = (1.88)^{2/3} = 1.52 \text{ AU}$$

which is exactly the measured average distance of Mars from the Sun. As a second example, let us calculate the orbital period for Pluto, given that it's observed average separation from the Sun is 39.44 astronomical units. From Kepler's 3rd Law

$$P = A^{3/2} = (39.44)^{3/2} = 248 \text{ years}$$

which is indeed the observed orbital period for the planet Pluto.

PART I

Problem:

What is the shape of the Earth's orbit?

Materials:

1. Pencil	3. Thumbtack	5. Cardboard
2. Paper	4. String	6. Ruler

Procedure:

1. Tie the ends of the string together to form a loop.

2. Fold a sheet of paper into thirds; then flatten in out. This will help you to properly space the ellipses that you are about to draw.

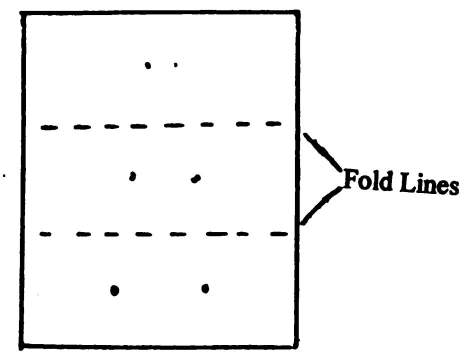


Figure 1

3. In the top third of the paper, make two dots 2 cm apart. In the middle third, make two dots 3 cm apart. In the bottom third, make two dots 4 cm apart.

4. Place the sheet of paper on the piece of cardboard carefully push two tacks through one set of points. Place the string loop around the tacks. Then use a pencil to draw an ellipse around the two foci, pulling the string tight against the tacks. Using the same procedure, draw an ellipse around each of the two remaining sets of points.

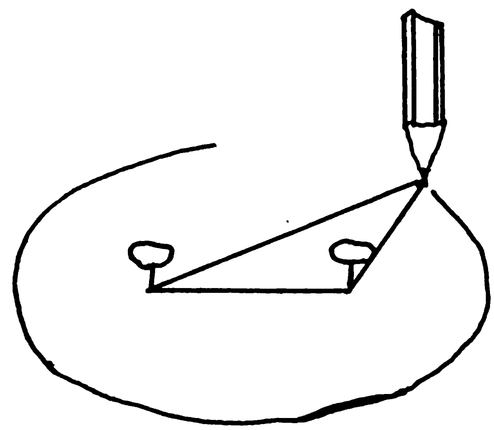


Figure 2

5. Because an ellipse is not a circle, it is said to be eccentric , or "out of round." The eccentricity, or "out of roundness," can be calculated and expressed as a number using the following equation:

$$\text{Eccentricity} = \frac{\text{distance between foci}}{\text{length of the major axis}}$$

Measure the distance between the foci and the length of the major axis from each of the three ellipses you have just drawn. Using the equation above, calculate their eccentricities. Enter your data in the data table.

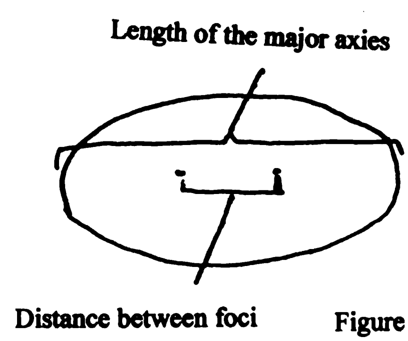


Figure 3

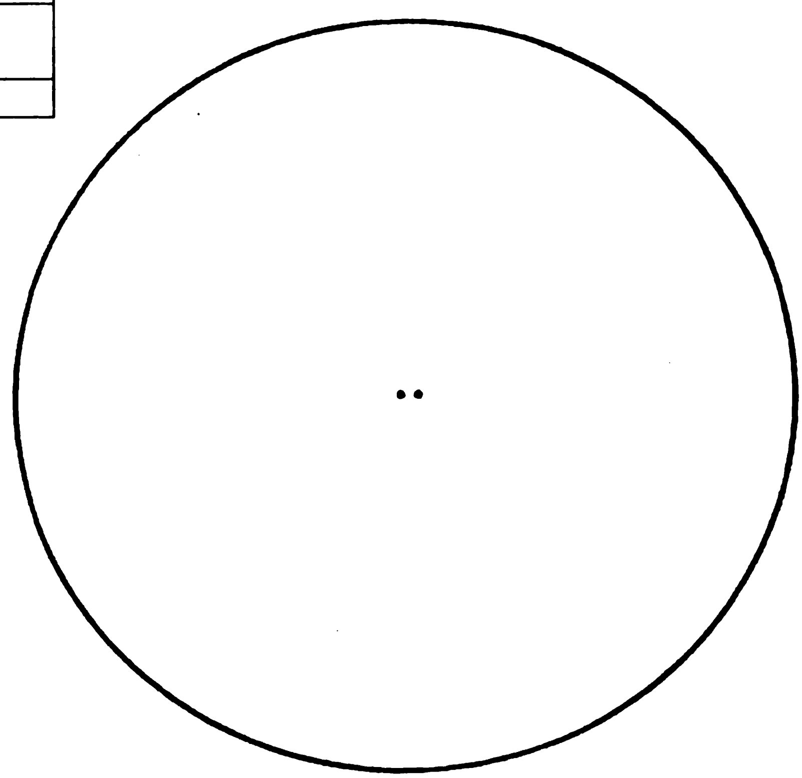
DATA

ELLIPSE	Distance between foci	Length of major axis	Eccentricity
Top			
Middle			
Bottom			

Results

1. If you were drawing an ellipse, what would happen to its shape if you used the same size loop but moved the foci farther apart?
2. The eccentricity of an ellipse can be expressed as a number. Does the eccentricity of an ellipse increase, decrease, or remain the same if its shape is changed to make it more nearly round?
3. What is the relationship between the eccentricity of an ellipse and how nearly round the ellipse appears to be?
4. The figure below represents the earth's orbit drawn to scale. The sun is located at one of the foci; there is nothing at the other. Measure the distance between the two foci and the major axis for the orbit drawn. Then calculate the eccentricity of the ellipse. Enter your data in the table below

Distance between the two foci	
Length of major axis	
Eccentricity	



5. Does the Earth's orbit look more of less eccentric than the three ellipses you drew on the sheet of paper?
6. Using the list of planets, which planets have orbits that are more eccentric than the earth's?
7. Which planet has the orbit that is most similar to the earth?
8. Describe the path of an orbit with an eccentricity of zero?

