STARLAB

Portable Planetarium System

— Part C —

Grades 7-12 Activities and Lessons for Use in the STARLAB Portable Planetarium

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Using the Curriculum Guide for Astronomy and Interdisciplinary Topics in Grades 7-12

Introduction

- This curriculum guide has been designed for two equally important purposes: to assist planetarium directors or classroom teachers in integrating classroom experiences with planetarium experiences, and to involve students in active inquiry lessons in the planetarium. It is our hope that your students will be active participants rather than passive observers. Many of the suggested activities can be modified or adjusted as you see fit for your students.
- Throughout this curriculum guide, objectives are stated to allow the student to become the chief investigator whenever possible. Often the students will be asked to point out objects or locations, measure distances, or even use various instruments to gather data and record it. For an individual student, an activity may not conclude until weeks later when he/she completes independent study.

This guide has been designed to take advantage of the true interdisciplinary nature of STARLAB. As you examine the guide you will find its structure includes:

- Major categories or disciplines (ex. Science-Earth, Life, Physical, Space)
- Topics of study consist of major concepts for student mastery.
- Student objectives include the process skills necessary for the learner to become actively involved in the learning process. Even though all of the objectives may not meet strict definitions set up for behavioral or performance objectives, they will be helpful in evaluating student learning and the success of the activity.
- PASS Volume activities are located in the 13 volume set of *Planetarium Activities for Student Success*. These tried, tested and proven activities are highly effective in achieving learning objectives by involving students in hands-on/minds-on activities that foster essential process and critical thinking skills.
- Other activities include learning experiences located in resources such as the STARLAB cylinder guides or the Project STAR book *Where We are in Space and Time* as well as many others. Many of the activities are designed specifically for use in STARLAB and others have more impact when conducted in the classroom. All activities may be modified at the instructor's discretion.
- A resource list is found at the end of this guide and should serve to assist you in locating various resources.

Note

One set of the 13-volume PASS series (referred to throughout this section) is sent to you free when you return your Product Registration form. If you haven't already received a set with your system, make sure to send in your form!

Additional sets can be ordered through Science First/STARLAB, by calling 800-537-8703 or 716-874-0133 or by visiting our Web site at: www.starlab.com.

Sciences: Earth, Life, Physical and Space

Curriculum Guide for Astronomy and Interdisciplinary Topics in Grades 7-12

Topic of Study 1: The Earth as an Astronomical Object

Concepts

1. The shape of the earth
2. The rotation of the earth
3. Proving the rotation of the earth
4. Causes of day and night
5. Precession

Student Objectives

1. Use the Earth Cylinder to point out regions of departure from sphericity.
2. Simulate the paths of satellites on the dome by sweeping the arrow pointer rapidly across the dome.
3. In the planetarium, dim the side lamps during daytime hours to reveal that the stars are really out and just obscured by the brightness of the sun.
4. Use the Celestial Coordinates Cylinder to help students visualize the precessional path of the earth's north and south polar axis.

PASS Volume Activities

- "Activity 16: The Trip to Treasure Island," Volume 2, *Activities for the School Planetarium*.
- "How Big Is the Earth?," Volume 10, *Who "Discovered" America?*.
- "What Shape is the Earth?," Volume 10, *Who "Discovered" America?*.

Other Activities

- "Motion of the Stars," by Gary D. Kratzer, from *A Collection of Curricula for the STARLAB Starfield Cylinder*.
- "The Earth's Shape and Gravity," *Earth, Moon and Stars*, Great Explorations in Math and Science (GEMS), Lawrence Hall of Science, University of California, Berkeley.

Suggested Cylinders

- Earth
- Celestial Coordinates
- Northern Starfield
- Ocean Currents
- Weather

Topic of Study 2: Latitude and Longitude

Concepts

1. Meridians (longitude)
2. Parallels (latitude)
3. International Date Line
4. Climatic Zones

Students Objectives

1. Use the Earth Cylinder to help students visualize the locations of continents, poles, equator, prime meridian, lines of latitude and longitude.
2. Compare the meridians (longitude) and parallels (latitude) on a globe to those projected in STARLAB.
3. Locate the regions of the earth known as the tropics.
4. Compare and contrast the climates of the tropics and arctic circle.
5. Using the coordinate system, locate various geographic locations.
6. Reinforce the use of the coordinate system with the Celestial Coordinates Cylinder. Demonstrate how celestial longitude (right ascension) and celestial latitude (declination) are used to located objects in space.

PASS Volume Activities

- "Activity 16: The Trip to Treasure Island," Volume 2, *Activities for the School Planetarium*.
- "Latitude and Longitude," Volume 10, *Who "Discovered" America*.

Other Activities

- "A Current Affair," *A Collection of Curricula for the STARLAB Weather Cylinder*.
- "Go with the Flow," *A Collection of Curricula for the STARLAB Ocean Currents Cylinder*.
- "Lost at Sea," *A Collection of Curricula for the STARLAB Ocean Currents Cylinder*.
- "Name That Star," *A Collection of Curricula for the STARLAB Celestial Coordinates Cylinder*.
- "Sailing With Columbus," *A Collection of Curricula for the STARLAB Weather Cylinder*.
- "Where On Earth Am I???," *A Collection of Curricula for the STARLAB Earth Cylinder*.

Suggested Cylinders

- Earth
- Celestial Coordinates
- Ocean Currents
- Weather

Topic of Study 3: The Earth's Atmosphere

Concepts

1. Layers of the atmosphere
2. Clouds

3. Water cycle
4. Air currents
5. Pressure systems
6. Jet streams

Student Objectives

1. Explain that planetary circulation is a result of the Coriolis effect, unequal heating of the earth and wind.
2. Use the Weather Cylinder to locate wind systems, pressure systems and jet streams.
3. Describe the water cycle.
4. Explain land and sea breezes.

Other Activities

- "A Current Affair," *A Collection of Curricula for the STARLAB Weather Cylinder*.
- "Stormy Weather," *A Collection of Curricula for the STARLAB Weather Cylinder*.
- "Bombs Away," *A Collection of Curricula for the STARLAB Weather Cylinder*.

