Lesson Plans

Prep in Advance of the Unit

- Make arrangements for a "hands-on" or guest presenter experience for as early on in the unit as possible. An evening of star gazing with families may be the most appropriate introduction. Support for this can be found by doing an internet search of astronomy clubs or observatories. This kind of activity provides students with an experience on which they can "hang" subsequent knowledge and concepts.

- Lower grade students will be involved in creating "folder books" which will be records of what they have learned. These can be made using file folders (each student's file folders should have identical tabs -- don't mix and match). Lay the first folder (closed) upside down. Take a second folder and fold it wrong side out. Now align and glue this folder so that the tabs match. Now align and glue a third folder (right side out) to the two which are already glued together. Repeat the pattern for as many pages as needed. It may be helpful to have these prepared in advance for younger students while it may be appropriate to involve older students in assembling their own folder book. Alternative ways to create books may include comb binding sheets of cover or cardstock or binding with rings.

- Because the current science textbook for upper grade students is outdated, it is suggested that it be used primarily as a resource and that lessons not be tied to it. This decision has proved to be a blessing in writing this unit because it has "forced" the integration of technology, the use of higher thinking levels, and student choice. It is suggested that the teacher create contracts for appropriate grade spans or individual students. These contracts might require that students choose and complete a specified number of activities in addition to the major project around which the lessons are planned. These activities might be organized in a cross-curricular fashion -- in other words, the students might be required to choose from a list of activities involving astronomy that use language arts skills or connect with social studies, math, or music, for example. A sample contract is provided at the end of the lesson plans.

- Gather as many age-appropriate books and other resources on the topic as possible. See resource list.

- It is highly recommended that each teacher have access to at least one copy of the book Exploring Creation with Astronomy. There is a companion *Experiment and*

Activity Pack which is also very useful. Some of the lessons which follow assume the availability of this book, which can be purchased at www.MediaAngels/com. This book also provides a pass code to a related website.

- Set a date for an end-of-unit culminating event (open house, home and school program, etc.) and communicate this with parents so they may plan ahead. Have students keep this in mind as they complete work throughout the unit.

- Consider integrating service learning with the unit. Suggestions are made for how to do so in the section tabbed "service learning."

Day 1

Objectives

Grades 1-4: To provide a real life experience related to the topic of astronomy which will pique students' interest in and build a foundation for subsequent learning on the topic.
Grades 5-8: To provide a real life experience related to the topic of astronomy which will pique students' interest in and build a foundation for subsequent learning on the topic.

Materials Needed

Depends upon resources available (see Advance Prep).

Advance Prep

Arrange for a field trip to a planetarium or have a knowledgeable guest presenter speak with students. Alternatively, consider involving families in an evening of star gazing. Do an internet search for observatories or amateur groups which meet in your area.

Introduction

Prior to participation in the experience described above, explain to students that the branch of science which studies the heavens is called "astronomy." Explain the difference between astronomy and astrology, emphasizing that as Christians we do not become involved with astrology.

Assessment

Have students journal about the experience or prepare a presentation on what they have learned.

Day 2

Objectives

Grades 1-4: Accept God as the creator of the universe; identify God's role in the creation of the universe; understand God as the Creator and Sustainer of the universe.
Grades 5-8: Distinguish between historical science and experimental science; begin to become familiar with course requirements.

Materials Needed

Grades 1-4: "folder books"; access to the internet and a color printer; paper; scissors; glue sticks; accompanying list of "Title Writing Guidelines"; copies of modified worksheet for emergent writers (with star and moon shapes).

Grades 5-8: copies of rubric, one per student; copies of worksheet, one per pair or small group of students; highlighter, one per pair or small group of students; computer access with PowerPoint software.
Both: a cup full of sand, sheets of paper (black construction paper may make the task easier).

Introduction

Instruct students to take a pinch of sand out of the cup and place it on the paper. Tell them to count the grains of sand and then have each share the number they found. Ask them to predict the number that would be in the cup and then, in a wheelbarrow (see picture on page 380 of *Explore God's World*). Explain that a galaxy is a cluster of millions or perhaps billions of stars that are held together by gravity. Ask for volunteers who can name the galaxy of which we are part (Milky Way). Explain that scientists believe there are more stars in one galaxy than there are grains of sand in a wheelbarrow and there are more galaxies, in our universe than there are people on Earth. Clarify that that means that every person on earth could represent one or more galaxies each with as many stars as there are grains of sand in a wheelbarrow. Ask students to think for a moment of words that come to mind for a God who is bigger than and who created such a large universe. On chart paper labeled "The night sky reminds me that God is….", write students' responses as they call them out.

Procedure

Explain to lower grade students that they will be creating a book which will record many of the things they will be learning about astronomy. Involve students in a brief discussion of possible titles for their folder books as well as a review of the rules related to writing titles. Have them write rough drafts of their proposed titles and have two peers edit

them before they write them neatly on the covers of their folder books. It may be helpful to post the accompanying list of title-writing guidelines. (For emergent writers, see the accompanying alternative. To use this, students will cut apart the words of the title, arrange them in a logical order, and glue them on the cover.) Have lower grade students work in mixed age pairs on computers with internet access to choose and print pictures taken by the Hubble telescope. These will then be glued on the front and back covers of their "folder books."
Consider the following website: http://www.nasa.gov/multimedia/imagegallery/index.html or http://grin.hq.nasa.gov/BROWSE/hubble_1.html.

Meanwhile, explain to upper grade students that they will be creating a PowerPoint presentation which will show what they have learned throughout this unit. (If computer resources are inadequate, students may create a book or other type of presentation.) Provide them with the accompanying rubric which will be used to evaluate the PowerPoint. It may be helpful for them to view some examples of PowerPoint presentations and evaluate what makes them effective. Consider the following site which features many PowerPoint presentations on astronomy:
http://www.worldofteaching.com/astronomypowerpoints.html. In pairs or small groups, have students read through the rubric, making a list of questions they have about the assignment. When they finish with this task, have them discuss the difference between historical science and experimental science and, in pairs or small groups, complete the accompanying worksheet. If time and computer access allow, students may begin working on their first PowerPoint slides for their presentation.

Assessment

Lower grades: Have students self-evaluate by printing extra copies of the "Title Writing Guidelines." Have them put a plus by each item on the list if it is evident in their cover and a minus if it is not.

Homework

Grades 1-4: Explain to their parents about the unit they have begun and the project they will be working on.

Grades 5-8: Begin work on PowerPoint presentation if they have computer and software access at home. If not, they can design the slide so that they can more efficiently accomplish the task at school.


The
Heavens
Tell
the Glory of
GOD

Title Writing Guidelines

1. The title matches what the book is about ☐
2. The title makes people Interested in the book ☐
3. The title is not a complete sentence ☐
4. The first and last words are always capitalized ☐
5. Capitalize other important words ☐
6. Spelling is correct ☐
7. The title is neatly and carefully written on the front cover ☐

Project Rubric

Name ___________________________

Content	Self Evaluation	Teacher Evaluation
1. Explain the difference between historical and experimental science.	0 1 2 3 4 5	0 1 2 3 4 5
2. Define universe.	0 1 2 3 4 5	0 1 2 3 4 5
3. Explain the big bang theory.	0 1 2 3 4 5	0 1 2 3 4 5
4. Identify evidence supporting the big bang theory.	0 1 2 3 4 5	0 1 2 3 4 5
5. Identify evidence contradicting the big bang theory.	0 1 2 3 4 5	0 1 2 3 4 5
6. Identify the contributions of at least two early astronomers.	0 1 2 3 4 5	0 1 2 3 4 5
7. Identify contributions of astronomy, including how it supports the concept of a Creator.	0 1 2 3 4 5	0 1 2 3 4 5
8. Describe the major projects in the U.S. space program, explaining the advantage of current space travel vs. that of earlier spacecraft.	0 1 2 3 4 5	0 1 2 3 4 5
9. Define telescope and explain the difference between refracting and reflecting telescope.	0 1 2 3 4 5	0 1 2 3 4 5
10. Describe the information obtained from a spectroscope.	0 1 2 3 4 5	0 1 2 3 4 5
11. Identify the parts of the electromagnetic spectrum.	0 1 2 3 4 5	0 1 2 3 4 5
12. Explain how astronomers study invisible energy present in space.	0 1 2 3 4 5	0 1 2 3 4 5
13. Describe Kepler's laws of planetary motion.	0 1 2 3 4 5	0 1 2 3 4 5
14. Explain how Newton proved Kepler's laws to be true.	0 1 2 3 4 5	0 1 2 3 4 5
15. Identify parts of Earth's solar system.	0 1 2 3 4 5	0 1 2 3 4 5

16. Describe the position of the planets in the solar system.	0 1 2 3 4 5	0 1 2 3 4 5
17. Describe the structure of the sun and identify its features.	0 1 2 3 4 5	0 1 2 3 4 5
18. Describe the position of the sun, earth and moon during a solar eclipse.	0 1 2 3 4 5	0 1 2 3 4 5
19. Describe solar flares and sunspots, explaining their effects.	0 1 2 3 4 5	0 1 2 3 4 5
20. Describe the topography of the moon.	0 1 2 3 4 5	0 1 2 3 4 5
21. Describe the moon's phases.	0 1 2 3 4 5	0 1 2 3 4 5
22. Explain why a lunar eclipse occurs.	0 1 2 3 4 5	0 1 2 3 4 5
23. Identify characteristics of the inner planets and describe their features.	0 1 2 3 4 5	0 1 2 3 4 5
24. Contrast earth with the other inner planets.	0 1 2 3 4 5	0 1 2 3 4 5
25. Identify characteristics of the outer planets and describe their features.	0 1 2 3 4 5	0 1 2 3 4 5
26. Define the terms <u>asteroids</u>, <u>meteoroids</u> and <u>comets</u>.	0 1 2 3 4 5	0 1 2 3 4 5
27. Distinguish between a meteor and a meteorite.	0 1 2 3 4 5	0 1 2 3 4 5
28. Describe how the sun affects a comet.	0 1 2 3 4 5	0 1 2 3 4 5
29. Define the term <u>light year</u> and explain how distances in space are determined.	0 1 2 3 4 5	0 1 2 3 4 5
30. Distinguish between apparent and absolute magnitude.	0 1 2 3 4 5	0 1 2 3 4 5
31. Define <u>constellation</u> and describe the circumpolar constellations.	0 1 2 3 4 5	0 1 2 3 4 5
32. Choose at least 5 common stars and constellations and describe them.	0 1 2 3 4 5	0 1 2 3 4 5
33. Define the term <u>star</u> and describe the various types.	0 1 2 3 4 5	0 1 2 3 4 5
34. Explain how stars produce energy.	0 1 2 3 4 5	0 1 2 3 4 5
35. Explain how stars are classified.	0 1 2 3 4 5	0 1 2 3 4 5
36. Describe the relationship between a nebula and new stars.	0 1 2 3 4 5	0 1 2 3 4 5
37. Describe the life cycle of stars.	0 1 2 3 4 5	0 1 2 3 4 5
38. Distinguish between a nova and a supernova.	0 1 2 3 4 5	0 1 2 3 4 5
39. Define a <u>black hole</u>.	0 1 2 3 4 5	0 1 2 3 4 5

40. Explain the Doppler effect.	0 1 2 3 4 5	0 1 2 3 4 5
41. Define red shift and explain its importance to astronomers.	0 1 2 3 4 5	0 1 2 3 4 5
42. Define the term galaxy.	0 1 2 3 4 5	0 1 2 3 4 5
43. Compare and contrast the main types of galaxies.	0 1 2 3 4 5	0 1 2 3 4 5
44. Describe the galaxy that includes Earth's solar system, identifying Earth's position in it.	0 1 2 3 4 5	0 1 2 3 4 5
45. Create a list of space science careers.	0 1 2 3 4 5	0 1 2 3 4 5
46. Critique racial and gender biases as they relate to space science careers	0 1 2 3 4 5	0 1 2 3 4 5

Scoring Scale: 0= not at all 1= minimally 2= below expectations 3= meets expectations 4= exceeds expectations 5= outstanding

Historical vs. Experimental Science

Names ______________________________ Date _________________

5-8

1. Based on the root words, explain what you believe each of the following means and give possible examples of each:

a. historical science:

Examples:

b. experimental science:

Examples:

2. Read the following excerpt and list any additional ideas you found:

Historical science refers especially to those aspects of science which are not as easily testable and predictable. They often represent concepts about the past. Physics and chemistry are usually considered less historical; geology, biology and paleontology more so. The difference is due partly to the complexity of what is being studied -- physics and chemistry, for example, being the simplest and most predictable, while biology and paleontology are more complex and uncertain. Historical science mainly centers around the problems of testing past events which can no longer be observed.

Adapted from Roth,A. (1986) *Historical science*. Retrieved July 8, 2008 from http://www.grisda.org/origins/13005.htm

3. On another sheet of paper or using a computer (print and attach if using a computer), create a Venn diagram which illustrates the similarities and differences between historical and experimental science. You may choose to incorporate this graphic organizer into your PowerPoint to fulfill the requirements of **Content** item number one.

Historical vs. Experimental Science

Names KEY Date

1. Based on the root words, explain what you believe each of the following means and give examples of each: *(answers may vary; accept any reasonable answer -- examples of reasonable responses are provided though they may not be completely accurate as students were asked to tell what they thought)*

a. historical science: *Historical science concerns things which have taken place in the past and may or may not have been witnessed by humans presently alive. There may not be recorded information about them either. Historical science is about things that have occurred in the past and the people who have studied them.*

Examples: *how the earth came into existence; the study of dinosaurs; the study of scientists who lived long ago such as Galileo or Isaac Newton.*

b. experimental science: *science which tests theories using evidence which is currently available.*

Examples: *determining the point at which water freezes; studying the effect of caffeine on memory; determining whether hot or cold air is more dense; testing the relative strength of magnets.*

2. Read the following excerpt and highlight any additional ideas you found:

Historical science refers especially to those aspects of science which are not as easily testable and predictable. They often represent concepts about the past. Physics and chemistry are usually considered less historical; geology, biology and paleontology more so. The difference is due partly to the complexity of what is being studied -- physics and chemistry, for example, being the simplest and most predictable, while biology and paleontology are more complex and uncertain. Historical science mainly centers around the problems of testing past events which can no longer be observed.

Adapted from Roth,A. (1986) *Historical science*. Retrieved July 8, 2008 from http://www.grisda.org/origins/13005.htm

(answers will vary)

3. On another sheet of paper or using a computer (print and attach if using a computer), create a Venn diagram which illustrates the similarities and differences between historical and experimental science. You may choose to incorporate this graphic organizer into your PowerPoint to fulfill the requirements of **Content** item number one.

(answers will vary)

Day 3

Objectives

Grades 1-4: Accept God as the creator of the universe; identify God's role in the creation of the universe; understand God as the Creator and Sustainer of the universe.
Grades 5-8: Define "universe"; describe the big bang theory; identify evidence that supports the big-bang theory; identify evidence that contradicts the big bang theory.

Materials Needed

Grades 1-4: "folder books"; Bibles; copies of *I Trust God's Word*, one per student; glue sticks; (if appropriate, copies of modified worksheet *The Bible Tells Me,* for grades 1-2*).*
Grades 5-8: project rubric (same as in day 2); computer access for research and PowerPoint presentation development.

Review/Introduction

Have students observe as you take a small paper bag and 10-20 popsicle sticks. Inflate the bag and explain that you are going to pop it. Tell students that as a result of the "explosion" you expect to see a house built from the popsicle sticks. Pop the bag. Talk with students about why your expectation was unrealistic and explain that many people believe that the earth and all of its contents began with a "big bang." Engage students in a discussion about their beliefs of how the earth came into existence. Ask them how they know. Inquire of older students whether this topic would involve historical or experimental science (*historical*). Lead them to conclude that while none of us was present to observe creation and therefore cannot prove it, the Bible and science work together to help us know that God's Word is true.

Procedure

Have upper grade students share and briefly discuss their completed homework assignments. Explain that today they will be doing research which will help them answer **Content** items number 2-5.

Meanwhile have lower grade students get out their "folder books." Explain that today they will be reading the Bible to find what it says about how the universe was created. Provide them with the accompanying list of texts or, if some are able, have them use a hard copy or on-line concordance. Have them create a page in their "folder books" entitled "I Trust God's Word." The page should include 3-5 texts of their choice which identify God as the Creator and Sustainer of the universe. This can be created by computer and printed, or hand printed. A worksheet, which can be glued into the "folder book," is provided for use with first or second graders as needed. Mixed age groupings may be helpful.

Consult back and forth between the two groups to ensure that accurate information is being gathered and that they understand the assigned task.

Assessment

Grades 1-4: Evaluate students based on the completed task, using the worksheet *I Trust God's Word* for accountability.

Grades 5-8: Frequently provide students with feedback on their developing PowerPoint and set deadlines along the way. At the end of the project, or at specified points along the way, have them self-evaluate using the rubric. The teacher should do the same, adding explanatory comments where appropriate.

Homework

Grades 1-4: Memorize one of the selected Bible verses.