Planets	Eccentricity
Mercury	0.12
Venus	0.01
Mars	0.09
Jupiter	0.05
Saturn	0.06
Uranus	0.05
Neptune	0.01
Pluto	0.25

9. In your own words write Kepler's first law.

PART II

Problem

How does the Sun's gravity keep the planets in orbit?

Materials

1. String 2. Thread spool 3. Plastic jug 4. One hole rubber stopper

Procedure

1. Slip the string through the hole in the spool. Tie one end to the jug.
2. Use a slip knot to tie the other end tightly to the stopper. The stopper is the planet and the spool is the sun. The weight of the jug represents the pull of the Sun's gravity.
3. Hold the jug in one hand. Hold the spool in the other, and move it in small, rapid circles. The eraser should start to whirl around in an orbit, like a planet around the sun. Let go of the jug.
4. If you whirl fast enough, the orbiting eraser will lift the jug. If you whirl more slowly, the jug will drop and pull the eraser into the spool. You do not have to whirl very fast to keep the pull of the Sun's gravity from pulling your planet into the sun. This is the situation with planets like Uranus and Neptune, which orbit far out in space. The pull of the Sun's gravity out there is fairly weak, so the outer planets don't have to move very fast to keep from being pulled into the sun.
5. Now add water to the jug and repeat steps 3 and 4. You will have to get your planet moving a lot faster to get it to lift the bottle and hold it hanging in one place. This is what happens with the inner planets, which orbit close to the sun where the pull of the Sun's gravity is strong. The stronger the pull of the Sun's gravity, the faster the planet has to move to stay in orbit.

Questions

1. In your own words write Kepler's second law.

2. Given constant radius, the greater the frequency of revolution, the greater the amount of water is needed in the jug. Explain

3. If the velocity is held constant, a decrease in the radius requires an increase in the amount of water in the jug. Explain

PART III

Problem

Do the moons of Jupiter obey Kepler's third law?

Materials

1. Ruler   2. Calculator

Procedure

1. Two telescope eyepiece views in Figure 1 show how Jupiter and its four largest moons appear through a telescope of earth at midnight on the 9th and 19th of a month. Compare these illustrations with figure 2. Figure shows the path of each moon as it orbits Jupiter during the same month. The central horizontal band on the chart represents Jupiter. When a moon's path crosses in front of this band, then moon is in front of the planet. When a moon's path crosses behind this band, the moon is behind Jupiter.

2. Use the data in table 1 to test Kepler's third law. Calculate P^2 and A^3 for each of the planets. Record your results in the table. Then calculate K for each planet using Kepler's third law $K = P^2/A^3$. Record you're your results in the table. Is K constant?

Table 1

Planets	A (in billion of kilometer)	P (in earth years)	A^3	P^2	K
Mercury					
Venus					
Earth					
Mars					
Jupiter					
Saturn					
Uranus					
Neptune					
Pluto					

2. Draw Jupiter and its moon as they would appear from the earth at midnight on the 2nd and 26 of the month.
3. Draw Jupiter's moons on the first day of the moon that all four are on the same side of the planet. Give the date.
4. Give the first date when only two moons will be visible. Name the two moons.
5. Follow each moon's motion of the chart. Find the length of time, in earth days, required for each moon to orbit Jupiter. Record your answers in Table 2.
6. Measure the scale distance between the maximum outward swing of each moon and the center of Jupiter in centimeters. Record your answers in table 2.

Moon	P (in earth days)	Scale R (in cm)	P^2	R^3	K
IO					
EUROPA					
GANYMEDE					
CALLISTO					

7. Square the period and cube the distance.
8. Calculate the K

Conclusion

1. Will you see all four of Jupiter's moons each time you look at Jupiter through a telescope or binoculars? Explain
2. Jupiter's moons look like dots in a telescope. You cannot tell them apart by their appearance. If you had no charts, how could identify each moon?
3. After you solved for K for each moon was K constant?

Portion of this activity were modified from
Modern Earth Science, IN-depth investigation: Galilean Moons of Jupiter Holt, Rinehart and Winston, Harcourt Brace and Company, Page 139-144.
Prentice Hall Earth Science, Characteristics of Elliptical Orbits Laboratory Manual, Page 41-44

Appendix B-9

Telescope Questions

Go to: http://www.astronomynotes.com/telescop/s1.htm to answer the following questions.

1. What are the two basic type telescopes? What are their advantages and disadvantages?

2. Why are the large modern telescopes reflector telescopes?

3. How does the size and shape of a radio telescope compare to an optical telescope? Why is there such a difference in their size?

4. What are the parts of a radio telescope?

5. What kinds of things can be seen with a radio telescope that cannot be detected by an optical telescope?

6. Of the three powers of the telescope) Light-gathering power, resolving power, and magnification) which is least important?