Suggested Cylinders

- Earth
- Weather
- Ocean Currents

Topic of Study 4: The Sun and Its Energy

Concepts

1. Emphasize that the sun is a star at the center of the solar system
2. Discuss the sun's influence on the earth and seasons
3. Model a solar eclipse

Student Objectives

1. Make a model of the earth-moon-sun system.
2. Show that seasonal variations of the sun's path is one of the reasons for the seasons.
3. Demonstrate the changing amount of energy received from the sun on a daily and seasonal cycle.
4. Track the motion of the sun.

PASS Volume Activities

- "Activity 12: The Reasons for Seasons," Volume 2, *Activities for the School Planetarium*.

Other Activities

- Activity 16: "How Many 200-watt Bulbs 'Equal' the Sun?" *Where We Are in Space and Time*, Project STAR, p. 121.
- "Keeping a Journal of the Sun's Motion," *Where We Are in Space and Time*, Project STAR, p. 8.
- "Modeling Moon Phases and Eclipses," *Earth Moon and Stars*, Great Explorations in Math and Science (GEMS), Lawrence Hall of Science, University of California, Berkeley. pp. 23-30.

- "Plotting the Daily Motion of the Sun," *Where We Are in Space and Time*, Project STAR, p. 12.
- "Scale Model of the Earth, Moon and Sun," *Where We Are in Space and Time*, Project STAR, p. 88.
- "Seasons On the Earth," *Where We Are in Space and Time*, Project STAR, p. 40.

Suggested Cylinders

- Starfield
- Constellation

Topic of Study 5: The Stars

Concepts

1. Understand the nature of stars
2. Distance to the stars
3. Apparent motion of the stars
4. Energy from stars

Student Objectives

1. Explain that stars form in great clouds of dust and gas called nebulae.
2. Discuss the ratio of brightness and numbers.
3. Discuss the magnitude system of star brightness and demonstrate that the apparent brightness is the result of real brightness and distance.
4. Explain that variable stars fluctuate in brightness over periods of time.
5. Using the Deep Sky Objects Cylinder, find the location of various variable stars.
6. Explain that stars have different colors due to variations in their temperatures.
7. Understand that the distances to stars is determined by a method known as parallax.
8. Interpret the differences of size, temperature, brightness, color, and mass of stars on the Hertzsprung-Russell Diagram.
9. Describe proper motion.

PASS Volume Activities

- Activity 8: "Measuring the Brightness of Stars," Volume 2, *Activities for the School Planetarium*.
- Activity 9: "Observing a Variable Star," Volume 2, *Activities for the School Planetarium*.
- "Colors and Temperatures of Stars," Volume 8, *Colors and Space*.
- "How Do We Tell Distance By Parallax?," Volume 9, *How Big is the Universe?*.
- "Brightness of Stars," Volume 9, *How Big is the Universe?*.
- "Cepheid Variable Stars," Volume 9, *How Big is the Universe?*.
- "Parallax-How Far Is It," Volume 9, *How Big is the Universe?*.
- "What Stars Are Made Of," Volume 8, *Colors and Space*.

Other Activities

- Activity 14: "Stellar Parallax," *Where We Are in Space and Time*, Project STAR, p. 99.

- Activity 15: "How Bright At What Distance?," *Where We Are in Space and Time*, Project STAR, p. 113.
- Activity 16: "How Many 200-watt Bulbs 'Equal' the Sun?" *Where We Are in Space and Time*, Project STAR, p. 121.
- Activity 17: "Using Brightness To Estimate Stellar Distances," *Where We Are in Space and Time*, Project STAR, p. 128.
- "How Many Stars," A Teacher Resource to Enhance Astronomy Education: Project SPICA, Sponsored by the Harvard Smithsonian Center for Astrophysics, Kendall/Hunt Publishing Co., Dubuque, Iowa, 1994, p. 175.
- "The Parallax of a Star," A Teacher Resource to Enhance Astronomy Education: Project SPICA, Sponsored by the Harvard Smithsonian Center for Astrophysics, Kendall/Hunt Publishing Co., Dubuque, Iowa, 1994, p. 168.
- "Star Counting," A Teacher Resource to Enhance Astronomy Education: Project SPICA, Sponsored by the Harvard Smithsonian Center for Astrophysics, Kendall/Hunt Publishing Co., Dubuque, Iowa, 1994, p. 164.

Suggested Cylinders

- Starfield
- Deep Sky Objects
- Celestial Coordinates
- Constellation

Topic of Study 6: The Physical Universe

Concepts

1. Deep sky objects (nebulae, star clusters and galaxies)
2. Classification of galaxies
3. The Milky Way Galaxy
4. Celestial coordinates system

Student Objectives

1. Explain that the universe is expanding.
2. Understand that galaxies are large systems of stars held together by gravity and billions of galaxies exist in the universe.
3. Discuss nature and types of nebulae.
4. Explain that stars form from great clouds of dust and gas known as nebulae and evolve over millions/billions of years.
5. Show slides of and identify different types of nebulae, open clusters, globular clusters and galaxies.
6. Using pictures of galaxies, classify them by shape and brightness.
7. Explain that the sun is only one of billions of stars that constitute our galaxy, the Milky Way.
8. Using the Deep Sky Objects Cylinder, locate the positions of various deep sky objects.
9. Using the Celestial Coordinates Cylinder, locate deep sky objects by their coordinate values.
10. Using the Celestial Coordinates Cylinder, locate the plane of the Milky Way and trace its path across the sky at various times of the year.

PASS Volume Activities

- "A Ballooning Universe," Volume 9, *How Big Is The Universe?*.
- "Cepheid Variable Stars," Volume 9, *How Big Is The Universe?*.
- "The Expanding Universe," Volume 9, *How Big Is The Universe?*.
- "Your Galactic Address," Volume 9, *How Big Is The Universe?*.