Grades 5-8: Work on PowerPoint; explain to parents evidences for and against the big bang theory.

I Trust God's Word

Name____________________________ Date ________________________

Read 6-10 of the following verses. Check those which you read. Highlight 3-5 verses you will include in your "folder book" and print them neatly on a page titled "I Trust God's Word." As you write the texts for the "folder book," leave room to write a sentence explaining why the verse is special to you.

- Genesis 1:16, 17 ☐
- Deuteronomy 4:19 ☐
- Deuteronomy 10:14 ☐
- 2 Chronicles 6:18 ☐
- Nehemiah 9:6 ☐
- Psalm 8:3 ☐
- Psalm 19:1 ☐
- Psalm 33:6 ☐
- Psalm 115: 16 ☐
- Isaiah 48:13 ☐
- Isaiah 65:17 ☐
- 1 Corinthians 15:41 ☐
- Revelation 21:1, 3 ☐

1-2

The Bible Tells Me

God created the _____, _____ and _____ on the fourth day of creation.

Genesis 1:14-19 ICV

The _________ owns the world and everything in it. Even the highest __________ are His. Deuteronomy 10:14 ICV

Each _________ is different in its beauty. 1 Corinthians 15:41

In the city which God is making for us we will not need a sun because the _______ of ______ is its light.

Revelation 21:23 ICV

(Assist or have a peer assist students to complete the texts, cut them apart on the dotted lines and glue them into the "folder book." The page may also be decorated according to the student's wishes.)

Day 4

Objectives:
Grades 1-4: Understand that God is the source of all natural laws; understand the purpose of God's law and order in the universe.
Grades 5-8: Identify contributions of early astronomers; identify the contributions of astronomy; explain how the study of astronomy supports the concept of a Creator.

Materials Needed
Grades 1-4: "folder books"; writing/illustrating materials; glue sticks.
Grades 5-8: computer access for research and creation of PowerPoint slides.
Both: Copy of quote from Patriarchs and Prophets, p.52, cut apart on dotted lines.

Review/Introduction
Briefly have select students share their work from **Day 3**. Print the accompanying page containing the quote from Patriarchs and Prophets, cut apart and distribute one sentence per student, among those who are capable of reading it. Have students in turn read one sentence at a time, pausing to discuss and explain the meaning of each. Engage students in a discussion about natural laws, brainstorming with them a list and recording it on chart paper. Some possible laws include gravity, seasons, reproduction by seeds, the earth's rotation and revolution around the sun, the orbit of planets, growth of living things, the water cycle, sin's leading to death, etc. Emphasize the fact that God allows humans choice in their response to moral laws while natural laws are not subject to choice. Involve students in a discussion of why God would use natural laws in His creative process (to bring order and predictability to life).

Procedure
Have lower grade students choose, record and illustrate in their "folder books" several of the natural laws which were recorded on chart paper. With remaining time or as a homework assignment, have students write about or draw pictures showing what life would be like without one or more of the natural laws.

Meanwhile, have upper grade students research early astronomers and their contribution to astronomy. Some names for them to consider should include Ptolemy, Aristotle, Copernicus, Galileo, Johannes Kepler, Isaac Newton, and Maria Mitchell. The following websites may be helpful:
http://www.hotliquidmagma.com/space/html/early.html (contains a timeline of astronomers but begins with 15,000 BC and Ice Age people)

http://www.womanastronomer.com/women_astronomers.htm (contains biographies of many female astronomers; may provide opportunity for a discussion about gender biases -- an objective to be covered later in the unit)
http://www.math.buffalo.edu/mad/physics/astronomy-peeps.html (contains information about astronomers with African ancestry, may provide opportunity for a discussion about racial biases -- an objective to be covered later)

Have upper grade students research and create slides to add to their PowerPoint presentation for rubric **Content** items 6 and 7. The book Men of Science, Men of God: Great Scientists Who Believed the Bible by Henry Morris may be helpful.

Assessment

Grades 1-4: Evaluate students based on their completed assignments.

Grades 5-8: Frequently provide students with feedback on their developing PowerPoint and set deadlines along the way. At the end of the project, or at specified points along the way, have them self-evaluate using the rubric. The teacher should do the same, adding explanatory comments where appropriate.

Homework

Grades 1-4: If not done during class, have students write about or draw pictures showing what life would be like without one or more of the natural laws.

Grades 5-8: Begin reading the biography of an early or recent astronomer.

1. The law of God is as sacred as God Himself.

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2. It is a revelation of His will, a transcript of His character, the expression of divine love and wisdom.

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3. The harmony of creation depends upon the perfect conformity of all beings, of everything, animate and inanimate *(living* and *non-living)*, to the law of the Creator.

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4. God has ordained *(established)* laws for the government, not only of living beings but of all the operations of nature.

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5. Everything is under fixed *(permanent)* laws, which cannot be disregarded.

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6. But while everything in nature is governed by natural laws, man alone, of all that inhabits the earth, is amenable *(answerable)* to moral law.

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7. To man, the crowning work of creation, God has given power to understand His requirements, to comprehend the justice and beneficence *(kindness)* of His law, and its sacred claims upon him; and of man unswerving *(complete)* obedience is required. Patriarch and Prophets, p. 52.

Day 5

Objectives
Grades 1-4: Define astronomy; distinguish between early and current space travel; describe benefits resulting from the space program.
Grades 5-8: Describe the major projects in the U.S. space program; explain the advantage of current space travel versus earlier manned spacecraft.

Materials Needed
Grades 1-4: dictionary; read aloud book of teacher's choice about space travel; "folder books; glue sticks.
Grades 5-8: materials for creating a hard copy timeline if this media is chosen; computer access for creation of PowerPoint presentation; optional, copies of *History of Astronomy Timeline* worksheet.
Both: computer access for viewing video clips

Review/Introduction
In heterogeneous cooperative groups have students in lower grade share their writing/pictures illustrating what life would be like without natural laws. Have upper grade students provide feedback on these works and/or tell about the astronomer whose biography they have chosen to read.

Procedure
Have students watch part or all of the video at
http://www.nasa.gov/multimedia/videogallery/Video_Archives_Collection_archive_2.html
or if you have access to Power Media, go to:
http://www.powermediaplus.com/player.asp?mediaID=8710; also consider searching clips on United Streaming (if that is available) on the history of US space travel. Have upper grade students begin to research and create a timeline of the major projects in the U.S. space program. Timeline may be created in PowerPoint or may be a hardcopy supplement to it. (For a more structured approach, see the activity *History or Astronomy Timeline* in the *NAD Essential Science/Health Update Grades 5-8*). At least one PowerPoint slide should also be created to explain the advantage of current space travel over earlier manned spacecraft, meeting the rubric **Content** requirements for item 8.

Meanwhile, have lower grade students look up and record the dictionary definition of "astronomy" in their "folder books." Read aloud an age-appropriate book on the history of space travel (see resource list) and discuss the benefits resulting from the space program. Have lower grade students create a page in their "folder books" entitled

"Benefits of the Space Program" and write and illustrate some examples. If time permits have students work on contract items of their choice.

Assessment

Grades 1-4: Evaluate students based on their completed assignments.

Grades 5-8: Frequently provide students with feedback on their developing PowerPoint and set deadlines along the way. At the end of the project, or at specified points along the way, have them self-evaluate using the rubric. The teacher should do the same, adding explanatory comments where appropriate.

Homework

Grades 1-4: Have students work on contract items

Grades 5-8: Have students continue reading their chosen biographies and/or work on contract items.

History of Astronomy

Time Line

Materials:

art supplies metric ruler computer paper – 6 sheets meter stick

Procedure:

1. Gather the necessary materials
2. Use the meter stick to draw a line down the center of the computer paper strip.
3. Mark a 5 cm vertical line every 6 cm along the time line. Label the first vertical line on the left "700 B.C." Label the next vertical line "600 B.C." Continue labeling the vertical lines until you reach the year 2000 A.D. Remember that once you reach "0 B.C.", the next century should be marked "100 A.D." The next vertical line to the right of "100 A.D." should be marked "200 A.D." Write the names of the astronomers listed on the Astronomer List where they belong on the Time Line. Include a brief summary of the contributions of each person on the list.
4. Add artwork to your time line to make it look interesting and attractive.

Minimum Requirements:

1. All people listed on the Astronomer List must be included on the Time Line.
2. The contribution of each astronomer must be written neatly on the Time Line along with the person's name.
3. All labeling must be typed or written in black ball-point pen.
4. Time line must be neat and attractive.
5. Time line must have a title.

Astronomer List:

Anaxaminder	Yuri Gargarin	Maria Mitchell
Aristarchus	Robert Goddard	Philip Morrison
Aristotle	Edmund Halley	Plato
Johann Bode	Heraclitus	Giuseppe Piazzi
Tycho Brahe	Hipparchus	Pope Gregory
Nicholas Copernicus	Sir William Herschel	Ptolemy
Julius Caesar	Edwin Hubble	Pythagoras
Albert Einstein	Johannes Kepler	Thales
Eratosthenes	Hans Lippershey	Werner von Braun
Galileo	Isaac Newton	Xenophanes

Day 6

Objectives
Grades 1-4: Understand why jet propulsion is used in space vehicles; describe the first human contact with the moon; explain the importance of rockets to space travel; explain the value of the space shuttle and subsequent space vehicles under consideration.
Grades 5-8: Define the term "telescope"; explain the difference between a refracting and a reflecting telescope; describe the information obtained from a spectroscope.

Materials Needed
Grades 1-4: copies of futuristic space vehicles, in color if possible (students may share sets as each will be choosing just one to cut and paste into "folder book"); glue stick.
Grades 5-8: Computer access for research and preparation of PowerPoint slides.
Both: Alka-Selter® tablets, Fuji® brand film canister (white with push-in lids).

Review/Introduction
Using a cooperative structure, review previously taught terms and concepts and/or have students share recent work. Conduct the accompanying Alka-Seltzer® Rocket demonstration as students observe, being careful to use safety precautions. (Ideally, demonstration should be conducted outside or in a gymnasium; students should stand back away from the "rocket.") Explain that rockets work similarly. They are propelled forward or upward by the backward release of an "explosion." In a rocket large quantities of hot gases are ejected out the rear of the rocket, thrusting it upward.

Procedure
Have upper grade students research telescopes and spectroscopes and prepare corresponding slides for their presentation to meet rubric **Content** requirements 9 and 10. Though several years old, the information at the following site may be quite helpful: http://spaceplace.nasa.gov/en/educators/sirtf.pdf.

Meanwhile have lower grade students view moonwalk video clips from Apollo 17 (found at http://history.nasa.gov/40thann/videos.htm) and discuss their observations. Alternatively, read a book about the first moon walk. Have students discuss the differences they see between early rockets and the space shuttle. Ask students what features they think would be important in future space vehicles, making a list of their thoughts. Pass out copies of the accompanying possible future designs and have students each choose one which he/she thinks will be ideal. Have them cut their choices out and glue them into their "folder books," writing why they think they would be good designs.

Alternatively, offer the choice for students to design and name spacecrafts of their own creation.

Assessment

Grades 1-4: Evaluate students based on their completed assignments. Incorporate language arts objectives in what students write about their chosen future space vehicles. Consider having students write and edit rough drafts before entering their work into "folder books."

Grades 5-8: Frequently provide students with feedback on their developing PowerPoint and set deadlines along the way. At the end of the project, or at specified points along the way, have them self-evaluate using the rubric. The teacher should do the same, adding explanatory comments where appropriate.

Homework

Grades 1-4: Explain to parents about jet propulsion as demonstrated with the "Alka-Seltzer rocket." Work on contract items.

Grades 5-8: Continue reading biography and/or work on contract items and/or PowerPoint presentation.

ALKA-SELTZER® ROCKETS

Matthew O'Brien

Description:
A very simple carbon-dioxide producing reaction can be used to create spectacular rockets using Alka-Seltzer® tablets, water and film canisters. This demonstration is very quick to set up, has nice projectile motion, noise and even a bit of mess – what more can a student want?!

Time: 15 min

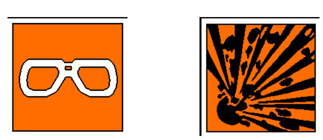
Short and sweet: A film canister is turned into a rocket using CO_2 as propulsion.
Keywords: rocket, film canister, Alka-Seltzer®, carbon dioxide, CO_2, effervescent, projectile, carbonate, propulsion, gas , pressure, Aspro® Clear
Subject areas: chemistry, physics, biology

MATERIALS AND METHOD

Materials:
- Alka-Seltzer®, or similar effervescent tablet such as Aspro® Clear.
- 35mm Film canisters – the white type with the "plug in" rather than "push over" lids work the best – Fujifilm® are one brand of this type of canister.

Method:
1. Place an Alka-Seltzer® tablet into the well inside the lid of the film canister – it should jam in nicely.
2. Place 5 ml. of water in the film canister.
3. In a quick motion, place the lid on the film canister and invert it, placing the lid on the bench.
4. Step back and wait for the "rocket" to go off!

SAFETY/DISPOSAL



1. The rocket does not explode, but gets projected up into the air. There is a very small chance that the canister could explode if the lid does not release, but this is very unlikely given the pressures involved.
2. The film canister gets projected very quickly, and can easily damage/break fluorescent light bulbs and/or their covers. Care should be taken to ensure that the projectile film canister cannot impact person or property to cause damage. This activity is a good one to conduct outside.

EDUCATIONAL CONCEPTS & REACTIONS/ANALYSIS

- Carbon dioxide production of an effervescent tablet
- Gas release as a source of propulsion
- Carbonate reactions
- Projectile motion, aerodynamics

www.sciencedemonstrations.com

INVESTIGATIONS/VARIATIONS

- How does changing the volume of water effect the time the rocket takes to take off and the height it travels?
- How does changing the amount of tablet effect the time the rocket takes to take off and the height it travels?
- What is the optimum volume of water and amount of tablet for the fastest/highest rocket launch?
- How can the rocket be designed to travel higher? Nose cone size and shapes.
- How can the rocket be designed to travel straighter? Fin size, shape and placement.

Potential Spacecraft

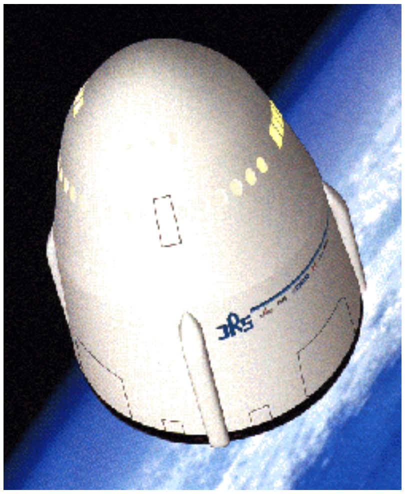
For many many people space tourism and even colonization are attractive ideas. But in order for these to start, we need vehicles that will take us to orbit and bring us back. Current space vehicles clearly cannot. Only the Space Shuttle survives past one use, and that's only if you ignore the various parts that fall off (intentionally!) on the way up. You could be forgiven for thinking that space is therefore an impossibly expensive place to get to. But this need not be the case. Launch to orbit requires accelerating to Mach 26, and so it uses a lot of propellant -- about 10 tons per passenger. But there's no *technical* reason why reusable launch vehicles couldn't come to be operated routinely, just like aircraft. The only reason why this hasn't been done yet is that launch vehicle development has been left to government space agencies. And they have had neither the priority nor the will to achieve it -- they don't use even 2% of their budgets (of $25 billion per year) to study the design of launch vehicles suitable for passenger service!

So it may well turn out to be private enterprise that is the solution -- plenty of ideas for reusable launch vehicles exist, and with incentives like the X-Prize, there's going to be fierce competition to see who can be first.

Space Vehicles presents some of the ideas that could change the meaning of "Space" from being a remote place where government staff carry out "missions" to being a weekend destination, just a few minutes' flight away.