7. How many times better resolution does a 48-centimeter telescope have than a 12-centimeter telescope?

8. Will a shorter or longer wavelength enable us to see smaller details?

9. Why do radio telescopes have to be so large?

10. The distance to the nearest star is 4.3 light years= 4.3 X 9.7 trillion kilometers= 41,800,000,000,000 kilometers. Does Mauna Kea's elevation of 4177 meters (2.6 miles) put it significantly closer to even the nearest star than something at sea level? Explain your answer. (1 Kilometer= 1000 meters)

11. What causes stars to twinkle? What would make good seeing?

12. Even with perfectly clear skies free of human pollution, the seeing on Mauna Kea (4177 meters elevation) is much better than at sea level. Why is that?

13. What absorbs infrared light in our atmosphere and up to what height above sea level is most of this infrared absorber found?

14. Why are all ultraviolet, X-ray, and gamma ray telescopes put up in orbit?

Appendix B-10

Ritter's Ultraviolet experiment

Physical Science
Astronomy Unit

Name________________
Date________________
Hour_________

History

Johann Wilhelm Ritter invented the dry cell battery and showed that galvanizing protected iron from rusting by an electrochemical effect. Ritter was also interested in the chemical reactions of silver chloride which breaks down to black silver when it is exposed to light. He concluded that heat from the infrared might speed up the reaction. After all, many reactions happen when you heat them up.

Hypothesis

To duplicate Ritter's experiment and show the existence of ultraviolet light.

Materials

1. Several sheets of blueprint paper
2. Prism
3. Cardboard box
4. Felt-tip pen

Procedure

1. Place the white sheet of paper flat in the bottom of the cardboard box.
2. Carefully attach the glass prism near the top edge of the box. Cut a notch that will hold the prism snugly, while permitting it to be rotated.
3. Rotate the prism in the notch until the widest spectrum appears on a shaded portion of the white sheet of paper.
4. Place the top back on the box making sure not to block the light going through the prism
5. Cut a hole in the side of the box so the spectrum can be seen. (about 25cm by 15cm)
6. Working quickly to prevent expose of the paper to too much light, place the blueprint paper underneath the spectrum. Keep paper in the shade at all times.
7. The blueprint paper reacts the same way as the silver chloride paper that Ritter used
8. Outline the area covered by the spectrum with a felt-tip pen. Label the violet and red ends.
9. Allow the blueprint paper to sit for 20 to 30 seconds

Data

Please draw a picture of what has happen to the blueprint paper.

Results

1. What happened to the different areas on the paper?

2. Did anything happen to the areas outside the visible light spectrum?

3. What does this tell you about the areas outside the visible light spectrum?

4. What would happen if you had the light go through a piece of glass before going through the prism?

Extra Credit

Explain what causes silver chloride to react with light.

Note: Portion of this lab were adapted from Discovery Communications Inc.
http://school.discovery.com/lessonplans/activities/infraredandultraviolet/activity2.html

Appendix B-11

Observing Wave Properties of a Slinky

Physical Science
Astronomy Unit

Name __________
Date ___________
Hour ______

Information

A wave is a displacement or disturbance that moves through a medium or space. A wave involves some quantity of disturbance that changes in magnitude with respect to time at a given location and changes in magnitude from place to place at a given time. A wave cannot exist only in one place but must extend from one place to another.

Waves transfer energy from one place to another, but cannot transfer matter. Mechanical waves such as sound require material medium such as air to propagate while electromagnetic waves such as light require no material medium.

To totally define a wave, we need to speak about *frequency* (the number of vibrations of oscillations in a given time), *amplitude* (displacement from the rest position), *period* (time for one complete oscillation), and *wavelength* (distance between successive similar points).

Problem

What are the characteristics of a wave?

Materials

Slinky

Procedure

1. On a smooth floor, stretch the spring to about three meters. **(D0 NOT OVER STRETCH)** Have one person hold the spring at each end.
2. Move one end of the spring back and forth on the floor. Draw a diagram of the wave you observe.
3. Repeat step three, but this time increases the rate at which you move the spring back and forth.
4. Now squeeze together the first 20 cm of the spring.
5. Release the compressed section of the spring and observe the wave as it moves down the spring.
6. Both partners should start waves of equal amplitude toward each other. Observe what happens when the waves meet.
7. Fill a pan with water to a depth of about 1.5 cm.
8. Place on a level surface.
9. Use a wooden dowel, just smaller than the width of the pan, and place it into one end of the pan.
10. Roll the dowel back and forth using one finger.
11. Roll the dowel at different speed to observe the shorter and longer wavelengths
12. The wave activity is important to show the relationship between the speed of a wave and the frequency and wavelength of the wave. The formula $\upsilon = f\lambda$ is true for all waves, even for electromagnetic waves such as light.

Questions

1. Are the waves generated in steps 1 to 3 transverse or longitudinal? Explain

2. Are the waves generated in steps 4 to 5 transverse of longitudinal? Explain

3. What is the relationship between the rate at which the spring is moving back and forth and the frequency? And the wavelength?

4. What are the characteristic of a wave?

5. What happen to the wave when it hits a barrier? (like your hand)

6. What happened when the two waves came in contact with each other?

7. While sitting in your anchored boat, you notice that waves that you estimate to be of wavelength 2.3 meters pass the anchor chain at a rate of 36 waves every 30 seconds. What is the speed of these waves?

Note portion of this activity were modified from Observing Wave Properties of a Slinky Laboratory Investigation, Prentice-Hall Chapter 21 pg 907-909

Appendix B-12

Fingerprinting the Stars

Physical Science
Astronomy Unit

Name ______________
Date ______________
Hour _______

History

At the turn of the century the new science of astrophysics was growing rapidly. This was due to the recent findings in photometry and spectroscopy. When Annie Jump Cannon began at Harvard scientists knew that when sunlight was dispersed through a prism it appeared to break up into component colors, like a rainbow. This rainbow was known as a spectrum. The spectrum was broken up by a series of dark lines and bands which resulted from various atoms in the solar atmosphere. After astronomers like Prof. Pickering attached prisms to their telescopes and took photographs of other stars they discovered that the lines in spectra differed from those of the sun. Stellar classification according to line patterns began. This was not easy to do. Annie excelled because of her sharp eye and memory.