Other Activities

- Activity 19, "Where Are We In the Milky Way Galaxy?," *Where We Are in Space and Time*, Project STAR, p. 153.
- Activity 20, "Determining Galaxy Sizes and Distances," *Where We Are in Space and Time*, Project STAR, p. 165.
- Activity 21, "Observing the Structure of the Universe," *Where We Are in Space and Time*, Project STAR, p. 169.
- "Name that Star!!," *A Collection of Curricula for the STARLAB Celestial Coordinates Cylinder*.

Suggested Cylinders

- Celestial Coordinates
- Constellation
- Deep Sky Objects
- Starfield

Topic of Study 7: The Solar System

Concepts

1. Earth, moon and sun system
2. Planets
3. Asteroids, comets, and meteoroids
4. Moons of the planets
5. Phases of the moon
6. Eclipses
7. Rotation and revolution
8. Orbital characteristics

Student Objectives

1. Understand that the sun is a star at the center of the solar system.
2. Create a model to demonstrate that the moon orbits the earth, causing the phases of the moon.
3. Create a model to demonstrate that the relative positions of the sun, earth, and moon cause eclipses.
4. Explain that the solar system encompasses nine planets, moons, asteroids, comets, and meteoroids.
5. Recreate the discovery of planets.
6. Make a model to gather data on the impact that meteors have on the earth.
7. Understand that the planets revolve around the sun in specific orbits.
8. Recognize physical characteristics of the moon and planets.

PASS Volume Activities

- Activity 10: "Using a Blink Comparator," Volume 2, *Activities for the School Planetarium*.
- "Find the Planet Activity," Volume 6, *Red Planet Mars*.
- "Telescope Views," Volume 6, *Red Planet Mars*.
- "Simulating The Solar System," Volume 6, *Red Planet Mars*.
- "Observing Phases of the Moon," Volume 7, *Moons of the Solar System*.
- "Explaining the Phases of the Moon," Volume 7, *Moons of the Solar System*.
- "The Galilean Moons of Jupiter," Volume 7, *Moons of the Solar System*.
- "Meteoroids and Craters," Volume 7, *Moons of the Solar System*.
- "Building A Lunar Settlement," Volume 7, *Moons of the Solar System*.
- "Moon Maps," Volume 7, *Moons of the Solar System*.

Other Activities

- Activity 2: "Keeping a Journal of the Moon's Motion," *Where We Are in Space and Time*, Project STAR, p. 8.
- Activity 5: "Phases of the Moon," *Where We Are in Space and Time*, Project STAR, p. 25.
- Activity 12: "Scale Models of the Earth, Moon, and Sun," *Where We Are in Space and Time*, Project STAR, p. 88.
- Activity 13: "Scale Models of the Solar System," *Where We Are in Space and Time*, Project STAR, p. 92.
- "Calculating the Moon's Diameter," A Teacher Resource to Enhance Astronomy Education: Project SPICA, Sponsored by the Harvard Smithsonian Center for Astrophysics, Kendall/Hunt Publishing Co., Dubuque, Iowa, 1994, p. 33.
- "How Big is the Sun," AA Teacher Resource to Enhance Astronomy Education: Project SPICA, Sponsored by the Harvard Smithsonian Center for Astrophysics, Kendall/Hunt Publishing Co., Dubuque, Iowa, 1994, p. 8.
- "Modeling Moon Phases and Eclipses," *Earth, Moon and Stars*, Great Explorations in Math and Science (GEMS), Lawrence Hall of Science, University of California, Berkeley, pp. 23-30.
- "Weight On Another Planet," A Teacher Resource to Enhance Astronomy Education: Project SPICA, Sponsored by the Harvard Smithsonian Center for Astrophysics, Kendall/Hunt Publishing Co., Dubuque, Iowa, 1994, p. 77.

Suggested Cylinders

- Constellation
- Starfield

Topic of Study 8: Constellations

Concepts

1. Constellations as boundaries in the sky
2. Constellations as sky markers
3. Historical significance

Student Objectives

1. Locate constellations in the planetarium/night sky.
2. Discuss the significance of the zodiacal constellations.

3. Create a model to explain the meaning of your "sign."

P.A.S.S. Volume Activities

- Activity 15: "What's Your Sign.?" Volume 2, *Activities for the School Planetarium*.

Other Activities

- "Using Star Maps," *Earth, Moon and Stars*, Great Explorations in Math and Science (GEMS), Lawrence Hall of Science, University of California, Berkeley, pp. 39-49.
- "The Big Dipper in Three Dimensions: A Box," A Teacher Resource to Enhance Astronomy Education: Project SPICA, sponsored by the Harvard Smithsonian Center for Astrophysics, Kendall/Hunt Publishing Co., Dubuque, Iowa, 1994, p. 157.
- "Three-Dimensional Models of Constellations," *Where We Are in Space and Time*, Project STAR, p. 139.

Suggested Cylinders

- Constellation
- Greek Mythology
- Starfield

Topic of Study 9: Astronomy and Cultures

Concepts

1. Origin and evolution
2. Historical and social significance
3. Practical uses of astronomy

Student Objectives

1. Differentiate between astronomy and astrology.
2. Discuss how astronomy and its history affect our understanding of humanity's place in the universe.
3. Examine the origins and evolution of mythological.
4. Compare and contrast mythologies of various cultures.

PASS Volume Activities

- Activity 1: "Predicting Today's Sunset," Volume 12, *Stonehenge*.
- Activity 2: "Reconstructing Stonehenge," Volume 12, *Stonehenge*.
- Activity 15: "What's Your Sign?," Volume 2, *Activities for the School Planetarium*.
- "Astronomy of the Americas," Volume 11, *Astronomy of the Americas*.
- "Stonehenge," Volume 12, *Stonehenge*.

Other Activities

- "African Skies," *A Collection of Curricula for the STARLAB African Mythology Cylinder*.
- *A Collection of Curricula for the STARLAB Greek Mythology Cylinder*.
- *A Collection of Curricula for the STARLAB Native American Mythology Cylinder*.
- "Ancient Models of the World," *Earth, Moon and Stars*, Great Explorations in Math and Science (GEMS), Lawrence Hall of Science, University of California, Berkeley, pp. 3-8.