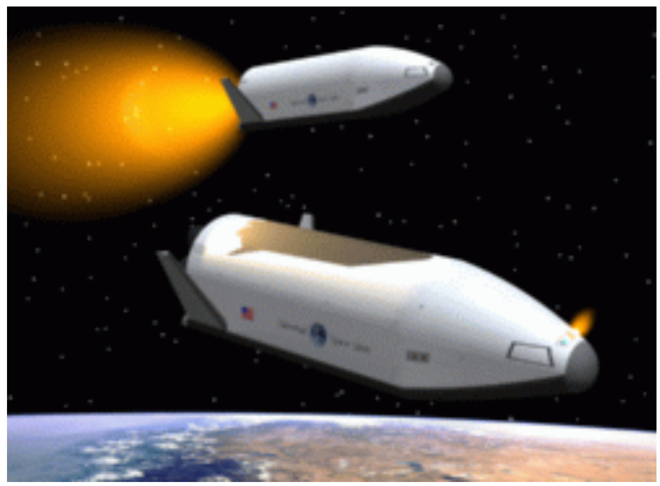
SPACESHIPONE

White Knight



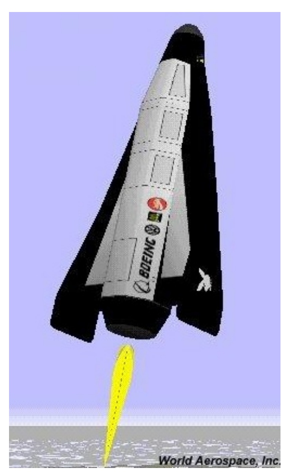
Kankoh-maru

Spacebus



Spaceclipper

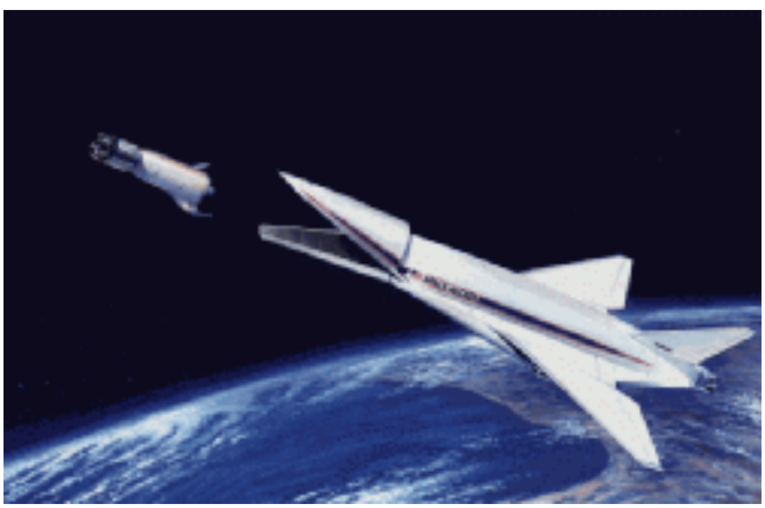
Black Armadillo



Alpha

Nova

Kistler K-Series



Space Access

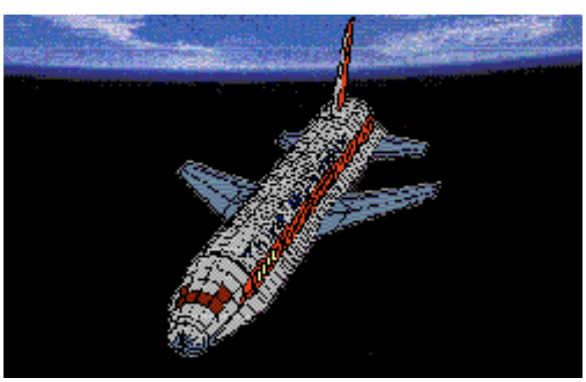
Canadian Arrow

Davinci

Cosmopolis

Space Cruiser System

Cosmos Mariner



Space Van

Space Future. Retrieved July 10, 2008 from http://www.spacethemes.com/vehicles/designs.shtml.

Day 7

Objectives
Grades 1-4: Explain the problem of escaping gravity.
Grades 5-8: Identify parts of the electromagnetic spectrum; explain how astronomers study invisible energy present in space.

Materials Needed
Grades 1-4: "folder books"; possibly chart paper for recording language experience story with first/second grade students;
Grades 5-8: computer access for research and creation of PowerPoint presentation.
Both: rope or jump rope

Review/Introduction
Use a cooperative structure to review previously taught terms and concepts. Have older students explain the concept of gravity to younger students. Remind students of what happened when the Alka-Seltzer Rocket demonstration was conducted. Elicit that the rocket came back down because it was unable to escape the pull of gravity. Explain that the more fuel we have the greater the "explosion" and the further the rocket can travel but the more fuel we use the bigger and heavier the rocket has to be, making it harder to get it off the ground; so, rather than fighting gravity, space engineers use gravity to help them. Take students to a large area outside or in a gymnasium and conduct the accompanying demonstration, Borrowing Energy from a Planet, discussing the concepts being demonstrated. (Teachers may need to carefully read the demonstration directions and explanations in advance of doing it with students).

Procedure
Return to classroom and have upper grade students view the following website, including the "Tell me 'me-owrre'" section at the bottom. They should follow the links at the end of each page. (*Land of the Magic Windows* and *Gateway to the Land of the Magic Windows*– does not contain magic in the sense of the occult; Infrared Matching Game.) *Explore God's World*, pages 396-398, may also be helpful. Have students prepare PowerPoint slides which fulfill the rubric **Content** requirements for items 11 and 12.

Meanwhile facilitate students in writing a summary of their experience of escaping gravity. Students in grades 3 and 4 may be able to do this independently while first and second graders may need assistance to write this jointly on chart paper. Include diagrams with the summaries as appropriate and have students transfer the information to their "folder books" as appropriate.

Assessment

Grades 1-4: Evaluate students' work based on their completed assignments.
Grades 5-8: Frequently provide students with feedback on their developing PowerPoint, and set deadlines along the way. At the end of the project, or at specified points along the way, have them self-evaluate using the rubric. The teacher should do the same, adding explanatory comments where appropriate.

Homework

Grades 1-4: Explain to parents what they experienced and learned today, and/or do contract work.
Grades 5-8: Continue reading biography and/or work on contract items and/or PowerPoint presentation.

Initially published in *The Technology Teacher,* November 1998, by the International Technology Education Association

Borrowing Energy from a Planet

Exploring space requires first of all that we get our spacecraft off the ground, at least into Earth orbit. Then, if we want to explore any other bodies in our solar system, we have to get our spacecraft out of Earth orbit and somehow propel it to its intended target. Unless we have unlimited fuel and unlimited time, we must take into consideration the gravitational forces exerted by the sun, the planets, and any other large bodies we may approach. And, of course, even if we could build a spacecraft big enough to hold all the fuel necessary to ignore gravity, it would probably be too heavy to get off the ground!

So rather than fight gravity, space mission planners use gravity to serve their own purposes. Trajectories to distant targets are planned to take advantage of the gravitational pull of other bodies along the way. For example, the Voyager 2 spacecraft, in exploring the outer planets, used the tremendous gravitational force of massive Jupiter to slingshot itself to Saturn, then used Saturn for an additional kick out to Uranus, and so on. NASA's first New Millennium Program mission, Deep Space 1, is the first spacecraft to use solar electric (ion) energy as its primary means of propulsion. The ion engine exerts no more force than a single
sheet of paper resting on your hand. But, over time, and with a trajectory planned to take advantage of the gravitational pull of the sun and Earth's orbital motion, Deep Space 1 will be able to accelerate to speeds faster than spacecraft that use conventional chemical propulsion, and will do so on a lot less fuel.

In this activity, students use their own bodies to create a model of the solar system and the forces the sun and planets exert on each other and on passing objects such as spacecraft. The verbal description by the teacher of what is being represented, along with the non-verbal kinesthetic and visual experience, can leave students with a life-long instinctive feel for one of the most basic of physical concepts.

In the first part of the activity, the students model giving a spacecraft a planetary gravity assist. In the second part, the students first get a feel for the idea of "projecting" gravitational force using mime. They then create a model of motions and interacting forces among the Sun, the Earth, the Deep Space 1 spacecraft, and its target asteroid.

Activity:

We can speed up a spacecraft by slowing down a planet! Because of the difference in mass between the two objects, the planet will scarcely miss the minute amount of energy lost, but to the spacecraft, the extra boost can mean the difference between reaching its destination in a reasonable time or getting there long after everyone who launched it is dead!

Three-person Model:

1. Two partners, representing a two-body gravitational system, face each other, reaching with outstretched arms to grab hands. They lean back to create tension, and one partner (the smaller) "orbits" the other, at a fairly rapid—yet controllable—pace.

2. A third partner, the "spacecraft," approaches the orbiting "planet." The spacecraft "borrows" energy by grabbing onto the planet's shoulder, thereby acquiring the energy needed to create acceleration.

3. As the spacecraft makes “gravitational” contact, the two-person system should feel a real energy transfer as momentary drag. The spacecraft should feel a boost of acceleration that causes it to speed up and change direction.

Four-or-more-person Model Using a Rope:

Photo: Courtesy of Robert M. Brown

1. Instead of grabbing hands, students use a rope to represent the gravitational force. Two or three partners holding on to one end of the rope represent the larger object (the Sun), and one partner holding on to the other end represents the smaller object (the planet). Keeping the rope taut, the planet “orbits” the sun at a fairly rapid—but controllable—pace.

2. The fourth (or fifth) partner becomes the spacecraft. As the spacecraft approaches the planet, matching speeds, the spacecraft grabs on to the planet (grabbing hands or locking arms). Some of the energy of the two-body gravitational system is transferred to the spacecraft, accelerating it. At the same time, the two-body system slows down just slightly.

3. When the spacecraft lets go, “it” can feel the acceleration and it flies off in a new direction, moving faster. This acceleration is the energy transfer of the gravity assist.

Creating a Force Field

In this part of the activity, students model gravitational forces reaching out into space, experiencing kinesthetically the abstract and difficult physical concept of a *field*.

Photo: Courtesy of Jennifer Schaupeter

1. Each student finds a partner. The partners stand facing each other, arms outstretched and palms together. Pushing gently, first one, then the other exerts the force, giving and taking, back and forth. They gradually push harder, adding energy to the force. (picture 2)
2. The partners back away from each other a bit, leaving a few inches between their hands as they continue to push and be pushed, give and take. Now, instead of using direct force, the partners are modeling a force *field*, like a gravitational field. If they concentrate and put their whole bodies into the movement, it will feel more realistic to them. (Picture 3)
3. The students experiment with modeling the force field from a greater distance, tuning into each other and paying attention to details of the other's movements to create the effect.
4. Now, instead of an invisible force of pushing, ask the students to think of an invisible force of *pulling* toward oneself, as if exerting energy of an active *attraction*, in waves of accelerating force.The partner with extended arms draws back, as if to pull the arms of the distant partner. Emphasize the movement of drawing in the arms and hands, then relaxing briefly to extend again, to draw in with another "wave" of gravity. (picture 4)

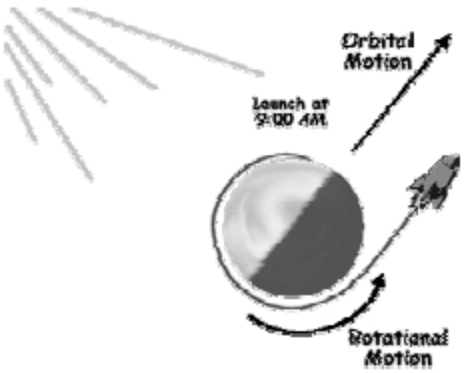
Ion Driving to "Higher" Orbit

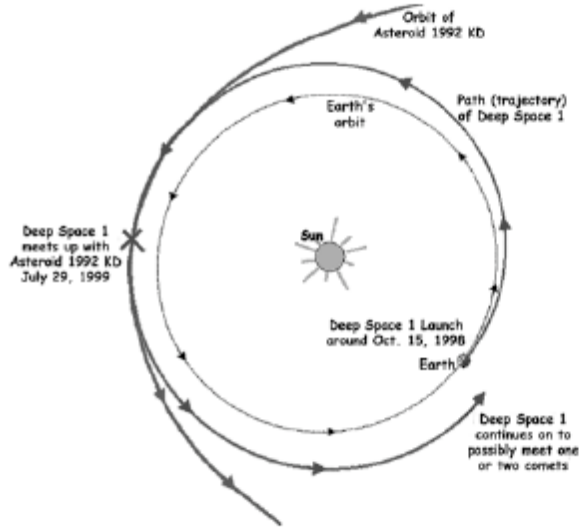
Spacecraft trajectories usually take advantage of Earth's orbital motion around the sun and leave Earth orbit heading in the same direction around the sun as Earth is already traveling (counterclockwise, looking "down" on the solar system). The final rocket boost pushes it out ahead of Earth and may give it enough of a kick to change its orbit around the sun slightly from that of Earth's. No longer traveling with Earth, the spacecraft coasts on its own orbital path defined by the initial thrust relative to the gravity of the Sun. With most spacecraft, no additional thrust is applied, except for minor altitude control or course correction maneuvers. This technique is called a Hohmann Transfer, essentially transferring the spacecraft from Earth's orbit around the sun to an orbital path that includes both Earth and the target body. If the spacecraft's target—an asteroid in the case of Deep Space 1— is orbiting farther from the Sun than the Hohmann

Initially published in *The Technology Teacher,* November 1998, by the International Technology Education Association

Transfer can accomplish, additional propulsive maneuvers are required to overcome the Sun's gravitational pull and boost the spacecraft into a more distant orbit so that it can eventually meet up with its target. Deep Space 1 at this point must activate its ion drive engine, aiming its gentle thrust against the force of the Sun's gravity to transfer to a new orbital path.

This part of the activity models Deep Space 1's launch, final rocket boost out of Earth orbit, activation of its ion engine, orbital transfer maneuver, and asteroid rendezvous, as influenced by the gravitational fields of Earth and the Sun.





1. Seven or eight students represent the Sun by standing in a central circle, facing outward, with hands mime-projecting an invisible gravitational force field. Students work together to create a series of wave motions that represent the attractive force of gravity.

2. Three or four students form a circle, facing outward, to represent planet Earth, standing at some distance from the Sun, with hands mime-projecting an invisible gravitational field around the planet. As the Earth group moves around the Sun group, they all mime-project the balanced tension between the gravitational attraction between the two bodies and the force of centripetal acceleration that keeps Earth in its orbit and prevents it from spiraling in toward the Sun.

3. One student represents the asteroid that Deep Space 1 will encounter. The "asteroid" moves through an eccentric elliptical orbit coming in just beyond Earth's orbit. You may want to ask several students, one at a time, to play asteroids or comets, using the mime force-field-at-a-distance technique to orbit around the Sun, transferring the "gravitational" kinesthetic connection to the Sun along the way.

4. One student represents Deep Space 1, and demonstrates the effect of the powerful thrust needed to escape Earth's gravity at launch to reach an orbit around Earth. 5. When the Deep Space 1 student is positioned just right (moving in the same direction the Earth group is orbiting the Sun group), he or she, in slow motion, demonstrates the thrust of the final rocket stage that sends the spacecraft into its own orbit around the Sun.

5. With the Sun group, the Earth group, and the Deep Space 1 individual all working together, Deep Space 1 demonstrates this temporary cruise in its own orbit around the Sun, then, as the ion engine starts up, slight acceleration that pushes it into a new orbit a bit farther from the Sun.

6. As Deep Space 1 approaches the point in its orbit opposite the launch point, the asteroid approaches in its orbit to meet up with Deep Space 1. The "encounter" occurs (with Deep Space 1 "taking pictures" and making other measurements of the asteroid) and then the asteroid and the spacecraft continue on their separate orbits.

In actuality, the asteroid's orbit is considerably inclined to the ecliptic—the plane in which most of the planets orbit the Sun—so a third dimension (or fourth, if we count time) is involved to further complicate the navigational problem.

Day 8

Objectives

Grades 1-4: Define satellite; identify the first earth-orbiting satellite; describe uses of satellites; describe benefits resulting from the space program

Grades 5-8: Describe Kepler's laws of planetary motion; explain how Newton proved Kepler's laws to be true.

Materials Needed

Grades 1-4: computer access to show You Tube video of Sputnik 1; printed student pages from Put Your Own Spin on Technology which accompanies this lesson. Consider printing the GOES/POES poster found at http://spaceplace.nasa.gov/en/educators/posters/ for students to view.

Grades 5-8: printed copies of Chasing Down a Satellite, one for every two or three students; computer access for research and creating PowerPoint presentations.

Both: String (about 3' long), nylon netting (approximately 1 sq. ft.), small rubber ball (2" – 3" diameter)

Review/Introduction

Using a cooperative structure, review previously taught terms and concepts. Ask students what a satellite is (an object in space that travels in circles around another object). Use the accompanying demonstration, *Satellites and Orbits: An Introduction*, to explain how satellites are kept in orbit.

Procedure

Distribute to upper grade students copies of Chasing Down a Satellite which accompanies this lesson. Tell them not to get bogged down in the math equations but to take advantage of the opportunity to show that math skills are critical to those working in space programs. Have them partner read it to learn who Johannes Kepler was, and describe his laws of planetary motion and how they relate to Isaac Newton and his discoveries. This information should be incorporated into their PowerPoint presentation to fulfill the requirements of rubric **Content,** items 13 and 14.

Meanwhile, show a You Tube clip of Sputnik 1 (type "Sputnik 1 video" in Google or other search engine) to lower grade students and provide them with the following information:

History changed on October 4, 1957, when the Soviet Union successfully launched Sputnik I. The world's first artificial satellite was about the size of a beach ball (58 cm. or 22.8 inches in diameter), weighed only 83.6 kg. or 183.9 pounds, and took about 98 minutes to orbit the Earth on its elliptical path… While the Sputnik launch was a single event, it marked the start of the space age and the U.S.-U.S.S.R space race.

NASA. *Sputnik and the Dawn of the Space Age.* Retrieved July 14, 2008 from http://history.nasa.gov/sputnik/

Ask students if they know of some ways that satellites are used in everyday life (television, cell phones, GPS systems, to gather data on weather). Ask if students know of other benefits from space exploration. Show them the student pages from Put Your Own Spin on Technology and/or Inventions from Space and discuss. Have students draw and label some of the items in a new page of their "folder books."