She created a spectral classification system for stars. It is mainly based on temperature. The O stars are the bluest and the hottest stars, and the M stars are the coolest red stars. The stars at the beginning of the sequence are called "early-type" stars and at the end, "late type" stars. With in each type there are subdivisions by taking the letter and adding decimals, such as B0-B9 stars. As we know from "Understanding Her Work" different temperatures cause the distinction in star spectra due to electrons occupying different orbital in atoms of the atmospheres of the stars. Classifications of spectral lines are also due to the composition of the stars and can be quite complicated. The following two tables appear in astronomical text books. Hopefully they will clear up any further confusion about general spectral classification.

Spectral Type	Characteristics	Examples	Temperature
O	Hottest blue0white star with few lines. Strong He II absorption lines. He I absorption lines becoming stronger	Lacertra	>25,000K
B	Hot blue-white stars. He I absorption lines strongest at B2. H I absorption lines becomes stronger.	Rigel Spica	11,000-25,000K
A	White stars. Balmer absorption lines strongest at AO becoming weaker later. Ca II lines becoming stronger.	Isrius Vega	7,5000-11,000K
F	Yellow-white stars. Ca I (I lines continue to strength as Balmer line continue to weaken.	Canopus Procyon	6,000-7,500K
G	Yellow stars Solar spectra Ca II continue to become stronger. Fe I other neutral metal becoming stronger.	Sun Capela	5,000-6,000K
K	Cool orange stars. Ca II Spectra dominated by actual absorption lines.	Arcturus Aldebaran	3,500-5,000K
M	Coolest red stars. Spectra dominated by molecular absorption bands, especially titanium oxide (TiO). Neutral metal absorption lines remain strong.	Betelgeuse Antares	<3,500

In 1800s when spectra from various luminous objects were first being studied it was found that all spectra were not like our customary rainbow: some have bands of color missing< and other has bright bands of colors. Spectra were divided into three main types by Gustav Kirchhoff when he proposed explanations for their origins. These explanations are Kirchhoff's three laws of spectra analysis.

1. A hot solid, liquid or gas under high pressure, gives off a continuous spectrum.
2. A hot gas under low pressure produces a bright line of emission line spectrum.
3. A dark line or absorption line spectrum is seen when a source of a continuous spectrum is viewed behind a cool gas under pressure.

Objective

1. Each student will learn to use a spectroscope.
2. Student will be able to identify different elements by the color spectrum that they emit when heated.

Materials

1. Spectroscope
2. 6-8 Vacuum filled tube with different gases
3. Colored pencil
4. Prism
5. Slide projector
6. Metal slide with small slit
7. Color filters (red, blue, green, and yellow)
8. Bunsen burner
9. Sodium Chloride, Strontium Nitrate, Lithium Chloride and Copper Chloride
10. Incandescent light source, mercury light, cigarette lighter, candle, firefly, matches, and spotlight
11. Beaker with chlorophyll

Procedure

1. Darken room
2. Use the slide projector to project light onto an overhead screen.
3. Place the metal slide into the projector.
4. Now place the prism so that the light coming through the slit creates the visible spectrum.
5. Explain to the students that the prism separates the white light into its separate components. This creates the rainbow and is what they should see when looking at white light through their spectroscopes.
6. Remove the metal slide and have students look through their spectroscopes.(Caution metal slide will be extremely hot)
7. Have students predict what will happen when a colored filter is placed over the light source.
8. Hold a piece of red cellophane over the slit. Sketch what you see.

9. Repeat step 8 using blue.
10. Hold both filters in the beam of light.
11. Repeat step 8 using green
12. Repeat step 8 using yellow
13. Have students draw the spectrum for each filter.
14. Use the spectroscope to examine the spectra produced by the following common light sources.
    a. Incandescent light bulb
    b. Fluorescent light
    c. Spotlight
    d. Matches
    e. Candle
    f. Cigarette lighter
    g. Firefly
15. Take the Bunsen burner and place a small amount of the chemicals listed above in to the flame.
16. Record the color of the flame.
17. Sketch the spectrum indicating both of the colors and relative spacing of the lines.
18. Use the spectrum tubes and have students draw what they see with the spectroscopes.
19. Show the students two or more unknown samples
20. Use the slide projector and place a beaker that is filled with chlorophyll in front of the light. Have students look at spectrum and discuss what they see.

Data

Filters

Red Cellophane	
Blue Cellophane	
Both Red and Blue	
Green Cellophane	
Yellow Cellophane	

Chemicals

Sodium Chloride	
Strontium Nitrate	
Lithium Chloride	
Copper Chloride	

Gas Tube	Spectral Lines
Oxygen	
Neon	
Helium	
Water Vapor	
Mercury	
Carbon Dioxide	

Unknown	Spectral lines
Sample A	
Sample B	

1. When you look at the white light, you observe the solar spectrum. How many color zones do you observe? How did the zones compare in size?

2. What effect in general does the use of a color filter have upon its corresponding color in the produced spectrum?

3. How can you determine the chemical composition of an unknown gas?

4. How can this technique be used to determine characteristics of stars?

5. Why do you think these compounds give off light having a characteristic spectrum when they are heated?

6. Observe the spectra of light from 25-watt, 40-watt, 60-watt and 100-watt light bulbs. How do the spectra differ? How can scientists determine the temperature of a distant star by using a spectroscope?

Portion of this activity were modified from

Bernstien, Leonard, Winkler, Alan, and Zierdt-Warshaw, Linda. Multicultural Women of Science 1996, The peoples Publishing Group Incorporated Maywood NJ.