- "The Skies of Ancient China I: Information and Activities," *A Collection of Curricula for the STARLAB Ancient Chinese Seasons Cylinder (the Four Beasts)*.

Suggested Cylinders
- African Mythology
- Ancient Chinese Seasons
- Greek Mythology
- Native American Mythology
- Starfield

Topic of Study 10: Astronomers and Their Tools

Concepts
1. Anaximander, Pythagoras, Erastosthenes
2. Ptolemy
3. Nicholas Copernicus
4. Tycho Brahe and Johannes Kepler
5. Galileo
6. Sir Isaac Newton
7. Albert Einstein
8. Telescope
9. Spectroscope
10. Radio astronomy

Student Objectives
1. Discuss the significance of the contribution of the ancient Greeks in the development of mathematical methods.
2. Explain how a reformation came about in the Middle Ages by the work of intellectuals such as Nicholas Copernicus.
3. Recreate some of the discoveries of Galileo.
4. Demonstrate Newton's Laws of Gravity.
5. Discuss the basic principles of Einstein's Theory of Relativity.
6. Demonstrate the significance of the telescope, spectroscope, and radio telescope to discoveries in astronomy.
7. Explain how various instruments study the universe through the electromagnetic spectrum.
8. Understand that the scientific method is used as a means of rational inquiry about natural phenomenon and forms the basis for science itself.

PASS Volume Activities
- "How to Build and Use a Spectrometer," Volume 8, *Colors and Space*.
- "The Galilean Moons of Jupiter," Volume 7, *Moons of the Solar System*.
- "The Moon Through a Telescope," Volume 7, *Moons of the Solar System*.

Other Activities
- "Ancient Models of the World," *Earth, Moon and Stars*, Great Explorations in Math and Science (GEMS), Lawrence Hall of Science, University of California, Berkeley, pp. 3-8.

- "Building and Using an Astronomical Telescope," *Where We Are in Space and Time*, Project STAR, p.72.
- "Images From Space," A Teacher Resource to Enhance Astronomy Education: Project SPICA, Sponsored by the Harvard Smithsonian Center for Astrophysics, Kendall/Hunt Publishing Co., Dubuque, Iowa, 1994, p. 141.
- "The Spectroscopic Analysis of Starlight," A Teacher Resource to Enhance Astronomy Education: Project SPICA, Sponsored by the Harvard Smithsonian Center for Astrophysics, Kendall/Hunt Publishing Co., Dubuque, Iowa, 1994, p. 111.

Suggested Cylinders

- Starfield

Topic of Study 11: Space Exploration

Concepts

1. Advanced astronomy
2. "Spin-off" technology
3. Spacecraft

Student Objectives

1. Understand that spacecraft have revolutionized astronomy by allowing astounding observations to be made outside of the earth's atmosphere.
2. Discuss how space flight provides a wide variety of benefits to modern civilization.
3. Speculate on the future of space exploration.

PASS Volume Activities

- "Building A Lunar Settlement," Volume 7, *Moons of the Solar System*.
- "Invisible Colors," Volume 8, *Colors and Space*.
- "The Mariner 9 and Viking Missions," Volume 6, *Red Planet Mars*.
- "Tour of Moons," Volume 7, *Moons of the Solar System*.

Other Activities

- "Images From Space," A Teacher Resource to Enhance Astronomy Education: Project SPICA, Sponsored by the Harvard Smithsonian Center for Astrophysics, Kendall/Hunt Publishing Co., Dubuque, Iowa, 1994, p. 141.

Suggested Cylinders

Starfield

Topic of Study 12: Exobiology

Concept

Possibilities of life in the universe

Student Objectives

1. Understand cellular functions of earth life.
2. Invent life forms which are adapted to their environment.
3. Discuss twentieth century exobiological studies.

PASS Volume Activities

- "Creatures From Omicron," Volume 6, *Red Planet Mars*.
- "Exobiology Activity," Volume 6, *Red Planet Mars*.
- "How Does Your Creature Survive?," Volume 6, *Red Planet Mars*.

Other Activities

- "The Cell Game," *A Collection of Curricula for the STARLAB Biological Cell Cylinder*.

Suggested Cylinders

- Biological Cell
- Starfield

Mathematics

Topic of Study: Mathematics Used in Earth and Space Science Applications

Concepts

1. Angles and distance measurements
2. Brightness of stars
3. Coordinate systems
4. Motions of the sun and planets
5. Parallax
6. Scale models
7. Time

Student Objectives

1. Measure the hourly movement of the sun and moon.
2. Use coordinates to plot the positions of stars and planets.
3. Use coordinates to plot locations on the earth.
4. Explain how the distance to stars and planets are calculated.
5. Create scale models of the solar system.
6. Calculate time in different parts of the world.

P.A.S.S. Activities

- "Activity 16: The Trip to Treasure Island," Volume 2, *Activities For The School Planetarium*.
- "How Do We Tell Distance By Parallax,?" Volume 9, *How Big is the Universe?*.
- "Latitude and Longitude," Volume 10, *Who "Discovered" America?*.
- "Parallax-How Far Is It," Volume 9, *How Big is the Universe?*.

Other Activities

- Activity 1: "Keeping a Journal of the Sun's Motion," *Where We Are in Space and Time*, Project STAR, p. 5.
- Activity 2: "Keeping a Journal of the Moon's Motion," *Where We Are in Space and Time*, Project STAR, p. 8.
- Activity 7: "Estimating Size and Distance," *Where We Are in Space and Time*, Project STAR, p. 53.
- Activity 11: "Solar System Distances Using Parallax," *Where We Are in Space and Time*, Project STAR, p. 81.