Assessment

Grades 1-4: Evaluate students based on their completed assignments.

Grades 5-8: Frequently provide students with feedback on their developing PowerPoint and set deadlines along the way. At the end of the project, or at specified points along the way, have them self-evaluate using the rubric. The teacher should do the same, adding explanatory comments where appropriate.

Homework

Grades 1-4: Have students do a search through their homes for items which were inspired by the space program. Have them write or draw a list of these items and bring in examples where practical. If they have internet access at home they may want to play the related concentration game found at http://spaceplace.nasa.gov/en/kids/spinoffs.shtml.

Grades 5-8: Continue reading biography and/or work on contract items and/or PowerPoint presentation.

Originally published in **The Technology Teacher***, Dec. 2002/Jan. 2003, by the International Technology Education Association*

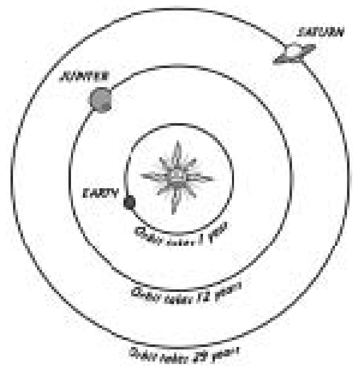
Chasing Down a Satellite

Have you ever spotted a satellite crossing the night sky over your town or city? Although it may have been a mere point of light like a star or planet, you could not mistake a visible satellite for a star, a planet, or even a high altitude plane. The reason? Even a plane does not move across the sky as fast as a satellite.

The International Space Station (ISS) is the easiest satellite to spot because it is by far the biggest, and its orbit is low compared to many satellites. Take a look on NASA's list of ISS viewing opportunities at **www.hq.nasa.gov/osf/station/viewing/issvis.html** to see whether the Space Station might be visible from your location. If so, make plans to look for it. Just how fast does the Space Station travel? And how does it (or any other satellite) stay in orbit? Why doesn't Earth's gravity just bring them crashing down? Why and how do they travel so fast? And how do spacecraft engineers here on Earth control them?

Weightless? No Way!

Satellites take advantage of some basic laws of physics that two scientists figured out around 400 years ago. *Johannes Kepler*, a German astronomer and mathematician, discovered that the time it takes for one body to orbit another (like a planet to orbit the Sun) is directly related to the distance between the bodies. For example, he discovered that it takes Jupiter (the 5th planet from the Sun) 12 years for one orbit, while Saturn (the 6th planet) takes about 29 years for one orbit. *Isaac Newton*, English scientist and mathematician, came along a few years later and discovered the direct relationship between mass and a force he called gravity, which acts to keep the planets in orbit about the Sun rather than shooting off into space in a straight line.



Jupiter's orbit, which is much larger than Earth's, takes about 12 years to complete, while Saturn's takes about 29 years. (Orbit and planet sizes are not to scale in this diagram.)

Newton had a clever way to explain how one body could orbit another. Imagine a cannon mounted on top of a ridiculously tall mountain. The cannon is fired, and the cannonball follows an arc (or trajectory), landing some distance away. If more gunpowder is used in the cannon, the cannonball will go even farther before crashing to the ground. Use enough gunpowder, and the cannonball will actually follow the curvature of Earth all the way around to where it started—and keep right on going! In other words, the cannonball will be in orbit.

An object in orbit around Earth is actually falling all the way around Earth. To put satellites into orbit, of course we don't use cannons on mountain tops! Instead, we use rockets to lift the satellite high enough and "throw" it hard enough that it will fall all the way around Earth. As Kepler noticed with

the planets orbiting the Sun, the lower the satellite's orbit, the faster it will fall. The higher its orbit, the slower it will fall. Newton's discoveries help explain why. The force of gravity between objects is directly proportional to their masses and inversely proportional to the square of the distance between them. So, the force of gravity (F) between two masses (M_1 and M_2) is proportional to M1 times M_2, with the result divided by the square of the distance (d) between them.

$$F \sim \frac{M_1 M_2}{d^2}$$

One thing missing in this formula is how to get force out of mass. Mass is the amount of matter in an object, which doesn't change whether it is on Earth's surface or in space or on the Moon. The force gravity exerts on it does change, however. The *Universal Gravitational Constant*, or just G, is the actual measured, very weak gravitational force exerted between two 1-kilogram objects 1 meter apart. It is a mere .0000000000667 Newton. (A Newton is the force it takes to accelerate 1 kilogram by 1 meter per second. A Newton can also be expressed by the unit kg·m/s2). To avoid writing all these zeros, and trying to keep track of them in calculations, scientists use a mathematical shorthand called scientific notation. In scientific notation, G would be written

G = 6.67 x 10-11 m3/kg·s2

The unit of G (**m3/kg·s2)** might not seem to make much sense, but rather than explain it now, we hope you will accept it on faith!

Let's Figure It Out

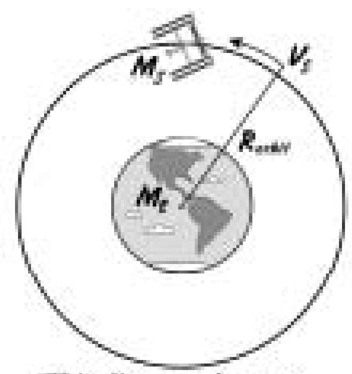
If you spot the Space Station, you will see it really moves! Just how fast is it going?

Based on Kepler's and Newton's discoveries, you can figure out the speed of a satellite in a circular orbit. (The orbit of the Space Station isn't exactly circular, but it's close enough that we will ignore its slight elongation.)

You need to know the mass of Earth (which was easy to figure out once the value of G was measured accurately), the mass of the satellite, and its altitude above Earth's surface. Their relationships can be expressed mathematically like this:

$$\frac{m_s v_s^2}{R_{orbit}} = \frac{G M_E m_s}{R_{orbit}^2}$$

This equation says that the mass of the satellite (**ms**) times the square of the velocity of the satellite (**v_s ^{2}**) divided by the radius of the satellite's orbit (**R_{orbit}**) (measured from the center of Earth) is equal to **G** times the mass of Earth (**M_E**) times the mass of the satellite (**m_s**) divided by the square of radius of the satellite's orbit. Then, if we solve for the velocity, we get



(This diagram does not represent the true orbital plane of the Space Station.)

$$v_s = \sqrt{\frac{G M_E}{R_{orbit}}}$$

This equation says that to find the velocity of a satellite, multiply **G** times the mass of Earth, then divide the product by the radius of the satellite's orbit. (The radius of its orbit is the radius of Earth plus the altitude of the satellite above Earth's surface.) Then take the square root of the result. But notice that the mass of the satellite has disappeared from the equation! Just as *Galileo* is said to have noticed when he leaned out of the Tower of Pisa and dropped a heavy object and a light object, mass has no bearing on the speed with which objects fall.

From the equation for $\mathbf{v}_s$, calculate the velocity of the Space Station. Here are the (approximate) numbers you will need for all the calculations:

G = 6.67 x 10-11 m3/kg·s2
ME = 6 x 1024 kilograms
Radius of Earth = 6,371 kilometers
Average altitude
of ISS orbit = 385 kilometers (as of 10/8/02)

Remember, to get the radius of the ISS's orbit, you have to add the radius of Earth to the altitude of the ISS above Earth.

So, how fast is the Space Station moving? How long would it take to cross the United States from one coast to the other at this speed? (Answer is on the last page of this article.)

Bonus Problem!

Would it be possible to put a satellite into an orbit so that it would seem to hover over one spot on Earth all the time? Absolutely. This type of orbit is called a *geosynchronous* or *geostationary* orbit. The satellite must orbit in (or very near) the same plane as Earth's equator, and must be at an altitude that will let it make just one orbit per day. Thus, it will be as if it is on a long string running down to Earth's surface and being swung around as Earth rotates on its axis. What would be the altitude of this satellite's orbit? Here's how to figure it out.

Let's call the radius of the satellite's geosynchronous orbit R_{geo}. We know that whatever its orbit, it will have to make it all the way around in 24 hours (86,400 seconds). The circumference (distance around) the orbit is $2\pi R_{geo}$. So the velocity of the satellite will be

$$v = \frac{2\pi R_{geo}}{86{,}400 \text{ sec}}$$

Solving for R_{geo}, we have

$$\frac{2\pi R_{geo}}{86{,}400 \text{ sec}} = \sqrt{\frac{GM_E}{R_{geo}}}$$

$$\frac{4\pi^2 R_{geo}^{\ 2}}{(86{,}400 \text{ sec})^2} = \frac{GM_E}{R_{geo}}$$

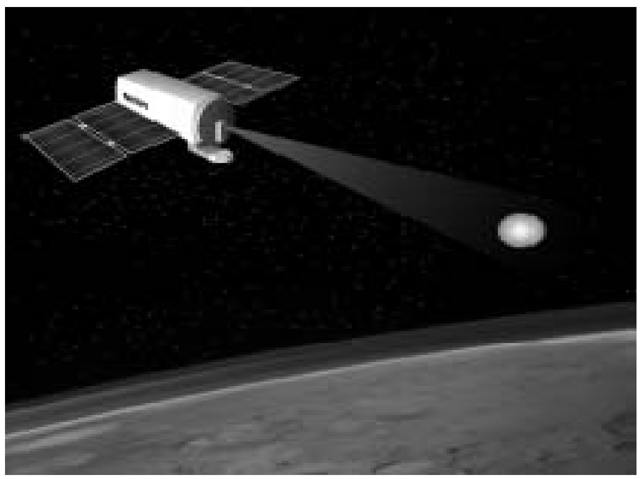
$$R_{geo} = \sqrt[3]{\frac{GM_E(86{,}400 \text{ sec})^2}{4\pi^2}}$$

So, using the values given before for G and ME and using 3.1416 for π, what will the altitude be of a satellite in geosynchronous orbit? (Answer is on the last page of this article.)

Just Imagine this Problem!

Even in very high altitude orbits, satellites are moving very fast. Every time the Space Shuttle makes a trip to the Space Station to deliver cargo or ferry astronauts, the Space Shuttle has to catch up, rendezvous, and dock with the Space Station. Astronauts train for months to learn how to do this.

Now, imagine this problem: One spacecraft needs to catch up and rendezvous with another spacecraft, and neither one of them has a human aboard. What's more, the mission controllers on Earth are so far away it takes a command signal several minutes to travel from Earth to the spacecraft. This is exactly the problem to be solved when NASA does its first Mars Sample Return mission. The Mars soil and rock samples will have been placed in a small canister and blasted into orbit around Mars by a robotic Mars lander. Another spacecraft that has been orbiting Mars needs to find the orbiting sample canister, rendezvous with it, and bring it home to Earth.



NASA's New Millennium Program Space Technology 6 mission will test advanced autonomous rendezvous technology.

What is needed is an *autonomous rendezvous* technology. NASA's New Millennium Program has the job of identifying new technologies that will be needed for future NASA missions and then testing them in space to make sure they will work. Part of New Millennium's Space Technology 6 mission is to test an Autonomous Rendezvous system in Earth orbit. The rendezvous system will fly in 2004 as part of the payload onboard an Air Force satellite.

The rendezvous system includes a laser radar sensor (called *LIDAR*) that will act as the eyes to find and detect the distance to a target spacecraft (which will be one that is no longer operating). The LIDAR will feed direction and distance information to the computer and software part of the rendezvous system. The software will then calculate the steps necessary to reach the target and give instructions to the thrusters on the spacecraft to change its attitude (orientation in space) and velocity so that the spacecraft will move toward the target. The LIDAR will continue to give feedback to the computer, and the software will continuously check and update its calculations and instructions to the spacecraft to close in on the target.

If you think calculating the velocity of a satellite is difficult, imagine the calculations needed to figure out how to change your velocity and orientation to rendezvous with another spacecraft (also moving at tens of thousands of kilometers per hour) in a different orbit. Of course, your calculations have to keep in mind that a change in your velocity is going to bring a change in your own altitude, and it might not be in the right direction!

In the next Space Place column, we'll explore further how software engineers tackle hard problems like that of ST6's Autonomous Rendezvous software.

Learn more about ST6 at nmp.jpl.nasa.gov/st6. For another fun activity and more about another new Space Technology 6 technology, see The Space Place Web site at spaceplace.nasa.gov/ st6starfinder/st6starfinder.htm.

This article was written by ***Diane Fisher****, writer and designer of The Space Place Web site at* ***spaceplace.nasa.gov****. Thanks to* ***Jack Stocky****, New Millennium Program Chief Technologist, for technical help.* ***Alex Novati*** *drew the illustrations. The article was provided through the courtesy of the Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, under a contract with the National Aeronautics and Space Administration.*

Answers:

At an altitude of 385 kilometers, the ISS travels at about 27,707 kilometers per hour. Since it goes all the way around Earth once every 92 minutes, no wonder it doesn't seem to stick around very long overhead.

The geosynchronous orbit is about 35,800 kilometers above the equator. Your answer may vary a bit, depending on how you rounded your numbers during the calculating.

Satellites and Orbits: An Introduction

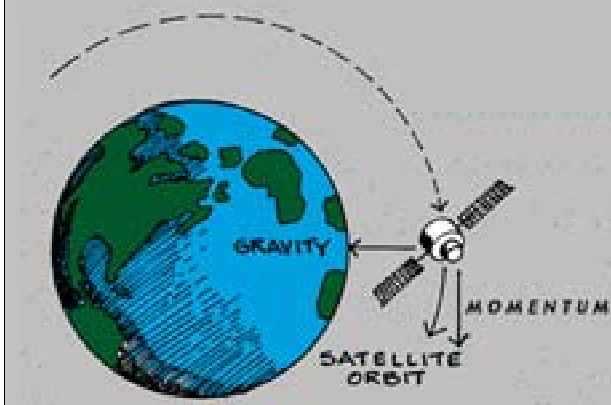
NOAA. *Discover how a satellite stays in orbit.* Retrieved on July 15, 2008 from www.eic.ipo.noaa.gov/IPOarchive/ED/k-12/IPO/unit01/classroom_demonstration.doc

1. Materials that you will need:
   - String (about 3' long), nylon netting (approximately 1 sq. ft.), small rubber ball (2" – 3" diameter)

2. Cut a piece of nylon netting and place it around the rubber ball to form a "bag" to hold the ball.

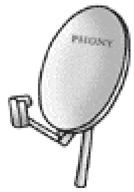
3. Tie one end of a 3-foot length of string securely around the nylon mesh to close off the bag holding the ball.

4. Hold the other end of the string in your hand and begin to whirl the ball in a circle around your head.
   - When you whirl the ball in a circle around your head, the ball is held in its "orbit" by the string. You must constantly pull on the string to keep the ball from flying off in a straight line. The force you apply to the ball through the string is the **Centripetal Force**.
   - Similarly, for a satellite that is in orbit around the Earth, it is the Earth's **Gravity** that exerts a **Centripetal Force** on the satellite that prevents it from flying off into space. The Earth's **Gravity** pulls on the satellite like you pull on the string to keep the ball whirling around your head.
   - The forward motion of the ball is its momentum. The swinging of the ball gives the ball its forward motion. If you were not pulling constantly on the string, the ball would continue to fly off in a straight line. However, the **Centripetal Force** exerted by you pulling on the string accelerates the ball inward towards you. This acceleration causes the ball to continuously change its direction from a straight line. The ball remains in a circular "orbit" around your head without falling into or flying away from you.
   - A satellite's forward motion is controlled by rockets. When the rockets are not fired, inertia keeps the satellite going in one direction. The Earth's **Gravity** exerts a **Centripetal Force** on the satellite that causes the satellite to accelerate towards the Earth and continuously change direction as the satellite orbits the Earth.
5. Let go of the string.
   - What happens? (The ball flies outward, because the Centripetal Force [Gravity] is now equal to zero.)
6. Discuss other examples of momentum and gravity: for example, swinging a bucket of water over your head without getting drenched; or riding amusement park rides where you turn upside down or move vertically in a loop without falling out.



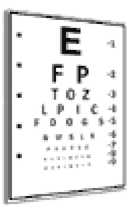
Inventions from Space: http://spaceplace.nasa.gov/en/kids/spinoffs2.shtml

What do all the things pictured on this page have in common? They all use technologies or materials that were originally developed for the space program.



TV Satellite Dish
NASA developed ways to correct errors in the signals coming from the spacecraft. This technology is used to reduce noise (that is, messed up picture or sound) in TV signals coming from satellites.

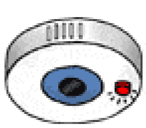
Medical Imaging
NASA developed ways to process signals from spacecraft to produce clearer images. (See more on digital information and how spacecraft send images from space.) This technology also makes possible these photo-like images of our insides.



Vision Screening System
Uses techniques developed for processing space pictures to examine eyes of children and find out quickly if they have any vision problems. The child doesn't have to say a word!

Ear Thermometer
Instead of measuring temperature using a column of mercury (which expands as it heats up), this thermometer has a lens like a camera and detects infrared energy, which we feel as heat. The warmer something is (like your body), the more infrared energy it puts out. This technology was originally developed to detect the birth of stars.