Appendix B-13

Herschel Infrared Experiment

Physical Science
Astronomy Unit

Name____________
Date____________
Hour______

History

William Herschel discovered the planet Uranus and heat rays. He discovered the existence of infrared light by passing sunlight through a glass prism. As the sunlight passes through the prism the light is dispersed into a rainbow of the visible colors, called the spectrum. Herschel was interested in determining which part of the spectrum carried the heat from the sun.

Hypothesis

To perform and determine which type of electromagnetic waves carry heat to the Earth.

Materials

1. One glass prism
2. CBL
3. Graphing Calculator
4. Temperature probe
5. Scissors
6. Cardboard box
7. Sheet of paper

Procedure

10. Place the white sheet of paper flat in the bottom of the cardboard box.
11. Carefully attach the glass prism near the top edge of the box. Cut a notch that will hold the prism snugly, while permitting it to be rotated.
12. Rotate the prism in the notch until the widest spectrum appears on a shaded portion of the white sheet of paper.
13. Place the top back on the box making sure not to block the light going through the prism
14. Cut a hole in the side of the box so the spectrum can be seen. (about 25cm by 15cm)
15. Now using the CBL, Graphing calculator and temperature probe measure the normal air temperature of the shaded portion of the box. Record temperature.
16. Place the temperature probe in the violet range and let it set for five minutes. Record temperature every minute.
17. Remove and allow temperature probe to return to normal air temperature.
18. Place the temperature probe in the yellow range and let it set for five minutes. Record temperature every minute.
19. Remove and allow temperature probe to return to normal air temperature.
20. Place the temperature probe in the region just outside of the visible red and let it set for five minutes. Record temperature every minute.

Data

	Starting	After violet	After Yellow	Ending
Normal Temperature				
Temperature in the spectrum	Violet	Yellow	Outside of visible red	____________
After 1 Minute				____________
After 2 Minutes				____________
After 3 Minutes				____________
After 4 Minutes				____________
After 5 Minutes				____________

Calculations

Temperature differences

	Violet	Yellow	Just outside of red
Temperature of spectrum			
Temperature of shade			
Difference			

Calculate the differences between the final temperatures in each part of the spectrum.

$T_{yellow} - T_{blue}$	$T_{outside\ red} - T_{yellow}$	$T_{outside\ red} - T_{blue}$

Class Average Temperatures

	Sum of Temperatures (T_{sum})	Total number of Observations(N)	Class Average (T_{sum})/N
Violet			
Yellow			
Outside red			

Compute the average differences measured by the class between the final temperatures in the spectrum and the shade temperatures for the three thermometers

	Sum of Temperature differences(T_{sum})	Total number of observations (N)	Class average (T_{sum})/N
$T_{yellow} - T_{blue}$			
$T_{outside\ red} - T_{yellow}$			
$T_{outside\ red} - T_{blue}$			

Conclusion

1. Certain types of photographic film are sensitive to infrareds radiation. When infrared film is developed, it allows you to see infrared radiation. What would an infrared picture of a recently driven automobile look like?

2. Fluorescent light fixtures are more efficient than incandescent light bulbs because they emit less infrared radiation. Explain

Note: Portion of this lab were adapted from
http://sirtf.caltech.edu/EPO/Herschel/experiment.html
http://sirtf.caltech.edu/EPO/Herschel/backyarfd.html

Chapter 24 STARS AND GALAXIES

Section 1 Stars

I. Constellations
   A. Define

   B. The brightest star in the sky is ____________ it is located in the constellation ______________________.

   C. The North Star is called ____________ and is located in the constellation ____________________ which is commonly called the ________ _________

   D. Circumpolar Constellations
      1. These stars rotate around _____________

      2. How often are these stars visible?______________

      3. Some constellations are only seen during different seasons. Why is this?

II. Absolute and Apparent Magnitudes
   A. Even though star Sirius is a brighter star than Rigel in the night sky, The star Rigel is many times brighter than Sirius. How is this possible?

   B. Define "absolute magnitude"

   C. Define "apparent magnitude"

III. Determining the Distance to Stars
   A. Define "Parallax"

   B. How do we determine the distance a star is from earth?

C. Define "light-year"

1. How far does light travel in one year?____________________
2. Our nearest star is ________________and is _____________ light-years away or _____________trillion kilometers.

D. The closest star to earth is really the ____________ and its distance is ___________________________

IV. Determining a Star's Temperature and Composition

A. The _____________ of a star indicates its ____________________
1. Hot stars are ________________in color
2. Cool stars are ________________ in color
3. Our sun is not hot or cold, but average in temperature and is ____________________ in color.

B. Astronomers study the stars_____________ or visible light that is radiated from the star. The instrument used is called a ________________________

C. As light radiated from a star passes through the stars atmosphere some of the light is absorbed by elements in the atmosphere.
1. The wavelengths of visible light absorbed appear as ______________ lines in the spectrum (look on page 695)
2. Certain patterns of ____________ lines can identify which ______________ are in the star's atmosphere.

Section 2 The Sun

I. Layers of the Sun

A. __________% of all matter in our ___________ _____________ is found in the sun.

B. Sun
1. ____________ _______________ age star
2. Absolute magnitude is _________________
3. Is __________________ in color.
4. Made up of _____________
5. How does it produce energy?