- Activity 12: "Scale Models of the Earth, Moon, and Sun," *Where We Are in Space and Time*, Project STAR, p. 88.
- Activity 13: "Scale Models of the Solar System," *Where We Are in Space and Time*, Project STAR, p. 92.
- Activity 14: "Stellar Parallax," *Where We Are in Space and Time*, Project STAR, p. 99.
- Activity 15: "How Bright At What Distance," *Where We Are in Space and Time*, Project STAR, p. 113.
- Activity 20: "Determining Galaxy Sizes and Distances," *Where We Are in Space and Time*, Project STAR, p. 165.
- "A Current Affair," *A Collection of Curricula for the STARLAB Weather Cylinder*.
- "Calculating The Moon's Diameter," A Teacher Resource to Enhance Astronomy Education: Project SPICA. Sponsored by the Harvard Smithsonian Center for Astrophysics, Kendall/Hunt Publishing Co., Dubuque, Iowa, 1994, p. 33.
- "Go with the Flow," *A Collection of Curricula for the STARLAB Ocean Currents Cylinder*.
- "How Big Is The Sun," A Teacher Resource to Enhance Astronomy Education: Project SPICA. Sponsored by the Harvard Smithsonian Center for Astrophysics, Kendall/Hunt Publishing Co., Dubuque, Iowa, 1994, p. 8.
- "Lost at Sea," *A Collection of Curricula for the STARLAB Ocean Currents Cylinder*.
- "Name That Star," *A Collection of Curricula for the STARLAB Celestial Coordinates Cylinder*.
- "Sailing With Columbus," *A Collection of Curricula for the STARLAB Weather Cylinder*.
- "Weight On Another Planet." A Teacher Resource to Enhance Astronomy Education: Project SPICA, Sponsored by the Harvard-Smithsonian Center for Astrophysics, Kendall / Hunt Publishing Co., Dubuque, Iowa, 1994, p. 77.
- "Where on Earth am I???," *A Collection of Curricula for the STARLAB Earth Cylinder*.

Suggested Cylinders

- Celestial Coordinates
- Earth
- Ocean Currents
- Starfield
- Weather

Topic of Study: Earth

Concepts

- Shape of the earth
- Rotation and revolution
- The seasons
- Latitude and longitude
- Winds and ocean currents
- Climatic zones
- Time
- Plate Tectonics

Student Objectives

1. Using the earth cylinder, show regions which depart from sphericity.
2. Model the earth's rotation (day) and revolution (year).
3. Calculate the length of day for the solstices and equinoxes.
4. Observe the altitude of the sun for each season.
5. Explain how points on the earth are found using coordinates.
6. Synthesize the connection between ocean currents, prevailing winds, and pressure systems.
7. Calculate time differentials in various time zones.
8. Show how the earth's surface is constantly changing due to the movements of plates and continental drift.

PASS Volume Activities

- "Activity 12: The Reasons for Seasons," Volume 2, *Activities for the School Planetarium*.
- "Activity 16: The Trip to Treasure Island," Volume 2, *Activities for the School Planetarium*.
- "Astronomy of the Americas," Volume 11, *Astronomy of the Americas*.
- "How Big Is the Earth?," Volume 10, *Who "Discovered" America?*.
- "Stonehenge," Volume 12, *Stonehenge*.
- "What Shape is the Earth?," Volume 10, *Who "Discovered" America?*.

Other Activities

- "A Current Affair," *A Collection of Curricula for the STARLAB Weather Cylinder*.
- "Go with the Flow," *A Collection of Curricula for the STARLAB Ocean Currents Cylinder*.
- "Lost at Sea," *A Collection of Curricula for the STARLAB Ocean Currents Cylinder*.
- "Name That Star," *A Collection of Curricula for the STARLAB Celestial Coordinates Cylinder*.
- "Sailing With Columbus," *A Collection of Curricula for the STARLAB Weather Cylinder*.
- "The Changing Earth," *A Collection of Curricula for the STARLAB Plate Tectonics Cylinder*.

- "The Earth's Shape and Gravity," *Earth, Moon and Stars*, Great Explorations in Math and Science (GEMS), Lawrence Hall of Science, University of California, Berkeley.
- "Where on Earth am I???," *A Collection of Curricula for the STARLAB Earth Cylinder*.

Suggested Cylinders

- Celestial Coordinates
- Earth
- Ocean Currents
- Plate Tectonics
- Starfield
- Weather

STARLAB Planetarium Curriculum Outline for Astronomy

Introduction

Your STARLAB Portable Planetarium is ideally suited for teaching astronomy. The following suggested outline should prove useful for designing lessons and your grade level curriculum. Many of the suggested topics and concepts can be modified for your students as you see fit.

The outline consists of a topic of study followed by a list of concepts for which new activities may be designed. Student objectives are written in performance terms which states what the learner should be able to accomplish by the end of the study. A list of suggested cylinders to use in STARLAB is also included.

When planning activities for your students, it is recommended that you refer to the previous section, "A Curriculum Guide for Astronomy and Interdisciplinary Topics for Grades 7-12," or refer to the resource list at the end of the guide.

I. Topic of Study: Introduction to the Planetarium and the Celestial Sphere (50 min.)

Suggested Cylinders: Starfield

A. Definition of astronomy

B. Cardinal points — N, E, S, and W

C. Sky at North Pole — note positions of Big & Little Dipper

D. Sky at your latitude — use the North Star to tell latitude

E. Stars — note brightness and color differences

F. Locating simple constellations with overlay Orion and Cassiopeia

G. Identify visible planets (inferior & superior)

H. Moon — phases and lunar month

I. Sunrise, moon sets, twilight

Student Objectives

During and following this program of instruction, students will be able to:

- Recognize and identify the cardinal points N, E, S, W.
- Locate the Big and Little Dipper at the North Pole and at your latitude.
- Explain that the height of Polaris above the horizon in degrees is equal to an observer's latitude in the northern hemisphere.
- Orally distinguish between star brightness and colors.
- Locate and identify the following additional constellations: Orion and Cassiopeia.
- Explain the difference between inferior and superior planets.
- Recognize and name the earth's equator and poles.
- Identify a full, new, and quarter phase moon.