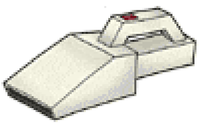
Fire Fighter Equipment
Fire fighters wear suits made of fire resistant fabric developed for use in space suits.



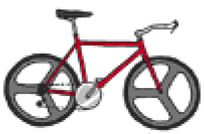
Smoke Detector
First used in the Earth orbiting space station called Skylab (launched back in 1973) to help detect any toxic vapors. Now used in most homes and other buildings to warn people of fire.

Sun Tiger Glasses
From research done on materials to protect the eyes of welders working on spacecraft, protective lenses were developed that block almost all the wavelengths of radiation that might harm the eyes, while letting through all the useful wavelengths that let us see.

Automobile Design Tools
A computer program developed by NASA to analyze a spacecraft or airplane design and predict how parts will perform is now used to help design automobiles. This kind of software can save car makers a lot of money by letting them see how well a design will work even before they build a prototype.



Cordless Tools
Portable, self-contained power tools were originally developed to help Apollo astronauts drill for moon samples. This technology has lead to development of such tools as the cordless vacuum cleaner, power drill, shrub trimmers, and grass shears.



Aerodynamic Bicycle Wheel
A special bike wheel uses NASA research in airfoils (wings) and design software developed for the space program. The three spokes on the wheel act like wings, making the bicycle very efficient for racing.

Thermal Gloves and Boots
These gloves and boots have heating elements that run on rechargeable batteries worn on the inside wrist of the gloves or embedded in the sole of the ski boot. This technology was adapted from a spacesuit design for the Apollo astronauts.

Space Pens
The Fisher Space Pen was developed for use in space. Most pens depend on gravity to make the ink flow into the ball point. For this space pen, the ink cartridge contains pressured gas to push the ink toward the ball point. That means, you can lie in bed and write upside down with this pen! Also, it uses a special ink that works in very hot and very cold environments.

Shock Absorbing Helmets
These special football helmets use a padding of Temper Foam, a shock absorbing material first developed for use in aircraft seats. These helmets have three times the shock absorbing ability of previous types.

Ski Boots
These ski boots use accordion-like folds, similar to the design of space suits, to allow the boot to flex without distortion, yet still give support and control for precision skiing.

Failsafe Flashlight
This flashlight uses NASA's concept of system redundancy, which is always having a backup for the parts of the spacecraft with the most important jobs. This flashlight has an extra-bright primary bulb and an independent backup system that has its own separate lithium battery (also a NASA developed technology) and its own bulb.

Invisible Braces
These teeth-straightening braces use brackets that are made of a nearly invisible translucent (almost see-through) ceramic material. This material is a spinoff of NASA's advanced ceramic research to develop new, tough materials for spacecraft and aircraft.

Edible Toothpaste
This is a special foamless toothpaste developed for the astronauts to use in space (where spitting is not a very good idea!) Although this would be a great first toothpaste for small children, it is no longer available.

Joystick Controllers
Joystick controllers are used for lots of things now, including computer games and vehicles for people with disabilities. These devices evolved from research to develop a controller for the Apollo Lunar Rover, and from other NASA research into how humans actually operate (called "human factors").

Advanced Plastics
Spacecraft and other electronics need very special, low-cost materials as the base for printed circuits (like those inside your computer). Some of these "liquid crystal polymers" have turned out to be very good, low-cost materials for making containers for foods and beverages.

Originally published in *The Technology Teacher*, November 2000, by the International Technology Education Association

PUT YOUR OWN SPIN ON TECHNOLOGY

Editor: Thanks to Diane Fisher (writer) and Alexander Novati (illustrator) for this activity. The research described in this article was partially carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration (NASA).

NOTES TO THE TEACHER

Many of the inventions and materials that we take for granted in our everyday lives came about through basic research originally done to fulfill the needs of the space program. Attempting to do things that have never been done before is the best incentive for innovation. And what human endeavor is more trailblazing than going into space, whether it is to send people to the moon or to place spacecraft in orbit to study our own planet?

This computer game joystick, made byThrustMaster, Inc., uses technology developed for a Space Shuttle hand controller. The design for these toy gliders (AeroNerf Gliders), made by Hasbro, Inc., benefited from NASA wind tunnel and

This activity introduces students to some of these useful, even life-saving products, as well as the process of designing them. Some of the products are technologies that start out to serve a particular purpose in space or aeronautics. But then clever inventors, engineers, and entrepreneurs find new uses. For example, excimer laser technology developed at JPL to study Earth's ozone layer has been further developed and adapted for use in laser angioplasty and vision correction surgery. Digital cameras, electron microscopes, and all sorts of medical imaging technologies use digital imaging and processing techniques whose development was greatly accelerated by NASA's need to record images in space and transmit them back to Earth.

After introducing the idea of space technology spinoffs, we give a few examples that may be familiar to most students, then invite students to come up with their own spinoff ideas, given an additional list of space technologies from which to choose.

The article, as printed on the following pages (minus this introduction), is suitable as a handout for upper middle school and high school students. The students could do the assignment individually or in pairs. A contest to invent the best spinoff could make it more fun and exciting. The activity can also be adapted for younger students. Small groups could work together. Or the whole class could brainstorm ideas and develop them. Questions are included at the end of the article to stimulate thinking and discussion.

More information about space program spinoffs can be found on JPL's Technology Applications Program web site at http://technology.jpl.nasa.gov/. Also, see the NASA Commercial Technology Network web site at http://nctn.hq.nasa.gov/success/. For our activity, we tried to find technologies and spinoff products that children would find nteresting. However, more advanced students may enjoy delving into the vast NASA searchable spinoff data base at http://www.sti.nasa.gov/tto/spinselect.html. Other activities and interesting facts can be found at NASA/JPL's web site for children, The Space Place, at http://spaceplace.jpl.nasa.gov.

Originally published in **The Technology Teacher**, *Dec. 2002/Jan. 2003, by the International Technology Education Association*

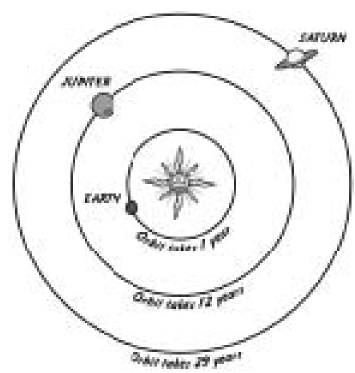
Chasing Down a Satellite

Have you ever spotted a satellite crossing the night sky over your town or city? Although it may have been a mere point of light like a star or planet, you could not mistake a visible satellite for a star, a planet, or even a high altitude plane. The reason? Even a plane does not move across the sky as fast as a satellite.

The International Space Station (ISS) is the easiest satellite to spot because it is by far the biggest, and its orbit is low compared to many satellites. Take a look on NASA's list of ISS viewing opportunities at **www.hq.nasa.gov/osf/station/viewing/issvis.html** to see whether the Space Station might be visible from your location. If so, make plans to look for it. Just how fast does the Space Station travel? And how does it (or any other satellite) stay in orbit? Why doesn't Earth's gravity just bring them crashing down? Why and how do they travel so fast? And how do spacecraft engineers here on Earth control them?

Weightless? No Way!

Satellites take advantage of some basic laws of physics that two scientists figured out around 400 years ago. *Johannes Kepler*, a German astronomer and mathematician, discovered that the time it takes for one body to orbit another (like a planet to orbit the Sun) is directly related to the distance between the bodies. For example, he discovered that it takes Jupiter (the 5th planet from the Sun) 12 years for one orbit, while Saturn (the 6th planet) takes about 29 years for one orbit. *Isaac Newton*, English scientist and mathematician, came along a few years later and discovered the direct relationship between mass and a force he called gravity, which acts to keep the planets in orbit about the Sun rather than shooting off into space in a straight line.



Jupiter's orbit, which is much larger than Earth's, takes about 12 years to complete, while Saturn's takes about 29 years. (Orbit and planet sizes are not to scale in this diagram.)

Newton had a clever way to explain how one body could orbit another. Imagine a cannon mounted on top of a ridiculously tall mountain. The cannon is fired, and the cannonball follows an arc (or trajectory), landing some distance away. If more gunpowder is used in the cannon, the cannonball will go even farther before crashing to the ground. Use enough gunpowder, and the cannonball will actually follow the curvature of Earth all the way around to where it started—and keep right on going! In other words, the cannonball will be in orbit.

An object in orbit around Earth is actually falling all the way around Earth. To put satellites into orbit, of course we don't use cannons on mountain tops! Instead, we use rockets to lift the satellite high enough and "throw" it hard enough that it will fall all the way around Earth. As Kepler noticed with

Day 9

Objectives
Grades 1-4: Identify the members of our solar system; define planet; compare planets with stars.

Grades 5-8: Identify parts of Earth's solar system; describe the position of the planets in the solar system.

Materials Needed
Grades 1-4: "folder books"

Grades 5-8: computer access to create slides for PowerPoint presentation.
Both: Exploring Creation with Astronomy; 8" ball; 3 pinheads; two peppercorns; a chestnut or pecan; a hazelnut or an acorn; two peanuts; sheets of paper or cardstock and stones to weight them, making it easier to find the aforementioned objects; journaling supplies.

Review/Introduction
Using a cooperative structure, review previously taught terms or concepts. Read to students pages 5 through the top of page 7 from Exploring Creation with Astronomy. Clarify that a planet is a heavenly body that circles or revolves around the sun and that there are 8 revolving around our sun, or in our solar system Explain that the moon is also part of our solar system but it orbits the earth rather than the sun. Explain to students that people have made up ways to remember the names of the planets in the order they are away from the sun. Give as an example, and show the focus of the following mnemonic device: My Very Early Morning Just Started Under Nancy's Pancakes. Explain that this one includes a letter for Pluto, which used to be, but is no longer, considered a planet. Tell them that as a homework assignment lower grade students will be asked to create a new mnemonic which does not include Pluto. Ask students to reiterate what they have learned about stars.

Procedure
Conduct the following activity outdoors (requires a large space). Don't let the size of the document scare you away. It provides some helpful dialog as well as a lot of extra information which may or may not be used, but the activity will go a long way toward helping students understand the vastness of God's creation. Be sure to use this activity to that advantage! Alternatively, create a model of the solar system. For help with making one to scale, use the following site: http://www.exploratorium.edu/ronh/solar_system/. Directions for a simply model can be found at http://www.enchantedlearning.com/crafts/astronomy/solarsystemmodel/.

The *NAD Essential Science/Health Update Grades 5-8* also contains an activity entitled Mini Solar System.

THE THOUSAND-YARD MODEL

or

The Earth as a Peppercorn

This is a classic exercise for visualizing just how BIG our Solar System really is. Both the relative size and spacing of the planets are demonstrated in this outdoor exercise, using a mere peppercorn to represent the size of the Earth. Guy Ottewell has kindly given permission for this electronic presentation of The Thousand-Yard Model; his exercise is presented in its original form, indexed with a few anchors to help you find your way around the large file.

Introduction

Can you picture the dimensions of the solar system?

Probably not, for they are of an order so amazing that it is difficult either to realize or to show them.

You may have seen a diagram of the Sun and planets, in a book. Or you may have seen a revolving model of the kind called an orrery (because the first was built for an Earl of Orrery in 1715). But even the largest of such models -- such as those that cover the ceilings of the Hayden Planetarium in New York and the Morehead Planetarium at Chapel Hill -- are far too small. They omit the three outermost planets, yet still cannot show the remaining ones far enough apart.

The fact is that the planets are mighty small and the distances between them are almost ridiculously large. To make any representation whose scale is true for the planets sizes and distances, we must go outdoors.

The following exercise could be called a Model, a Walk or a Happening. I have done it more than twenty times with groups of varied ages (once we were televised) or with a single friend; and others, such as elementary-school teachers, have carried it out with these instructions. Since it is simple, it may seem suitable for children only. It can, indeed, be done with children down to the age of seven. Yet it can also be done with a class consisting of professors of astronomy. It will not waste their time. They will discover that what they thought they knew, they now apprehend. To take another extreme, the most uncontrollable high-school students or the most blase college students unfailingly switch on their full attention after the first few paces of the excursion.

There is one other party that may profitably take the planet-walk, and that is yourself, alone. Reading the following description is no substitute: you must go out and take the steps and look at the distances, if the awe is to set in.

First, collect the objects you need. They are:

Sun-any ball, diameter 8.00 inches
Mercury-a pinhead, diameter 0.03 inch
Venus-a peppercorn, diameter 0.08 inch
Earth-a second peppercorn
Mars-a second pinhead
Jupiter-a chestnut or a pecan, diameter 0.90 inch
Saturn-a hazelnut or an acorn, diameter 0.70 inch
Uranus-a peanut or coffeebean, diameter 0.30 inch
Neptune-a second peanut or coffeebean
Pluto- a third pinhead (or smaller, since Pluto was thought to be the smallest planet)

You may suspect it is easier to search out pebbles of the right sizes. But the advantage of distinct objects such as peanuts is that their rough sizes are remembered along with them. It does not matter if the peanut is not exactly .3 inch long; nor that it is not spherical.

A standard bowling ball happens to be just 8 inches wide, and makes a nice massive Sun, so I couldn't resist putting it in the picture. But it may not be easy to find and certainly isn't easy to carry around. There are plenty of inflatable balls which are near enough in size.

The three pins must be stuck through pieces of card, otherwise their heads will be virtually invisible. If you like, you can fasten the other planets onto labeled cards too. Begin by spilling the objects out on a table and setting them in a row. Here is the moment to remind everyone of the number of planets -9- and their order--MVEMJSUNP. (This mnemonic could be made slightly more pronounceable by inserting the asteroids in their place between Mars and Jupiter: MVEMAJSUNP.) **(Since the writing of this, Pluto has lost planet status.)**

The first astonishment is the contrast between the great round looming Sun and the tiny planets. (And note a proof of the difference between reading and seeing: if it were not for the picture, the figures such as "8 inches" and ".08 inch" would create little impression.) Look at the second peppercorn--our "huge" Earth--up beside the truly huge curve of the Sun.

Having set out the objects with which the model is to be made, the next thing is to ask: "How much space do we need to make it?" Children may think that the table-top will suffice, or a fraction of it, or merely moving the objects apart a little. Adults think in terms of the room or a fraction of the room, or perhaps the corridor outside.

To arrive at the answer, we have to introduce scale.

This peppercorn is the Earth we live on.

The Earth is eight thousand miles wide! The peppercorn is eight hundredths of an inch wide. What about the Sun? It is eight *hundred* thousand miles wide. The ball representing it is eight inches wide. So, one inch in the model represents a hundred thousand miles in reality.

This means that one yard (36 inches) represents 3,600,000 miles. Take a pace: this distance across the floor is an enormous space-journey called "three million six hundred thousand miles."

Now, what is the distance between the Earth and the Sun? It is 93 million miles. In the model, this will be 26 yards.

This still may not mean much till you get one of the class to start at the side of the room and take 26 paces. He comes up against the opposite wall at about 15!

Clearly, it will be necessary to go outside.

Hand the Sun and the planets to members of the class, making sure that each knows the name of the object he or she is carrying, so as to be able to produce it when called upon.

You can make some play with the assigning of the objects to the "gods" who are to be their bearers. Selecting a blond Sun, a hyperactive Mercury, a comely Venus, a redhaired or pugnacious Mars, a ponderous or regal Jupiter, a ring- wearing Saturn, a blue-eyed Uranus, a swimming-champion Neptune, a far-out Pluto can enliven the proceedings and teach a few scraps of mytholgy or planetology. It is unfortunate that only Venus and Earth (the Moon) are female (most of the goddesses have given their names to asteroids instead).

You will have found in advance a spot from which you can walk a thousand yards in something like a straight line. This may not be easy. Straightness of the course is not essential; nor do you have to be able to see one end of it from the other. You may have to "fold" it back on itself. It should be a unit that will make a good story afterwards like "All the way from the flagpole to the Japanese garden!"

Put the Sun ball down, and march away as follows. (After the first few planets, you will want to appoint someone else to do the actual pacing -- call this person the "Spacecraft" or "Pacecraft" -- so that you are free to talk.)

10 paces. Call out "**Mercury**, where are you?" and have the Mercury-bearer put down his card and pinhead, weighting them with a pebble if necessary.

Another 9 paces. **Venus** puts down her peppercorn.
Another 7 paces. **Earth.**

Already the thing seems beyond belief. Mercury is supposed to be so close to the Sun that it is merely a scorched rock, and we never see it except in the Sun's glare at dawn or dusk-yet here it is, utterly lost in space! As for the Earth, who can believe that the Sun could warm us if we are that far from it?

The correctness of the scale can be proved to skeptics (of a certain maturity) on the spot. The apparent size of the Sun ball, 26 paces away, is now the same as that of the real Sun-half a degree or arc, or half the width of your little finger held at arm's length. (If both the size of an object and its distance have been scaled down by the same factor, then the angle it subtends must remain the same.)