C. The Sun's Atmosphere

1. Surface is called ___________________________but it is actually the lowest layer.
    a. Temperature_____________________

2. The layer above the photosphere is called ___________________________

3. The outer layer, the largest layer is called the ____________________
    a. Temperatures______________________
    b. Solar winds come from here. What are they

D. Diagram 24-6

1. How is energy produced by the sun? Where does it come from?

2. How does energy get to the corona? (2 ways)

V. Surface Features of the Sun

A. What are "sun spots"?

B. What have we learned about the sun from "sun spots"?

C. Prominences - What are they? How are they caused?

D. Solar Flares - What are they?

E. Explain how ultraviolet light and X rays from solar flares cause radio and telephone disruptions.

F. Our Sun is not in a binary system. Explain what a binary system is and give an example on one.

Section 3 Evolution of Stars

I. The H-R Diagram

A. This is a graph that shows the relationship between a stars ________________ and its ______________ ______________________.(Fig.24-10)

B. Main Sequence

1. These stars are found where on the H-R diagram?

2. What percent of stars are main sequence stars?__________

3. The hottest stars are __________ in color and produce the most light.

4. The coolest stars are ______________ in color and produce the least light.

5. Explain the following stars

(a) White dwarfs

(b) Supergiants and Giants

C. Fusion

1. Occurs in the _____________ of a star. Where temperatures and pressure are the highest.

2. Fusion takes place when ____________fuses to produce __________________ and energy is released.

3. Einstein's Theory that "mass can be converted into energy" is proven by the formula_________________________ where

E =
M=
c=

D. Evolution of Stars

1. Using the figure 24-13 draw the various births and deaths of stars

B. Explain

1. Neutron Star

2. Black Hole

3. Nebula

Section 4 Galaxies and Expanding Universe

I. Galaxy

A. Define

B. What galaxy do we belong to?____________________

C. What are the main "groups" of galaxys? Describe each.

1.

2.

3.

D. Describe the galaxy that we belong to

II. Expansion of the Universe

A. The "Doppler Shift"

1. Define this

2. How is this used to prove the movement toward or away of stars and galaxies

Appendix B-15

Sun's Interior Structure

Physical Science
Astronomy Unit

Name ___________
Date ____________
Hour ______

History

Our sun is a middle-aged, medium sized star, big enough to hold a million Earths. The ancient Greeks thought that the Sun was a perfect sphere of fire. Anaxagoras proposed that the moon shines by reflected light from the "red-hot stone" which was the sun. He also was the first to explain the reason for eclipses of the sun and the moon. His explanation of the eclipses of the sun is completely correct but he did propose that other dark bodies between the earth and the moon also caused some of the eclipses of the moon. Today we know that the Sun is a variable star that produces life giving light and heat as well as harmful radiation. It causes space weather that can harm astronauts working in space and can interfere with satellites orbiting our planet.

Information

Although the average distance from the Earth to the sun is a whopping 149,000,000 kilometers, careful observation from the Earth reveals a surprisingly large number of different visible features such as: sunspots, plages, solar flares, prominences, filaments, the corona, and coronal holes.

Objective

Develop an understanding of the structure of the Sun by constructing a scale model of a slice of the interior of the Sun.

Material

1. 5 pieces of computer paper connected
2. Meter stick
3. Pencil
4. 100cm long string
5. Markers
6. Transparent tape

Procedure

1. Fold the paper in half length wise to find the center of the page.
2. In pencil, draw a dashed line down the center of the page.
3. On the dotted line 5cm from the edge make a dot to represent the 'center of the Sun'
4. To determine the width of the 15° slice, measure 139 cm from the center of the sun. From that point, measure 8.3 cm from the center line in both directions.
5. Now, using the string loop it around a pencil. Place the pencil at the point that was measure 139 cm from the center of the sun. Hold the other end at the point marked center of the sun.
6. Draw an arc to mark the outer boundary of the sun

Determining the layers of the Sun to scale

7. The scale that you need to you is 1 cm to 10,000km. Calculate the radius to scale for each layer of layers of the sun.

Layer	Thickness(km)	Radius(km)	Conversion	Color
Center of Sun	0	0	0	-
Core	175,000	175,000		Red
Radiation Zone	382,012	557,012		White
Convection Zone	139,253	696,265		Purple
Photosphere	805	697,070		Yellow
Chromosphere	2000	699,070		Blue
Corona	690,930	1,390,000		Orange

8. Measure from the center of the sun outward for each layer. Draw the arc for each layer from the center of the page to the edge of the slice at the corresponding measurement.
9. Color and label each layer.
10. Draw in three of the solar features mentioned in the information section. Remember that all of these are on the surface.
11. Cut out the slice, put your name on the back and turn in. Slices will be put together to create a full sun.

Note: Portion of this lab were adapted from
Origins Education Forum. (2000) Star Formation.
http://origins.stsci.edu/under/stars.shtml

Appendix B-16

HERTZSPRUNG-RUSSELL DIAGRAM LESSON

Physical Science
Astronomy Unit

Name ______________
Date _______________
Hour ______

History

In 1910 Ejnar Hertzsprung and Henry Russell, independently plotted the relationship between the luminosity (absolute magnitude) and spectral classes (temperature) of the star. Looking at the night sky you can see that there are bright and dim stars. The brightness of the star depends on how much radiation is coming off the star and how close it is to the observer.

Hertzsprung and Russell fond that stars have limited possible combinations between temperature and brightness. All the stars they plotted fell in three distinct regions on the graph instead of being widely distributed over the graph. About 90% of all stars fall in the main sequence. This is the band of stars that extends from the upper left hand corner to the bottom right hand corner. Our sun is a main sequence star.

The second region of stars are called Giant and supergiant Stars. These are cool, very bright star that emit mostly red light and are located in the upper right hand corner of the graph. These stars are thousands of times bigger then the main sequence stars.

The third and final region is the White Dwarfs. These stars are located in the lower left hand corner of the graph. These stars are about the size of the Earth and emit a bluish white light.

Objective

To draw and evaluate a Hertzsprung-Russell diagram.

Materials

1. Colored pencils
2. Graph paper

Procedure

1. Use the data in the Table A to plot points of the 20 brightest stars in the night sky. Plot these stars with a red pencil.
2. Plot the data in Table B, the 15 nearest stars. Use a blue pencil to mark points.
3. The Sun has a luminosity of 1 and a temperature of 6000 K. locate the sun on your diagram and circle it.