II. Topic of Study: Celestial Sphere Relationships

Suggested Cylinders: Celestial Coordinates, Earth, Constellation, Starfield

A. Earth as a sphere — divides into hemispheres, has poles

B. Celestial sphere orientation

C. All objects in the sky seen against the celestial sphere (sun, moon, planets, stars)

D. Earth's poles — rotates about these poles

E. Sky poles — sky appears to turn about celestial poles

F. Earth's equator — divides into N and S hemispheres

G. Celestial equator — divides sky into N and S hemispheres

H. Ecliptic: sun's apparent path against star background in the course of a year

   1. Ecliptic's relation to the celestial equator during the year
   2. Used for setting planetarium
   3. All planets and moon near ecliptic
   4. 12 zodiac constellations along ecliptic

I. Local point of reference

   1. Horizon
   2. Zenith
   3. Meridian

Student Objectives

Following this program of instruction, students will be able to:

- Recognize, identify and name: celestial sphere, north and south celestial poles, earth's equator, north and south poles of earth, ecliptic and celestial equator from a diagram of the celestial sphere.
- Recognize, identify and name: horizon, meridian and zenith from diagram of a local point of observation.
- Recall or look up astronomical definitions for the points in A and B above.
- Identify at what two times during the year the ecliptic and celestial equator cross.
- Explain the line where the planets, moon, sun and zodiac are located.

III. Topic of Study: Light in Astronomy Demonstrations I

A. Light and sound

B. Dispersion of white light into spectrum (R-O-Y-G-B-I-V)

   1. Prism
   2. Diffraction grating

C. Polarizing light

   1. Light from source vibrating in all directions
   2. Passing through single polarizer emits only light vibrating in one plane; passing through second at right angle cuts off all light
   3. Double polarizer demonstration

D. Fluorescence and phosphorescence

   1. Light emission from ultraviolet, stimulation (long and short wave) — use chalk, ink, minerals that fluoresce under U-V light, relate to fluorescent lighting

2. Phosphorescent minerals and paint — gives off light with no external stimulation

E. Light from an electric arc — carbon arc demonstration

F. Light from a sound-modulated light generator

Student Objectives

During and following this program of instruction, students will be able to:

- Disperse light into a spectrum with a prism and a diffraction grating.
- Recall and recite the exact order of colors in the spectrum.
- Observe a prepared slide on the theory of polarizing light.
- Use a variable density filter to polarize light and relate observations to prepared slide.
- Distinguish between and identify fluorescent minerals from phosphorescent minerals.
- Relate observations to fluorescent lighting and explain how a fluorescent light works.
- Collect carbon rods and observe operation of a carbon-arc lamp taking necessary precautions to protect eyes.
- Question the operation of a sound-modulated light generator.

IV. Topic of Study: Light in Astronomy Demonstrations II

A. Light and sound

B. The spectroscope — observe 3 types of spectra: continuous from projector bulb, bright-line from fluorescent lights, dark-line from sunlight reflected off a light object. (Cardboard and plastic spectrometers are available through Project STAR, c/o Science First/STARLAB, 1-800-537-8703, www.starlab.com).

C. Fiber optics — "crofon" used to bend light around corners; light passes in and out of ends only

D. Reflections — flat mirrors, concave, convex (relate to telescopes)

E. Refraction (lenses) — convex (converge and magnify), concave (divergent and reduce)

F. Light versus distance — use light meter to measure footcandles at 1, 2, 3, 4 and 5 feet from light source (hopefully develop a good approximation of Inverse Square Law Relationship)

G. Effects of U-V light on fluorescent paint, chalk, posters

Student Objectives

During and following this program of instruction, students will be able to:

- Observe continuous, bright-line and dark-line spectra and differentiate between them.
- Demonstrate ability of fiber optics material to bend light around corners.
- Experiment with and describe differences between reflections off of flat, concave and convex mirrors.
- Experiment with and describe effects convex and concave lenses have on light.
- Use a light meter to read intensity in foot-candles and draw conclusions about how intensity of light falls off with distance.
- Observe effects of ultraviolet light on fluorescent paint, chalk, posters.

V. Topic of Study: Milky Way, Here We Come

Suggested Cylinders: Celestial Coordinates, Deep Sky Objects, Starfield

A. Classifying stars
   1. Distance — miles, A.U., light years, parsecs
   2. Magnitude — lower number = brighter, higher number = dimmer
   3. Size — dwarfs, middle-sized, giants, supergiants
   4. Color & temperature — blue-white = hottest, white, yellow, orange, red = least hot
   5. Relate 1 to 4 above by showing example stars and classifying them

B. Unusual types of stars
   1. Multiple stars — binaries, triple-stars (give examples)
   2. Nova & supernova — example and results
   3. Variables — Delta Cephei classic example (value in determining stellar distances)

C. Relate types of stars to inclusion in Milky Way Galaxy and other galaxies

Student Objectives

During and following this program of instruction, students will be able to:

- Cite at least 3 units for measuring stellar distances.
- Compare the brightness of several magnitude numbers of stars.
- Classify as dwarf, middle-sized, giant, supergiant.
- Observe and identify the color of at least 10 bright stars.
- Locate, point out and observe at least one binary star.
- Locate, point out and observe at least one variable, pulsating star.
- Locate, point out and observe at least one supernova in planetarium sky.
- Locate, point out and observe the plane of the Milky Way in STARLAB using the Celestial Coordinates Cylinder.