Another 14 paces. **Mars**

Now come the gasps, at the first substantially larger leap:

Another 95 paces to **Jupiter**

Here is the "giant planet" -- but it is a chestnut, more than a city block from its nearest neighbor in space!

From now on, amazement itself cannot keep pace, as the intervals grow extravagantly:

Another 112 paces. **Saturn**
Another 249 paces. **Uranus**
Another 281 paces. **Neptune**
Another 242 paces. **Pluto**

You have marched more than half a mile! (The distance in the model adds up to 1,019 paces. A mile is 1,760 yards.)

To do this, to look back toward the Sun ball, which is no longer visible even with binoculars, and to look down at the pinhead Pluto, is to feel the terrifying wonder of space.

That is the outline of the Thousand-Yard Model. But be warned that if you do it once you may be asked to do it again. Children are fascinated by it enough to recount it to other children; they write "stories" which get printed in the school paper; teachers from other schools call you up and ask you to demonstrate it.

So the outline can bear variation and elaboration. There are different things you can remark on during the pacings from one planet to the next, and there are extra pieces of information that can easily be grafted on. These lead forward, in fact, to the wider reaches of the universe, and make the planet walk a convenient introduction to a course in astronomy. But omit them if you are dealing with children young enough to be confused, or if you yourself would prefer to avoid mental vertigo.

I recommend that you stop reading at this point, carry out the walk once, and then read the further notes.

Establishing the scale

While you are talking and introducing the idea of the model, it may be helpful (depending on the age of the audience) to build up on a blackboard something like this:

	real	**in model**
Earth's width	8,000 miles	8/100 inch
Sun's width	800,000 miles	8 inches
therefore scale is	100,000 miles	1 inch
therefore	3,600,000 miles	36 inches or 1 yard
and Sun-Earth distance	93,000,000 miles	26 yards

Follow-up

Having come to the end of the walk, you may turn your class around and retrace your steps. Re-counting the numbers gives a second chance to learn them, and looking for the little objects re-emphasizes how lost they are in space.

It works well, in this sense: everyone pays attention to the last few counts- "240...241...242"-wondering whether Neptune will come into view. But it does not work well if the peanut cannot be found, which is all too likely; so you should, if you plan to do this, place the objects on cards, or set markers beside them (large stones, or flags such as the pennants used on bicycles).

Also, the Sun ball perhaps cannot be left by itself at the beginning of the walk -- it might be carried off by a covetous person if not by the wind -- so send someone back for it when the walk has progressed as far as Mars.

(I once, having no eight-inch ball, made a colored paper icosahedron, and had to give chase for afar when I saw someone appropriating it. On the return from another walk, I met a man holding his mouth while his worried companion said, "Did you bite it?" -- incredibly, he had picked up one of the peppercorns! The other edible planets are, of course, prey for passers-by. Hazards like these may be regarded as our model's counterparts of such cosmic menaces as supernovae and black holes.)

On each card, the child who recovers it may write briefly the place where it was -- "At 5th Street," "At John Cabonie's house" -- Then, back in the classroom, the objects as kept in a row on a shelf, as a reminder of the walk. Or they may be hung on strings from a rafter.

Since pecans, pinheads, peanuts, and especially peppercorns cannot always be readily found when another demonstration is called for, I keep at least one on hand, in one of the small canisters in which 35-millimeter film is sold.

Looking at the real things

Anyone you take on this planet-walk may finish it with a desire to set eyes on the planets themselves. So it is best to be able to do it at a date when you can say: "Look up there after dark and you will see [Jupiter, for instance]."

Thus on the first nights of 1990, when darkness falls, Jupiter will be the brightest "star" high in the east of the sky, and Venus will be the brightest one setting in the west. For any other specific times, consult the Astronomical Calendar, the magazines Sky & Telescope or Astronomy, or a local college science department, planetarium, or amateur astronomer.

Orbits

Point out that the nine planets do not stay in a straight line. They stay about the same distances from the Sun, but circle around it (counterclockwise as seen from the north).

They go around at various speeds. The inner planets not only have smaller circles to travel but move faster. Thus, Mercury goes around in about 3 months; the Earth, in a year; and Pluto in about 250 years.

The circling movements mean that the planets spend most of their time much farther apart even than they appear in out straight-line model. The distance between two planets can be up to the sum of their distances from the sun, instead of the difference. Jupiter and Saturn, for instance, can be as close as 95 paces as in the model, or up to 382 paces apart at times when they are on opposite sides of the orbits. This is the case in the years around 1970,1990, and 2010. (Jupiter overtakes Saturn about every 20th year.) Think of the spacecraft Pioneer 11, which actually covered this immense distance. Launched from Earth in April of 1973, it looped around Jupiter in December 1974, and arched back all the way over the solar system, on its way to visit Saturn also. This journey is so long -- the distance back from Jupiter plus the even greater distance out to Saturn -- that the spacecraft did not reach Saturn till September 1979. During the Thousand- Yard walk is the dramatic time to tell people about this, and let them reflect on the refinement with which the spacecraft had to be aimed around the south pole of Jupiter in just such a way that it might five years later drop between Saturn (this acorn) and its rings.

The Spacing of the Planets

Schematic pictures often show the planets on parade at about equal distances- much as when you first arrayed them on the table. This, as we have seen is unrealistic: the intervals are very unequal. There are these features to point out:

1. In general, the intervals get strikingly larger as we go outward.
2. But they increase very irregularly. No need to dwell on this unless someone asks, but for instance the first three jumps actually get smaller; after that they increase, but neither in an arithmetical progression (like 1, 2, 3, 4...) nor in a geometrical progression (like 2, 3, 8, 16...). A more complicated regularity has been discerned; it is known as "Bode's law," but is only a rough rule rather than a law. If Mercury is 4 units of distance from the Sun, the Venus is 4+3, the Earth 4+6, Mars 4+12. Then Jupiter is 4+48 and Saturn more roughly 4+96.
3. The most obvious exception to this "law" is the gap between Mars and Jupiter. This was where your class swooned, on hearing that the next distance was to be the suddenly larger leap of 95 paces (more than twice as long as the total distance walked up till then). This gap marks the boundary between the inner and outer solar systems. The inner solar system contains the four small, hard, "terrestrial" (Earth-like) planets; the outer solar system contains the four large, fluid, "Jovian" (Jupiter-like) planets, with the exception of Pluto. If, instead, there were a planet in the gap, Bode's law would be more regular. Indeed, this is where most of the asteroids are, so they may be fragments of a planet which broke up or which was never able to form.
4. Mercury is not one ninth but only one hundredth of the way out to Pluto.
5. The Earth is only a little more than one fortieth of the way out to Pluto.
6. Where is the half-way point in the journey out to Pluto? Most people would guess Jupiter or Saturn. But the surprising answer is Uranus. (It is 496 yards in our model.)

So, if you need to fold the walk back on itself, because of not having space to walk a thousand yards, Uranus is the point at which to turn.

The Outer Planets

Throughout most of human history, only six planets have been known: Mercury, Venus, Earth, Mars, Jupiter, Saturn. (Most of the time nobody knew what planets are or that the Earth is a planet.) Then, in the last three centuries, three new planets were discovered. Uranus, though theoretically visible to the naked eyer on fine nights if you know just where to look, was not noticed till 1718; Neptune was discovered by careful calculation and search in 1846; and Pluto in a similar way, but not till 1930 after a quarter of a century of meticulous search, for even in large telescopes it is lost among countless thousands of equally faint stars.

And anyone who takes our planet-walk will say: "No wonder!"

Pluto's Oddity

Pluto not only is smaller than the other eight planets, but is smaller than the Moon and half a dozen other satellites of planets. It is, as we have seen, the exception to the rule that the inner planets are small (and rocky) and the outer planets large (and gaseous). It is also exceptional in its orbit, which somewhat messes up our model.

It is true that Pluto's average distance from the Sun is about 3,666,000,000 miles (1,019 paces in our model). But its orbit, instead of being nearly circular like those of the other planets, is very eccentric or elliptical: part of it is much nearer in toward the Sun and part much farther out. At present Pluto is on the inward part. In fact, it is nearer in than Neptune! This is so from 1979 until 1999, when Pluto will again cross outward over Neptune's orbit.

Thus a true statement is that Pluto is usually the outermost known planet (but for just these ten years out of 250 Neptune is) and that the distance in our model from the Sun to the outermost planet is about a thousand yards on average (but it should really vary from only Neptune's 777 yards in these ten years, to as much as 1,275 yards when Pluto is at the outermost part of it orbit).

The other planets circulate in the same plane as the Earth, at least nearly enough that we can represent this by the plane of the ground. But Pluto's orbit is inclined to this general plane by the fairly large angle of 17 degrees. This means that part of the huge orbit lies far above (north of) ours and part far below. At present Pluto is still well to the north side. So if you want to mention this, you can tell the last planet-carrying child to walk 242 paces and then climb a tree-"just kidding..." (Actually the tree should be 200 yards high! And there are parts of the orbit where Pluto should be up an even higher tree or down a very deep hole in the ground.)

Angular Size

When Mars, moving rapidly along its relatively nearby orbit, passes in front of Jupiter or Saturn, and we look at these planets through a telescope, we are surprised to find that the disk of Mars looks much the smaller. Jupiter looks three times as wide as Mars, though it is eight times farther away!

The planet-walk will have impressed you with the great distance from Mars onward to Jupiter, and thus will give this observation its surprising quality. However, the planet-walk also gives you the means to visualize the reason. The farther away two objects are, the less the distance between them counts, and the more it is a matter of their own actual sizes. Or, put another way, angular size decreases slower and slower with distance.

The Sun Vs. the Planets, and Jupiter Vs. the Rest

When we first laid the row of objects out on the table, there was an extreme contrast between the Sun and the rest. The word "size" is vague, since it could mean width (diameter), volume, or mass (amount of matter). In volume, the Sun is 600 times greater than all the planets put together. As compared with the small but rather dense Earth, the Sun is 109 times greater in width; 1,300,000 times greater in volume; and 330,000 times greater in mass.

Within the planets themselves, there is quite a contrast between Jupiter and the rest. Jupiter contains almost three times as much matter as all the other planets together -- even though Saturn comes a good second to it in width.

This is partly because Saturn is the least dense of all the planets (it would float on water, if there was an ocean big enough). But it is also an illustration of the difference between the kinds of "size." If you multiply a planet's width by, say, 3, you multiply its cross-sectional area by 9, and its volume by 27. Thus a relatively small difference between the widths of Saturn and Jupiter means a much larger difference between their capacities. This, too, is easier to understand when you look at the solid objects representing them.

The Moon

The Moon is, on our scale, 2.4 inches from the Earth.

You can, on reaching the position for the Earth, pause and put down a Moon beside it. This Moon will have to be another pinhead (theoretically between the sizes of Mercury and Pluto).

Look down on this distance, the length of your thumb; the greatest distance that Man has yet leaped from him home planet. Reflect on the manned mission to Mars now being suggested (14 yards in our model) or the trips proposed in science fiction: to Jupiter as in the film <u>2001 Space Odyssey</u> (109 yards); to the nearest star (four thousand miles in our model); to the Andromeda Galaxy (half a million times farther again).

The Emptiness of Space

The planet walk is an antidote to the "scientific" school of astrologers, who suggest that the planets disturb particles in our bodies. When one can visualize how remote these planets are, it is easy to understand that the nearest of them, Venus, when nearest to us, has the same gravitational or tidal effect as a truck 14 miles away, or a high-rise building 300 miles away.

During the walk, the immense distances between the planets and the Sun may make people incredulous that the planets can truly feel the gravitational influence of the Sun at all, let alone be so much in its control that they orbit faitfully around it forever. After all, if our model is to scale, then this peppercorn, representing the Earth, must experience a similar gravitational pull from that far-off ball, representing the Sun. Does it? It certainly shows no inclination to fall toward the ball, and has no need to stave off such a fall by orbiting around the ball!

The peppercorn does feel the gravitational pull of the ball. The difference is that there is so much other matter in the environment of the model, which is not present in the environment of the things being modeled: the sidewalk, the pillars of the arcade you are walking along, the grass and trees, your feet and above all the air pressing down and the total mass of the Earth underneath. These are all so huge that the attraction of the ball, without becoming any less, becomes by comparison a negligible influence in the distance. If there were, in interplanetary space, any object corresponding to even one of these things -- say, a four-million-mile slab of rock, corresponding to the paving-stone on which the peppercorn is lying - then the Sun's influence on the Earth would become negligible. It is only because space is so empty that the Sun is the nearest important gravitational influence on the Earth.

Greater Distances

The solar system does not really end with Pluto. Besides the planets, there is a thin haze of dust (some of it bunched into comets). Any of this dust that is nearer to the Sun than to any other star may be in the gravitational hold of the Sun and so counts as part of the solar system. So the outermost of such dust may be half way to the nearest star.
On the scale of our model, Pluto is a thousand yards or rather more than a half a mile out. But this true limit of the solar system is two thousand miles out.

A thousand miles, in our mode, is the distance called a light-year (in reality, about six million miles).

The distance to the nearest star, Proxima Centauri, is 4.2 such light-years.

The human mind can never conceive this thing called a light-year, which is the currency of our small-talk about the universe. (It is probable that we cannot directly conceive any distances above about 600 yards, which is where we sub- consciously place the horizon). But through the model we move as far toward conceiving it as we ever can.

I, at least, have seemed to have some respect for the term light-year; and to have some sense of what I mean when I use it -- since I made the sensory approach to it through this model.

The rest of the stars in our galaxy are probably on the order of four to ten light-years apart from each other, as we are from our nearest neighbor.

This is a stunning thought when (having done the Thousand-Yard exercise) you go out at night and look at the Milky Way. It is a haze of light so delicate that it can no longer be seen from inside our light-ridden cities. It consists of the bulk of the stars in our galaxy, piled up in the distance, so numerous and so faint that we cannot see them separately. Yet they are all the same kind of distance from each other as we are from the nearest of them. That is to say, if we could hop to any one of them, cavernous black space would open out around us, and the Sun itself would become part of that same dense far-off wall of stars, the Milky Way!

National Optical Astronomy Observatory. *The thousand yard model: or the earth as a peppercorn.* Retrieved July 14, 2008 from http://www.noao.edu/education/peppercorn/pcmain.html#intro

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When students return to the room, have them write (in the case of emergent writer, dictate) a journal response to the activity. Encourage them to make spiritual connections. Lower grade students should place their journal entries in their "folder books." If time allows, upper grade students should prepare PowerPoint slides summarizing what they learned from today's experience to meet the rubric **Content** requirements for items 15 and 16.

Assessment

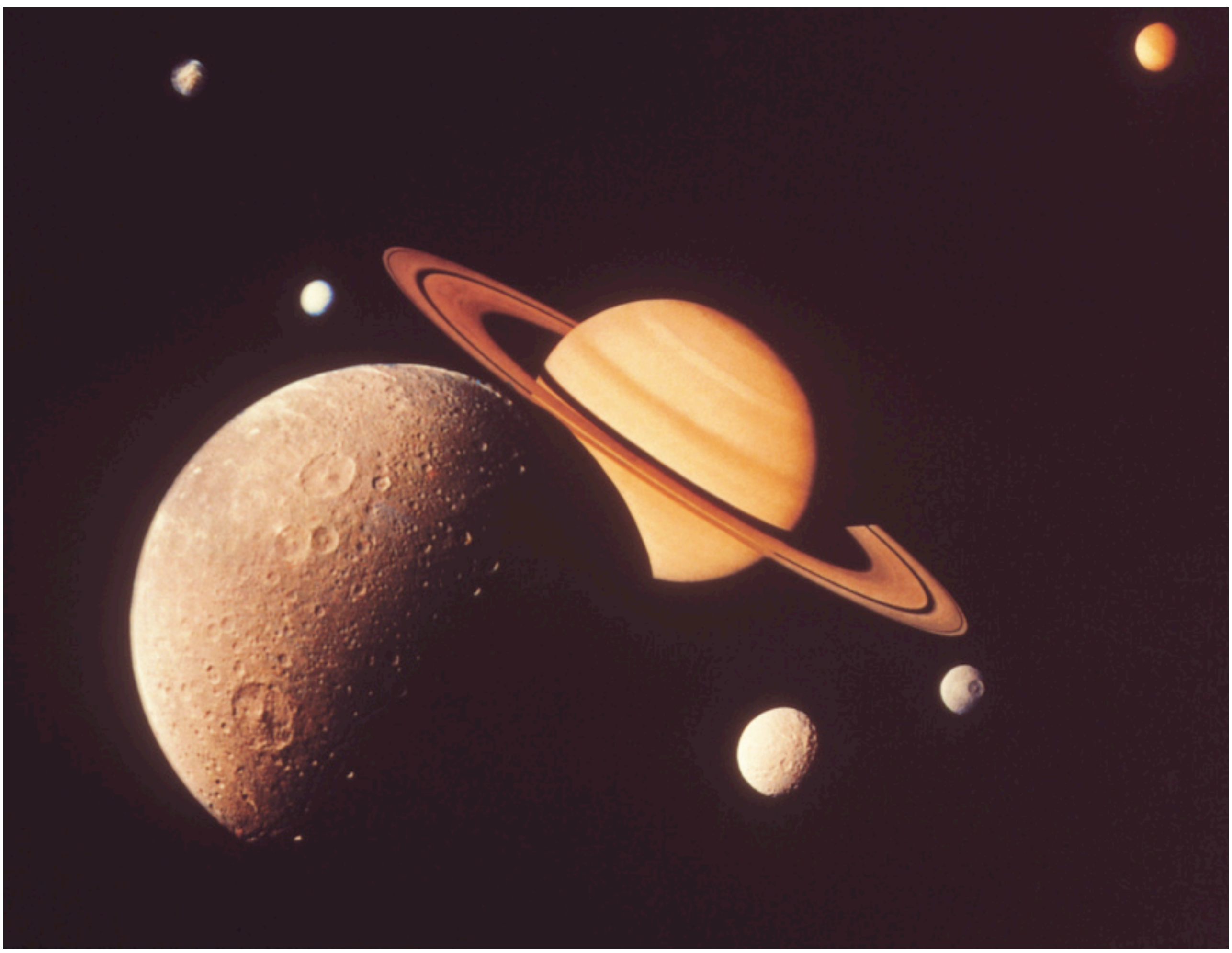
Grades 1-4: Evaluate students based on their completed assignment.