TABLE A: THE BRIGHTEST (APPARENT) STARS		
STAR	**Temperature (K)**	**# of times the Sun's Luminosity**
Sirius	14,000	2.0×10^{1}
Canopus	7400	1.2×10^{3}
Alpha Centauri	5800	1.0
Arcturus	4500	9.0×10^{1}
Vega	10,700	4.0×10^{1}
Capella	5900	1.3×10^{2}
Rigel	11,800	4.0×10^{4}
Procyon	6500	6.0
Achernar	14,000	1.7×10^{2}
Beta Centauri	21,000	3.3×10^{3}
Betelgeuse	3200	1.1×10^{4}
Altair	8000	10
Aldebaran	4200	8.0×10^{1}
Crucis	21,000	2.7×10^{3}
Antares	3400	4.4×10^{-3}
Spica	21,000	1.9×10^{3}
Fomalhaut	4500	1.1×10^{-1}
Pollux	4900	4.0×10^{-3}
Deneb	9900	4.0 X 104
Beta Crucis	22,000	4.8×10^{3}

TABLE B: THE NAREST STARS		
STAR	**Temperature (K)**	**# of times the Sun's Luminosity**
Centauri	5800	1.0
Barnard's Star	2800	4.0×10^{-4}
Wolf 359	2700	1.3×10^{-4}
Lalande 21185	2700	4.0×10^{-2}
Luyten 728-8	2700	5.0×10^{-3}
Sirius	10,400	2.5×10^{-1}
Ross 154	2800	4.0×10^{-4}
Ross 248	2700	1.0×10^{-4}
Epsilon Eridani	4500	2.5×10^{-4}
Tau Ceti	2800	2.5×10^{-4}
61 Cygni	4200	6.7×10^{-2}
Procyon	6500	1.7×10^{-1}
Luyten 789-6	2700	7.7×10^{-7}
Epsilon Indi	4200	1.0×10^{-1}
Ross 128	2800	2.5×10^{-4}

Data

1. How does the Sun compare to the 20 brightest stars with reference to luminosity and temperature?

2. How does the Sun compare to the 15 nearest stars with reference to luminosity and temperature?

3. Compare the positions of the nearest stars with those of the brightest stars.

4. Would the surface temperature of the stars classified as white dwarfs are generally higher or lower than that of stars classified as supergiants?

5. What is the color of the stars shown on the diagram that have the highest surface temperature? Lowest temperature?

6. How is it possible for white dwarfs to have a lower luminosity than the Sun even though the sun is much cooler than the white dwarfs?

Note: Portion of this activity were modified from the following sources;
http://einstien.stcloudstate.edu/nook/IDEAS/computers/ramseth/webpage.html
Using Science Skills: Interpreting diagram, Prentice-Hall Chapter 21 pg 907-909.

Appendix B-17

Expanding Universe

Physical Science
Astronomy Unit

Name ________________
Date ________________
Hour _____

History

In the early 1920's Edwin Hubble played a key role in establishing just what galaxies are. Hubble measured the distances to a handful of other galaxies. He realized that as a rough guide he could take their apparent brightness as an indication of their distance. The speed with which a galaxy was moving toward of away from us was relatively easy to measure due to the Doppler shift of their light. He calculated that most galaxies are receding from us, and each other, as the university expands.

Material

1. Paper
2. Pencil or Pen

Procedure

1. Make 5 copies of you universe.
2. Make each consecutive copy with a zoom of 25%
3. Now measure the velocities of the galaxies as they recede from one another.
4. Measure the distance from your home galaxy to each of the other galaxies and enter it in the following table.
5. Do step for each of the 6 copies. Enter data in Table 1.
6. Now determine the SPEED of each galaxy. (Hubble did this indirectly by looking at the spectrum.)
7. Enter data in table 2.
8. Figure the relationship between the distance to the galaxy and the velocity of the galaxy. (This relationship is know as Hubble's Law)
9. Do the calculation in Table 3.
10. Graph the Velocity versus the distance on a sheet of graph paper.

Data

Table 1

Galaxies	**Distance (Zoom 0)**	**Distance (Zoom 1)**	**Distance (Zoom 2)**	**Distance (Zoom 3)**	**Distance (Zoom 4)**	**Distance (Zoom 5)**
Galaxy 1 to Galaxy 2						
Galaxy 1 to Galaxy 3						
Galaxy 1 to Galaxy 4						
Galaxy 1 to Galaxy 5						
Galaxy 1 to Galaxy 6						

Table 2

Galaxies	$D_1 - D_0$	$D_2 - D_1$	$D_3 - D_2$	$D_4 - D_3$	$D_5 - D_4$
Galaxy 2					
Galaxy 3					
Galaxy 4					
Galaxy 5					
Galaxy 6					

Table 3

Galaxies	D_5	$V=D_5 - D_4$
Galaxy 2		
Galaxy 3		
Galaxy 4		
Galaxy 5		
Galaxy 6		

Questions

1. Looking at table 2- what \can you say about how all the galaxies are moving? Do any of the galaxies ever get closer together per time?

2. Can you make a statement about how the velocity of a galaxy depends on its distance?

3. What is the relationship between velocity and distance?

Extra Credit

You know the distance to each galaxy in cm, and velocity of each galaxy in units of cm/copy. Using the formula

DISTANCE = VELOCITY X TIME

Make an estimate of the age of this universe in number of copies. How many copies ago would the big bang has occurred in this universe? (Show *your calculation)*

Portion of this activity have been modified from <u>Sharpen Your Skills: Identifying Relationships</u> Prentice-Hall page 70.

Appendix B-18
Stargazers Movie

1. How has the telescope changed over the last 100 years?

2. What new innovations and inventions have changed the way we look at the sky?

3. What role did the Lowell Observatory play in the development of the big bang theory?

4. How pivotal was the research conducted at Lowell to eventual theory proposed by Edwin Hubble?

5. How did Clyde Tombaugh come to be employed by the Lowell Observatory?

6. Why have the Shoemakers joined the staff of the Lowell Observatory?

7. Why does Earth show relatively few impact sites from asteroids, comets, and meteorites compared to the moon and other bodies in the solar system?