VI. Topic of Study: Surveying the Sky

Suggested Cylinders: Celestial Coordinates, Deep Sky Objects, Earth, Starfield

A. Surveying the earth — review of latitude and longitude
   1. Latitude measured in degrees N & S of earth's equator
   2. Longitude measured in degrees E & W of prime meridian

B. Surveying the sky
   1. Horizon system
      a. Altitude — number of degrees above horizon (not good because changes with latitude and time)
      b. Azimuth — number of degrees measured W of N end of meridian (not good because changes with time)
   2. Equatorial system
      a. Declination — number of degrees above or below celestial equator (remains constant)
      b. Right ascension — hours and minutes east of vernal equinox (remains constant with time)

C. Locating objects using the equatorial system (declination and right ascension)
   1. Andromeda Galaxy, Crab Nebula, Orion Nebula, Ring Nebula
D. Surveyors use horizon system, astronomers usually use equatorial system — telescopes usually fitted with equatorial mountings
E. Deep sky objects are often known as Messier objects (ex. M31) or NGC (New General Catalog, ex. NGC 7217)

Student Objectives

During and following this program of instruction, students will be able to perform the following tasks:

- Measure one location for N & S latitude, and E & W longitude.
- Measure height of at least 4 objects above horizon in degrees along meridian.
- Measure height of at least 4 objects above celestial equator along meridian.
- Measure azimuth of at least 4 objects east from North Star Polaris.
- Measure right ascension of at least 4 objects east from vernal equinox.
- Locate these objects using declination and right ascension equatorial coordinates: Crab Nebula, Orion Nebula, Andromeda Galaxy, Ring Nebula.
- State which coordinate system surveyors use and astronomers use.

VII. Topic of Study: Constellations — Circumpolar

Suggested Cylinders: Constellation, Deep Sky Objects, Greek Mythology, Starfield

A. Definition of constellation; numbers recognized in ancient times (48); numbers recognized today (88)
B. Circumpolar constellations (why called circumpolar)
   1. Ursa Major
      a. Other names for constellation — Big Bear, Big Dipper
      b. How to locate — look north for large dipper shape
      c. Important stars — Mizar-double star next to last star in handle ("Pointer Stars" Dubhe & Merak)
      d. Other important objects
   1. Galaxy M-81 Spiral
   2. Galaxy M-82 Irregular
   3. Ursa Minor
      a. Other names — Little Bear, Little Dipper
      b. How to locate — Follow "Pointer Stars" of Big Dipper to North Star
      c. Important stars — Polaris, North Star (sky appears to turn around this star which is last star in handle)
   4. Cassiopeia
      a. Other names — the Queen, the Lazy "M" or "W"
      b. How to locate — look on opposite side of Little Dipper from Big Dipper, look for "M" or "W" shape
      c. Other important objects — Great Nova in 1572 in Cassiopeia could be seen in daylight
   5. Cepheus
      a. Other names — the King, "Little House"

b. How to locate — line drawn from "Pointer Stars" through Polaris brings you to star at top of little house shape (next to Cassiopeia, the Queen)

c. Important star — Delta Cephei, first Cepheid variable star discovered just below base of house shape

5. Draco

a. Other names — the Dragon

b. How to locate — tail between dippers, swings around Little Dipper, 4 stars form head

c. Important star — Thuban, former North Star 2000 years ago used by Egyptians to orient the pyramids, 3rd star from end of tail

C. Review the 5 major circumpolar constellations (note the absence of very bright stars in this region of the sky)

Student Objectives

During and following this program of instruction, students will be able to:

- Define constellation, circumpolar.
- Recite how many constellations ancients named; how many named today.
- Name and locate features under a, b, c and d for each constellation.

VIII. Topic of Study: Fall Constellations

Suggested Cylinders: Constellation, Celestial Coordinates, Deep Sky Objects, Greek Mythology, Starfield

A. Poorest season for observing bright stars, but good for viewing other astronomical objects

B. Review circumpolar constellations

C. Constellations of fall

1. Pegasus

a. Other name — Winged Horse

b. How to locate — line drawn from Polaris through west end of Cassiopeia hits the "Great Square" of Pegasus

c. Important star — Alpheratz, a triple star common to Pegasus and Andromeda

d. Other important objects — Galaxy in Pegasus NGC-7331 Galaxy in Pegasus NGC-7217

2. Andromeda

a. Other name — Chained Lady

b. How to locate — same as Pegasus, connects to "Great Square" at Alcheratz, lazy "V" shape

c. Important star — Alpheratz, a triple star common to Andromeda and Pegasus

d. Other important objects — M-31 Great Andromeda Galaxy: brightest galaxy to unaided eye, much like our Milky Way except slightly larger, about 2.2 million light years away. Note satellite galaxies — Satellite Galaxy left of M31, Satellite Galaxy right of M-31 (M32)

3. Auriga

a. Other names — the Charioteer, the "Big House"

   b. How to locate — line drawn from top stars of Big Dipper's bowl points to Capella
   c. Important star — Capella, a bright yellow star
   d. Other important objects — Nebula IC405 in Auriga, the "Kids" star clusters near Capella
4. Perseus
   a. Other name — Lazy "A" or "R"
   b. How to locate — look close to Cassiopeia, one leg of "A" points to Pleiades, another to Auriga
   c. Important star — Algol, eclipsing binary (double star with the 2 stars 13 million miles apart), changes in brightness, called the "demon" star since ancient times
   d. Other important objects — double star cluster
5. Point out Cetus

Student Objectives

During and following this program of instruction, the students will be able to:

- Recognize and indicate poorest season for observing bright stars, but good for viewing deep-sky objects.
- Review and locate the 5 major circumpolar constellations in the sky.
- Name and locate features under a, b, c, and d for each constellation.