Grades 5-8: Evaluate students based on their completed assignment.

Homework

Grades 1-4: Create a mnemonic devise for the planets in order of distance from the sun but not including the former planet Pluto.

Grades 5-8: Continue reading chosen biography and prepare PowerPoint slides summarizing what was learned from today's experience.



Day 10

Objectives
Grades 1-4: Distinguish the difference between revolution and rotation; understand that the sun gives light and warmth to the earth and is necessary for life; understand that day is when the sun shines on the lighted part of the earth; understand that the earth takes one year (365 days) to revolve around the sun; understand that the moon is earth's satellite.

Grades 5-8: Describe the structure of the sun; identify the features of the sun; describe the position of the sun, earth, and moon during an eclipse.

Materials Needed
Grades 1-4: "folder books"

Grades 5-8: computer access for creating slides for PowerPoint presentation.
Both: a bright, hand-held light (flashlight or table lamp with the shade removed and a long enough extension cord to conduct the demonstration); journaling materials

Review/Introduction
Using a cooperative structure, review previously taught terms and concepts.

Procedure
Pair older students with younger to assist them and move to a fairly large open area. Explain that there are two ways in which planets move -- rotation and revolution -- which we will be demonstrating. With students in a circle, have them stand in one position and turn their bodies, rotating 360 degrees. Ask older students to confer with each other and determine if what they just did is called rotation or revolution *(rotation)*. Explain that this is like what the earth does every 24 hours and it is what gives us day and night. Place a bright light in the center of the circle aimed at one of the students and explain that it represents the sun. Have the student at which it is aimed rotate. When the light shines on the front of the person's body the rest of the students should say "day," and when it shines on his/her back they will call out "night." Say, "If the student represents the earth, what is its axis?" *(his/her feet or shoes)*. Explain that the earth's axis is an imaginary line that just helps us know where the top and bottom of the earth are. Further explain that some Christians believe the earth was tipped during the Flood, which is why the axis does not point straight up and down. Now have students circle around the sun and ask upper grade students what the name for this movement is *(revolution)*. It may be helpful to explain that the word comes from the root word revolve, meaning "to circle," as opposed to the root world revolt which gives a different meaning to the word

revolution as in the American Revolution. Ask if anyone knows how long it takes for the earth to revolve around the sun *(365 days)*. Ask lower grade students what time period this is *(one year)*. Explain to students that the earth actually moves in two ways at the same time -- it both rotates and revolves all the time. Have students move (revolve) around the "sun" rotating as they do. Have them call out "day" and "night" as well as seasons ("summer" when in the full sun, "fall" as they go past it, "winter" when opposite the sun, spring as they come toward the sun). Explain that this model isn't perfect because it isn't that we are on the back side of the sun during winter but rather that we are tipped away from it and aren't catching all of its rays. Have an older student representing the moon revolve around a younger one, who is rotating and revolving around the sun. Explain that the moon is considered a satellite, though a natural one as opposed to man-made. Ask students what it would look like if they were to represent the other planets in their orbit around the sun and model it if time permits. *(Mercury and Venus would be revolving in circles closer to the sun while the other planets would be doing so further out beyond Earth.)* Have students return, if necessary, to the classroom and guide them to brainstorm a list of terms and concepts they just learned to include in their "folder books" or PowerPoint presentations. Upper grade students should research solar eclipses and address rubric **Content** items 17 and 18 in PowerPoint slides.

Assessment

Grades 1-4: Evaluate students based on their completed assignments.

Grades 5-8: Frequently provide students with feedback on their developing PowerPoint and set deadlines along the way. At the end of the project, or at specified points along the way, have them self-evaluate using the rubric. The teacher should do the same, adding explanatory comments where appropriate.

Homework

Grades 1-4: Have students explain and demonstrate to their parents the concepts of rotation and revolution. It may be wise to review these before sending the students home at the end of the day! They may also work on contract items.

Grades 5-8: Have upper grade students work on contract items and/or their PowerPoint presentation.

Day 11

Objectives

Grades 1-4: Describe the sun's role in the solar system; define star.
Grades 5-8: Describe solar flares and sunspots and their effects.

Materials Needed

Grades 1-4: "folder books"
Grades 5-8: computer access for research and creation of PowerPoint slides.
Both:

Review/Introduction

Using a cooperative structure, review previously taught terms and concepts. Read to students pages 12 through the top of page 14 and page 20 (the section title "Creation Confirmation") in *Exploring Creation with Astronomy.*

Procedure

Have upper grade students research solar flares, sunspots and solar eclipses and prepare PowerPoint slides for their presentations covering rubric **Content** item 19. *Exploring Creation with Astronomy* has helpful information.

Meanwhile, assist lower grade students in compiling a list of facts they have learned about the sun. Explain to students that a star is a glowing ball of hot gas that produces its own energy. Ask if they can think of the name of one. If no one mentions the sun, be sure to explain that the sun is a glowing ball of hot gas so it is a star, just one that we know better than the rest. Have lower grade students compile their facts for another page in their "folder books".

Assessment

Grades 1-4: Evaluate students based on their completed assignments.

Grades 5-8: Frequently provide students with feedback on their developing PowerPoint and set deadlines along the way. At the end of the project, or at specified points along the way, have them self-evaluate using the rubric. The teacher should do the same, adding explanatory comments where appropriate.

Homework

Grades 1-4: Explain to parents what they learned and/or do contract work.

Grades 5-8: Complete biography if it is not already done, work on PowerPoint presentation and/or contract work. Read the information at the following website and be prepared to share with class tomorrow: http://spaceplace.nasa.gov/en/kids/ulysses/index.shtml (very interesting!).

Day 12

Objectives
Grades 1-4: Describe the moon's phases; compare the size of the moon with the earth.
Grades 5-8: Describe the topography of the moon; describe the moon's phases; explain how a lunar eclipse occurs.

Materials Needed
Grades 1-4: "folder books"; copies of the appropriate recording form for homework, one per student (Note that the form for third and fourth graders consists of two pages).
Grades 5-8: computer access for creating PowerPoint slides
Both: computer with internet access for viewing video clip

Review/Introduction
Have upper graders share with lower grade students what they learned about the sun in their work for **Day 11**. Have them model the position of the sun, Earth and the moon during a solar eclipse. Ask an upper grade student to report on what s/he learned at the "spaceplace" website indicated in the homework section for **Day 11**. Ask students what they know (or think they know) about the moon.

Procedures
Have all students watch the video found at the following website: http://www.newtonsapple.tv/video.php?id=1671, which explains why we see the various phases of the moon. (Alternatively, read to students pages 66 through the top of 70 from *Exploring Creation with Astronomy*.) Inform students that the moon is much smaller than earth (the surface area of the moon is roughly equal to that of Africa). Make a list of the things students have learned about the moon and its phases. Have them assist you to sequence them logically. Have lower grade students prepare pages for their "folder books." Have upper grade students prepare slides for their PowerPoint presentation to meet the rubric **Content** requirements for items 20-22. The following website may be helpful to upper grade students: http://home.hiwaay.net/~krcool/Astro/moon/ . Explain to lower grade students that they will be keeping a record of the changing appearance of the moon as homework. Provide them with the appropriate form which accompanies this lesson and explain its use.

Assessment
Grades 1-4: Evaluate students based on their discussions and completed assignments.
Grades 5-8: Frequently provide students with feedback on their developing PowerPoint and set deadlines along the way. At the end of the project, or at specified points along the way, have them self-evaluate using the rubric. The teacher should do the same, adding explanatory comments where appropriate.

Homework
Grades 1-4: Have students observe the moon each evening for the rest of this unit and draw what they see. (see accompanying worksheet) Students may also complete contract work.
Grades 5-8: Work on PowerPoint presentation and/or contract work.

ES – Activity #16

Mini Solar System

Question:

What scale must be used to make a model of our Solar System using a roll of adding machine tape?

Materials:

Adding machine tape – roll
Coloring markers
Index card (4" x 6") – 10
meter stick or metric tape measure
Solar System pictures and information

Procedure:

1. Read over the paragraph below with your group

   Interplanetary travel is extremely difficult due to the almost unimaginable distances between the planets in our Solar System. Voyager II, traveling at nearly 50,000 mph, took 12 years to reach the planet Neptune. We can make a scale model of the distances between the planets using almost anything as our reference. In doing so, we may be able to determine a variety of ways to classify the planets of our solar system. It is almost impossible to make a scale model of the solar system that is correct in both planetary diameter and distance.
2. On an index card draw an illustration of the Sun. On other cards, do the same with each of the eight planets, one object per card. Write interesting facts about the object on the back of the card.
3. Once you have made your set of cards, look them over and list as many ways as possible to classify (group) them by the appearance of the cards.
4. Using a roll of adding machine tape, mark off the distances to the planets using a scale of 10 cm = 10,000,000 miles (refer to the table below).

CELESTIAL OBJECT	NUMBER OF CENTIMETERS FROM THE SUN	NUMBER OF CENTIMETERS FROM THE PREVIOUS OBJECT
Sun	0.0	0.0
Mercury	36.0	36.0
Venus	67.0	31.0
Earth	93.0	26.0
Mars	141.0	48.0
Jupiter	484.0	343.0
Saturn	887.0	403.0
Uranus	1786.0	900.0
Neptune	2800.0	1010.0

Homework

Grades 1-4: Have students observe the moon each evening for the rest of this unit and draw what they see. (See accompanying worksheet.) Students may also complete contract work.

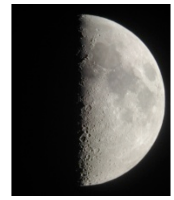
Grades 5-8: Work on PowerPoint presentation and/or contract work.

Name ______________________ 1-2

Phases of the Moon

Directions: Each evening look outside at the moon. Shade the circle to show how much of the moon you see. Write the date.

DATE:____________	DATE:____________	DATE:____________	DATE:____________
DATE:____________	DATE:____________	DATE:____________	DATE:____________
DATE:____________	DATE:____________	DATE:____________	DATE:____________



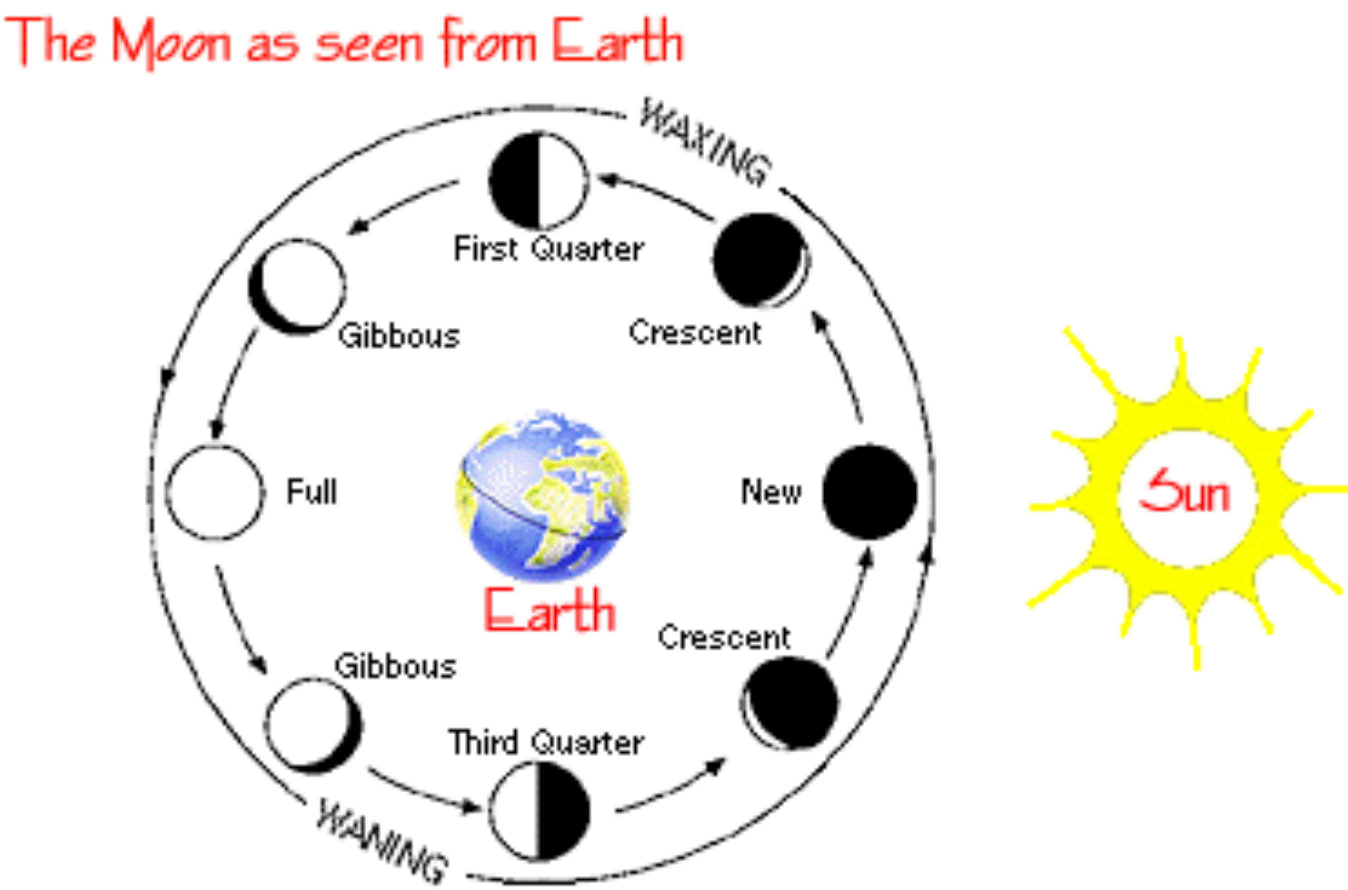
Name ______________________________

Phases of the Moon

Each evening observe the moon. Shade the circle to show the portion of the moon you see (unshaded portion). Use the diagram on the back to help you label the phases.

DATE:____________ PHASE:___________	DATE:____________ PHASE:___________	DATE:____________ PHASE:___________
DATE:____________ PHASE:___________	DATE:____________ PHASE:___________	DATE:____________ PHASE:___________
DATE:____________ PHASE:___________	DATE:____________ PHASE:___________	DATE:____________ PHASE:___________
DATE:____________ PHASE:___________	DATE:____________ PHASE:___________	DATE:____________ PHASE:___________

Note to teacher: print this diagram on the back of the previous page for student reference.



Taken from NASA. (1998) *Star child question of the month for November 1998. Retrieved on July 16, 2008 from* http://starchild.gsfc.nasa.gov/docs/StarChild/questions/question3.html

Complete the following:

In the context of the moon, waxing means

____

and waning means________________________________.

Day 13

Objectives

Grades 1-4: *Supplemental objectives:* Name the inner planets; describe one or more of the inner planets.

Grades 5-8: Identify characteristics of the inner planets; describe features of the inner planets; contrast Earth with the other inner planets.

Materials Needed

Grades 1-4: *Exploring Creation with Astronomy;* collection of books about Mercury, Venus and Mars; index cards

Grades 5-8: Computer access for research and creation of PowerPoint slides; collection of books about Mercury, Venus and Mars.
Both:

Review/Introduction

Using a cooperative structure, review previously taught terms and concepts. Ask students what phase they observed the moon to be in last night. Explain that the planets of our solar system are divided into two groups, inner and outer planets. Ask students what planets they think would be considered "inner planets" and why (*they are Mercury, Venus, Earth and Mars.)*

Procedures

Have upper grades students each choose Mercury, Venus or Mars to research and create a PowerPoint slide including information about how the planet compares with Earth. Each student will then share their slide with the other students so that all students have a slide of each of these inner planets. In a larger class obviously more than one student may be working on each planet or they may work in pairs or small groups. PowerPoint slides should fulfill the rubric **Content** requirements for items 23 and 24.