Appendix B-19

Apparent and Absolute Magnitude

Physical Science | Name ______________
Astronomy Unit | Date ________________
Hour _____

History

The absolute magnitude of a star is determined by its size and temperature. In about 120 B.C., Hipparchus devised the system of quantifying the brightness of stars still in use today. He catalogued about 1000 stars visible to the unaided eye into six categories according to their apparent magnitude. In 1854, the British astronomer N.R. Pogson figured out that the naked eye is capable of seeing stars that differ in brightness by about a factor of 100 so that 1st magnitude stars are about 100 times brighter than 6th magnitudes ones. Henrietta Swan Leavitt (1868-1920) reported that stars brighten and dim at regular intervals and there was a relationship between the length of a star's period of brightness and its magnitude. In 1912, she made a table which showed that the longer the interval of variation, the brighter the star. This table is known as the Period Luminosity Relationship for Variable Stars and is still used today. This table was used to find the distances of stars in the Milky Way and other galaxies. Astronomers study the brightness, or magnitude, of stars, by using a device called a photometer. An astronomical photometer consists of a surface that is sensitive to light and a device that measures the amount of light that reaches the surface. The brightest part of the star's spectrum can occur at any wavelength of optical light. Some stars look bluish while others look reddish. Color is an indication of the star's surface temperature. There is also a relation between the color of a star and its brightness.

Objective

In this investigation, you will determine the effect of distance on brightness and the relation between temperature and color.

Materials

1. 2 3-volt flashlight bulbs
2. 3 AA batteries
3. 2 Plastic-coated wires
4. Masking tape
5. 2 Paraffin bricks
6. Aluminum foil
7. Large rubber band
8. Ruler
9. Lamp/incandescent bulb

Procedure

1. Teacher will have two simple flashlights made for each group.
2. Construct a photometer: Fold the aluminum foil in half with the shiny side out, and place it between the paraffin bricks. Hold the pieces together with a rubber band.
4. Place the two flashlights on a table about 2 meters apart. Place the photometer between them with the largest sides of the bricks facing each flashlight bulb.
4. Turn on both lights

5. Move the paraffin photometer until both sides are equally bright. Measure the distance, in centimeters, from each light bulb to the center of the photometer. Record distance
6. Square the distances you recorded in step 6. Record this information.
7. Incandescent light glow at a temperature much cooler than the sun surface. Place the photometer between the desk lamp and the window.
8. Compare the color difference between the paraffin sides of your photometer. Which light, the light bulb or sunlight, is more yellow? Which light is whiter?
9. Darken the room once again, and compare the colors of the bulbs powered by one battery with the color of the bulb powered by two batteries.
10. Use the incandescent bulb controlled by the dimmer that the teacher has set-up on the side bench. Watch the color of the light as it fades.

Analysis and Conclusions

1. As you move away from a light source, the brightness decreases in relation to the square of the distance. What is the ratio of the square of the distance of the two-battery flashlight to that of the one-battery flashlight? What does this tell you about the relation of the brightness of the two flashlights?

2. An astronomer knows that two stars have the same spectra and should be of the same brightness. Yet one is four times fainter than the other. How much further away is the faint star?

3. Based on the results of the investigation, would you expect a white star or a yellow star to be hotter?

4. Would you expect a white star to be hotter or cooler than an orange star? Predict whether a blue star is hotter or cooler than a white star?

Note: portion of this lab were adapted from Phillips, Clifford R., Ramsey, William L., Sager, Robert J., and Watenpaugh, Frank M. (1998) Modern Earth Science
Holt, Rinehart and Winston Harcourt Brace and Company, Laboratory Manual page 125-126.

Appendix B-20

Life Cycle of a Star

Physical Science
Astronomy Unit

Name ______________
Date _______________
Hour _____

History

Cosmologists believe that the universe was created about 15 billion years ago with the "Big Bang" a cosmic explosion that resulted in an expanding cloud of the two lightest elements, the gases hydrogen and helium. At that time there were no other elements. Where there were higher concentrations of gases, the mutual gravitational attractions of the gas molecules led to the growth of the first generation of stars. As more and more materials fell into a new star, the pressure at its center finally became high enough to start the process of nuclear fusion, in which the nuclei of hydrogen and helium merge to from heavier elements. This was accompanied by the released of energy, which made the star begin to shine.

Eventually, all the hydrogen and helium, and those products that could be used to generate energy in the core of the star, were exhausted, and the nuclear furnace was extinguished. The outer layers of the star could no longer resist the central force of gravity, which was pulling the star's outer matter inward toward its core. What happened next depended on the mass of the star. In some cases, the star became a supernova, exploding violently and rapidly creating even heavier elements, spewing much of the stellar material into space. In other cases, the process was slower; instead of an explosion, elements from the star's interior zones rose to the surface and were then lost to space when the outer layers blew off. The end results were similar: the space between the stars was enriched with heavy elements, many of which condensed to form small solid grains. The processes of the birth and death of stars occurred over and over again, with each successive generation of stars starting off with a greater quantity of heavy elements then the previous generation.

Objectives

1. To illustrate the various stages in the life cycle of stars
2. To relate these stages to the positions on the H-R diagram.

Procedure

1. Create a rough draft of your drawing in pencil on a scrap piece of paper. Show the rough draft to teacher
2. All of the following terms must be illustrated: Nebula, main sequence, supernova, red super giants, red giants, neutron star, black hole, white dwarf, protostar (high and low mass), and black dwarf. They must be labeled.
3. Using, your illustration as a guide write a paper describing what happens during the life cycle of a star.

Note portion of this activity were modified from http://origins.stsci.edu/under/stars.shtml

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