Have lower grade students work in mixed-age small groups, or organize third and fourth graders in small groups to work independently while you work with first and second graders to research one of the three planets. Have them write individual facts on index cards and then sequence them logically and write a rough draft. Lower grade students will continue work on this task on **Day 14**.

Assessment

Grades 1-4: Evaluate students based on their discussions and completed assignments.

Grades 5-8: Frequently provide students with feedback on their developing PowerPoint and set deadlines along the way. At the end of the project, or at specified points along the way, have them self-evaluate using the rubric. The teacher should do the same, adding explanatory comments where appropriate.

Homework

Grades 1-4: Tell parents what they have learned about the inner planets. Work on contract choices.

Grades 5-8: Work on PowerPoint presentation and/or contract work.

Day 14

Objectives

Grades 1-4: *Supplemental objectives:* Name the inner planets; describe one or more of the inner planets.
Grades 5-8: Identify characteristics of the outer planets; describe features of the outer planets.

Materials Needed

Grades 1-4: research begun on **Day 13.**
Grades 5-8: computer access for research and creation of PowerPoint slides.
Both:

Review/Introduction

Using a cooperative structure, review previously taught terms and concepts. Have students share some of the things learned through their research on **Day 13**.

Procedures

Have each upper grade student research the characteristics and features of one or more of the outer planets and prepare PowerPoint slides to fulfil rubric **Content** requirements for item 25 Students will then share their slides with each other so that every student has slides on each of the outer planets.

Meanwhile, use a writers' workshop approach to assist lower grade students to continue drafting, editing and publishing the research they began yesterday. Additional time may be needed to complete this task and could appropriately be found during a language arts block.

Assessment

Grades 1-4: Evaluate students based on discussions and their completed assignments.
Grades 5-8: Frequently provide students with feedback on their developing PowerPoint and set deadlines along the way. At the end of the project, or at specified points along the way, have them self-evaluate using the rubric. The teacher should do the same, adding explanatory comments where appropriate.

Homework

Grades 1-4: Work on contract items.
Grades 5-8: Work on PowerPoint presentation and/or contract items.

Day 15

Objectives

Grades 1-4: Define and describe asteroids and meteors; discover how the orbits of comets differ from those of planets.

Grades 5-8: Define the terms asteroids, meteoroids, and comets; distinguish between a meteor and a meteorite; describe how the sun affects a comet.

Materials Needed

Grades 1-4: Hard copy of accompanying astronomy song
Grades 5-8: computer access for research and creation of PowerPoint slides.
Both: *Exploring Creation with Astronomy*

Review/Introduction

Use a cooperative structure to review previously taught terms and concepts. Ask students to identify the phase of the moon which they observed last night.

Procedures

Read to all students pages 90-99, or selected passages, of *Exploring Creation with Astronomy,* showing students the pictures which are included. The following website is very student friendly, written at two reading levels, and contains much relevant information on this lesson's objectives but contains some references to evolutionary beliefs, so teacher guidance in its use is recommended; the video at the site is not recommended:
http://starchild.gsfc.nasa.gov/docs/StarChild/solar_system_level1/solar_system.html

Have upper grade students prepare PowerPoint slides to meet the objectives outlined as rubric **Content** items 26-28. Have lower grade students begin learning the accompanying song which reinforces these concepts, and draw and label pictures in their "folder books" of asteroids, meteors, meteorites and comets, adding descriptions where appropriate.

Assessment

Grades 1-4: Evaluate students based on discussions and completed assignments.
Grades 5-8: Frequently provide students with feedback on their developing PowerPoint, and set deadlines along the way. At the end of the project, or at specified points along the way, have them self-evaluate using the rubric. The teacher should do the same, adding explanatory comments where appropriate.

Homework

Grades 1-4: Have students work on contract choices. Inform them that they will have time to work on these in class on **Day 16** and should bring to school any materials they need in order to do so.

Grades 5-8: Have students work on PowerPoint and/or contract choices.

Day 16

Objectives

Grades 1-4: Work on contract choices

Grades 5-8: Define the term light year; explain how distances in space are determined; distinguish between apparent and absolute magnitude.

Materials Needed

Grades 1-4: Materials for contract choices.

Grades 5-8:

Both:

Review/Introduction

Using a cooperative structure, review previously taught terms and concepts. Remind students of the activity, *The Earth as a Peppercorn*. Explain that the distances needed to describe the planets in our solar system are only the tiniest part of what we are beginning to understand is in the universe, so in order to talk about such great distances, scientists invented the concept of a light-year. A light-year is the distance that light can travel in one year, or about 9.5 trillion kilometers (6 trillion miles). For the benefit of younger students, turn the room lights off and ask them to observe how long it takes for them to see light after you turn the switch on. This may help them to understand that light travels very quickly so the distance it could travel in a year would be very great. Consider using one of the two opener activities found in *Explore God's World*, TE pages 454, 455.

Procedures

Remind lower grade students that they will be working on contract activities of their choice in class today. Have them organize to do so and get started.

Meanwhile, have upper grade students research and prepare PowerPoint slides to meet rubric **Content** items 29 and 30. Have them share and compare their findings.

Assessment

Grades 1-4: Evaluate students based on their completed assignments.

Grades 5-8: Frequently provide students with feedback on their developing PowerPoint and set deadlines along the way. At the end of the project, or at specified points along the way, have them self-evaluate using the rubric. The teacher should do the same, adding explanatory comments where appropriate.

Homework

Grades 1-4: Have students continue work on their contract choices.

Grades 5-8: Have students work on their PowerPoint presentation and/or contract choices.

Day 17

Objectives

Grades 1-4: Define constellation; identify the common constellations.
Grades 5-8: Define constellation; describe the circumpolar constellations; identify several common stars and constellations.

Materials Needed

Grades 1-4: pencil and paper; small star stickers; lined paper; "folder books."
Grades 5-8: computer access for research and creating PowerPoint slides.
Both: *Exploring Creation with Astronomy*, pages 153 through the middle of 154;

Review/Introduction

Using a cooperative structure, review previously taught terms and concepts. Explain to students that the stars appear in groups or clusters with a particular pattern and that these patterns are called "constellations." Read to students the information on pages 153 through the middle of 154 in *Exploring Creation with Astronomy*. Make a list of the English names of the constellations (the virgin and an infant boy, the half-man/half-horse, the balance scales, the southern cross, the slain victim, the crown, the scorpion, the serpent, the mighty one, the archer, the harp, the altar, the dragon, the goat, the water-bearer, the fish, the bridle, the crowned king, the chained queen, the ram). Elicit responses to this list to see if students make spiritual connections as suggested in *Exploring Creation with Astronomy.* Explain that not everyone agrees that these were God's way of explaining the salvation plan, but that God does seem to like symbols so it is possible and at the very least is quite interesting.

Procedures

Using Overhead Master 19-3A or 3B from the resource binder of *Explore God's World*, show students the constellations and name them. Have upper grade students research circumpolar constellations and prepare PowerPoint slides to fulfill rubric **Content** items 31 and 32.

Meanwhile, brainstorm with lower grade students a list of Biblical symbols that could be used to help tell the salvation story (manger, stable, dove, heart to represent God's love, camel to represent the wise men, etc.). Explain that their assignment is to create imaginary constellations that could help to tell the story of Jesus. Have them draw simple line drawings of these images and then make dots at strategic places as they would if they were creating a dot-to-dot picture. When they are satisfied with their drawing have them transfer it to their "folder books" and mark the dots with star stickers. Then have them write a paragraph explaining their "constellation" and add it to their "folder books."

Assessment

Grades 1-4: Evaluate students based on their completed work.

Grades 5-8: Frequently provide students with feedback on their developing PowerPoint and set deadlines along the way. At the end of the project, or at specified points along the way, have them self-evaluate using the rubric. The teacher should do the same, adding explanatory comments where appropriate.

Homework

Grades 1-4: Have students explain to their parents what some Christians have suggested about the constellations and describe the constellation which they created. Consider also having students work on contract choices. Bring in any contract projects that need to be completed as there will time during class on **Day 18.**

Grades 5-8: Have students work on PowerPoint and/or contract choices.

Day 18

Objectives

Grades 1-4: Extend astronomy learning through completing various optional activities provided.

Grades 5-8: Define the term star; explain how stars produce energy; explain how stars are classified; describe the various types of stars; describe the relationship between a nebula and new stars.

Materials Needed

Grades 1-4: As required by optional projects.

Grades 5-8: Computer access for research and creation of PowerPoint slides.

Both:

Review/Introduction

Using a cooperative structure, review previously taught terms and concepts. Organize lower grade students to work on contract activities.

Procedure

Have lower grade students work on contract choices. Meanwhile have upper grade students research and create PowerPoint slides to summarize what they learned to meet the objectives for rubric **Content** items 33-36. Sources for them to consider include pages 142-148 of *Exploring Creation with Astronomy* and/or *Explore God's World* pages 438-442 as well as internet sites.

Assessment

Grades 1-4: Evaluate students based on their completed assignments.

Grades 5-8: Frequently provide students with feedback on their developing PowerPoint, and set deadlines along the way. At the end of the project, or at specified points along the way, have them self-evaluate using the rubric. The teacher should do the same, adding explanatory comments where appropriate.

Homework

Grades 1-4: Have lower grade students continue to work on contract choices at home if necessary.

Grades 5-8: Have upper grade students work on contract choices and/or PowerPoint presentation.

Day 19

Objectives
Grades 1-4: Extend astronomy learning through completing various optional activities provided.
Grades 5-8: Describe the life cycle of stars; distinguish between a nova and a supernova; define a black hole; explain the Doppler effect; define red shift and explain its importance to astronomers.

Materials Needed
Grades 1-4: As required by optional projects.

Grades 5-8: Computer access for research and creation of PowerPoint slides;
Both:

Review/Introduction
Organize lower grade students for continued work on their contract or group projects.

Procedure
Have lower grade students work on contract or group projects. Meanwhile have upper grade students research and create PowerPoint slides to fulfill the requirements of rubric **Content** items 37-41.

Assessment
Grades 1-4: Evaluate students based on their completed projects.

Grades 5-8: Frequently provide students with feedback on their developing PowerPoint, and set deadlines along the way. At the end of the project, or at specified points along the way, have them self-evaluate using the rubric. The teacher should do the same, adding explanatory comments where appropriate.

Homework
Grades 1-4: Continue work on contract choices if necessary.

Grades 5-8: Have upper grade students work on contract choices and/or PowerPoint presentation.

Day 20

Objectives
Grades 1-4: Extend astronomy learning through completing various optional activities provided; prepare for end of unit project/presentation.
Grades 5-8: Define the term galaxy; compare and contrast the main types of galaxies; describe the galaxy that includes Earth's solar system; identify Earth's position in the galaxy.

Materials Needed
Grades 1-4: As required by optional projects
Grades 5-8: computer access for research and creation of PowerPoint slides.
Both:

Review/Introduction
Using a cooperative structure, review previously taught terms and concepts.

Procedure
Organize lower grade students to work on contract projects.

Meanwhile have upper grade students research galaxies and prepare PowerPoint slides to meet the requirements of rubric **Content** items 42-44.

Assessment
Grades 1-4: Evaluate students based on their completed assignments.
Grades 5-8: Frequently provide students with feedback on their developing PowerPoint and set deadlines along the way. At the end of the project, or at specified points along the way, have them self-evaluate using the rubric. The teacher should do the same, adding explanatory comments where appropriate.

Homework
Grades 1-4: Have students work on contract items.
Grades 5-8: Have students work on PowerPoint presentation and/or contract items.

Day 21

Objectives

Grades 1-4: Extend astronomy learning through completing various optional activities provided; prepare for end of unit project/presentation.
Grades 5-8: Critique racial and gender biases as they relate to physical science careers; explore careers in space science.

Materials Needed

Grades 1-4: As required by optional projects
Grades 5-8: Computer access for research and creation of PowerPoint slides
Both: paper and pencil for drawing

Review/Introduction

Using a cooperative structure, review previously taught terms and concepts.
(c) The following activity was written by Alan Friedman (New York Hall of Science) and Andrew Fraknoi (Foothill College).

The Universe At Your Fingertips Activity: Picture an Astronomer

The media and our past experiences have shaped and created our expectations of people in various careers. Astronomers are often typecast as middle-aged, white, "nerdy" males by students and adults alike. However, astronomy is carried out by men and women in every country and by people young and old. This activity is a wonderful way to call attention to, and discuss, our preconceptions about who "can" be an astronomer.

Read the following paragraph to students:

Close your eyes and picture this scene. It is the end of a long night at the observatory and the astronomer is closing up as the first rays of dawn are seen on the horizon. The astronomer is tired and ready for a good day's sleep. Now focus in on the astronomer, coming toward you on the road that comes from the observatory. Get a good close look at the astronomer, rubbing tired eyes. Draw a picture of what the astronomer looks like.

Note that this paragraph carefully omits any hint about the gender, age, or race of the astronomer. After students have made their own picture (as elaborately or as simply as time allows), have them compare and discuss the different pictures they came up with. In the past, there has been a tendency for participants of all ages to draw scientists as middle-aged white men. If your students also show such a tendency, this gives you an opportunity to discuss who became an astronomer in the past, and how the opportunities have expanded today and some (but by no means all) of the societal barriers have fallen.

Procedure

Have lower grade students work on contract or culminating projects. This might include designing invitations for parents, church constituents or the community to attend a culminating event. Meanwhile have upper grade students research space careers and create PowerPoint slides to fulfill the requirements of rubric **Content** items 45 and 46.

Assessment

Grades 1-4: Evaluate students based on their completed assignments.

Grades 5-8: Frequently provide students with feedback on their developing PowerPoint, and set deadlines along the way. At the end of the project, or at specified points along the way, have them self-evaluate using the rubric. The teacher should do the same, adding explanatory comments where appropriate.

Homework

Grades 1-4: Complete contract items as necessary.

Grades 5-8: Complete PowerPoint and/or contract items.

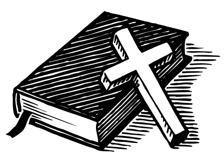
A sample student contract follows. In some cases it may advisable to create contracts without grade levels listed at the top. For students in grades 3-8 add a section of astronomy projects. Many are provided in the projects section of this binder.

First and Second Grade Contract

Name ________________ Date ___________

Choose at least one activity from each section to complete.

<u>Bible</u>



☐ Draw and color pictures to show what God made on each day of creation.

☐ Draw a picture showing what you think it will be like to travel through space with Jesus when He comes back to get us. Write at least two sentences to explain your picture.

☐ Write a prayer to God thanking Him for the things He made in the heavens.

☐ Tell a friend who doesn't know Jesus what you have been studying and invite him or her to come to Sabbath School or do some star gazing with you.

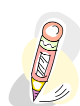
Social Studies

☐ Choose a book about an astronaut or other worker in the field of astronomy and read it alone or with a helper. Write at least 5 sentences telling what you learned about the person.

☐ Find out what another country is doing for space exploration. Write down what you learned and share it with your class.

☐ Use the internet to visit the following site: http://starchild.gsfc.nasa.gov/docs/StarChild/StarChild.html. Under level one go to space stuff and find out what a person has to do to become an astronaut. Also check out the section on space clothes. Make a poster showing what you learned about at least one of these things.

Language Arts



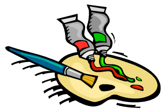
☐ Make a picture dictionary of at least 10 new words you have learned. Be sure they are in abc order.

☐ Make a word search puzzle using words you have learned in the astronomy unit.

☐ Write and illustrate a story about your trip from earth to heaven with Jesus at His second coming.

- Write a poem about astronomy. It doesn't have to rhyme.

☐ Make an astronomy memory game using matching words and their meanings.

<u>Arts</u> 

☐ Make a mobile showing the 8 planets of our solar system.

☐ Print pictures of outer space from the internet or cut them from magazines. Organize them into a photo album or scrap book and label them.

- With an adult, make a star sun catcher (your teacher has directions).

☐ Build a model spacecraft from a kit or from recycled materials.

- Color the robot puzzle your teacher can give you. Make sure all the similar robots are colored the same. Cut the puzzle pieces apart and mix them up. Work with a family member to put them back together correctly.

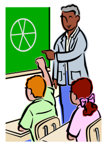
☐ Ask your teacher for permission to do an art project you think up.

<u>Music</u> 

☐ Ask someone to help you find a hymn which talks about going to or being in heaven. Learn the hymn and be ready to help your classmates sing it.

- Ask someone to help you find a recording of classical music. Take it outside on a clear night and listen to it while you look at the stars. Draw a picture or write about your thoughts while you listened.

Math



☐ Using the Internet or science supply catalogs, find the prices of at least three different telescopes. Choose one to buy. Using your actual or a reasonable allowance amount, find out how long it would take you to save enough money to buy the telescope after taking out tithe and offerings. If you started saving right now, on what date would you be able to buy the telescope?

☐ Write at least 5 math story problems about astronomy things. Be sure you give enough information to solve the problems. Find the answers and write them on the back of the paper with the problems.

☐ Think of a question you can ask family and friends (for example, what planet would you most like to know more about?). Make tally marks to keep track of their choices. Make a graph to show their answers.