IX. Topic of Study: Winter Constellations

Suggested Cylinders: Constellation, Celestial Coordinates, Deep Sky Objests, Greek Mythology, Starfield

A. Late winter — best for observing bright stars, also excellent for viewing deep-sky objects

B. Review fall constellations

C. Constellations of winter

1. Orion
   a. Other name — the Great Hunter
   b. How to locate — look south for 3 bright stars in a row close together forming belt with 4 other bright stars making a rectangle around the 3
   c. Important stars
      i. Betelgeuse — a red supergiant
      ii. Rigel — a blue-white supergiant, brightest in Milky Way, one foot
      iii. Bellatrix
      iv. Mintaka — on celestial equator
   d. Other important objects (note Trapezium)
      i. Great Orion Nebula M-42
      ii. Horsehead Nebula NGC-2024
2. Taurus
   a. Other name — the Bull
   b. How to locate — line drawn north through Orion's belt brings you to bright star Aldebaran in Taurus

c. Important star — Aldebaran, orange-red giant at bull's eye

d. Other important objects

i. The Pleiades — star cluster (wound on shoulder)

ii. Pleiades with nebulosity

iii. Hyades — star cluster around bull's eye

iv. Crab Nebula M-1 between horns which is result of a supernova explosion in 1054 recorded by Chinese astronomers

3. Canis Major

a. Other name — the Big Dog (hunting dog of Orion)

b. How to locate — line drawn southeast through Orion's belt brings you to Sirius (brightest star in the sky)

c. Important star — Sirius, brightest star in the sky at magnitude 1.6, one of closest to earth (8.8 light years away), actually a double star (small companion is a blue-white star called "Dog Star" — explain Dog Days)

4. Canis Minor

a. Other name — Little Dog (hunting dog of Orion)

b. How to locate — line drawn directly east from Betelgeuse in Orion takes you to Procyon

c. Important star — Procyon, white star and bright, only one other star in this constellation

Student Objectives

During and following this program of instruction, the students will be able to:

- Recognize and indicate best season for observing bright stars, deep sky objects (but poor for observing Milky Way).
- Review and locate the 4 major fall constellations in the sky.
- Name and locate those features under a, b, c and d for each constellation.

X. Topic of Study: Spring Constellations

Suggested Cylinders: Constellation, Celestial Coordinates, Deep Sky Objects, Greek Mythology, Starfield

A. Early spring is excellent for observing bright stars, not as rich in deep sky objects

B. Review winter constellations

C. Constellations of spring

1. Gemini

a. Other name — the Twins

b. How to locate — line drawn through Rigel and Betelgeuse north and east brings you to Castor and Pollux

c. Important stars — Pollux, a bright red-yellow star (left), Castor, a green double-triple star (6 in all!)

d. Other important object — open cluster, M-35

2. Leo

a. Other name — the Lion

b. How to locate — draw line of Big Dipper's bowl south to Regulus and the "sickle-shape"

c. Important stars — Regulus, blue-white giant almost on ecliptic, Denebola

d. Other important objects — very dim galaxy clusters

3. Bootes

a. Other name — the Herdsman

b. How to locate — follow curve of Big Dipper's handle to bright star Arcturus and look for "kite" shape

c. Important star — Arcturus, very bright orange giant star at base of "kite"

4. Virgo

a. Other name — the Virgin

b. How to locate — follow curve of Big Dipper's handle through Arcturus and on to bright star Spica, look for "Y" shape opening toward Denebola

c. Important star — Spica, blue-white 1st magnitude star

d. Other important objects — cluster of galaxies, Sombrero Galaxy, M104

5. Cancer

a. Other name — the Crab

b. How to locate — look between Gemini and Leo, small and dim

c. Important stars — no bright ones, all quite dim

d. Other important objects — Beehive or Praesepe Cluster M44

6. Locate minor constellations Coma Berenices and Canes Venatici between Leo and Bootes below Big Dipper

Student Objectives

During and following this program of instruction, students will be able to:

- Recognize and indicate excellent season for observing bright stars, not as rich in deep-sky objects; better for observing Milky Way.
- Review and locate the 4 major spring constellations in the sky.
- Name and locate those features under a, b, c and d for each constellation.

XI. Topic of Study: Summer Constellations

Suggested Cylinders: Constellation, Celestial Coordinates, Deep Sky Objests, Greek Mythology, Starfield

A. Summer sky — rich in bright stars, best for observing Milky Way, sometimes obscured by smog, haze, etc.

B. Review spring constellations

C. Constellations of summer

1. Corona Borealis

a. Other name — the Crown

b. How to locate — find Bootes, "U" shape just east of Bootes

2. Hercules

a. Other name — the Kneeler, Strong Man

b. How to locate — locate Corona, just east lies the keystone shape of center of Hercules with scrawling arms in 4 directions

   c. Other important objects — M-13 Globular Cluster (black & white) along western side of keystone 2/3 of the way up

3. Lyra
   a. Other name — the Lyre
   b. How to locate — continue eastward line from Hercules and look for very bright star Vega and diamond shape
   c. Important star — Vega: brightest star in summer sky, blue-white giant, forms part of summer triangle of Vega, Deneb, Altair
   d. Other important objects — M-57 Ring Nebula between bottom stars of diamond

4. Cygnus
   a. Other names — the Swan, Northern Cross
   b. How to locate — continue eastward line from Lyra and look conspicuous cross shape
   c. Important stars — Deneb: bright, white star at tail, forms dart of summer triangle Vega, Deneb, Altair. Albireo: spectacular orange and blue double star, at head of swan
   d. Other important objects — Veil Nebula NGC-6992

5. Aquila
   a. Other names — the Eagle, the Anchor
   b. How to locate — line drawn just south and east of Cygnus brings you to anchor shape
   c. Important star — Altair, bright white star near head of eagle forming part of summer triangle of Vega, Deneb, Altair
   d. Other important objects (small nearby constellations) — Sagitta, the Arrow; Delphinus, the Dolphin

6. Scorpius
   a. Other name — the Scorpion
   b. How to locate — look in southern sky for giant fishhook shape, three stars in row for front, bright red star
   c. Important star — Antares, red supergiant at heart of Scorpion

7. Sagittarius
   a. Other names — the Archer, the Teapot
   b. How to locate — look just east of Scorpius, small milk dipper shape
   c. Other important objects — the Milky Way is rich here. This direction is looking toward the center of our galaxy. Trifid Nebula

D. Summer triangle of Vega, Deneb, Altair

Student Objectives

During and following this program of instruction, students will be able to:

- Recognize and indicate season rich in bright stars; best for observing Milky Way; skies of summer frequently obscured by smoke, smog, haze.
- Review and locate the 5 major spring constellations in the sky.
- Name and locate those features under a, b, c and d for each constellation.

XII. Topic of Study: Mapping the Stars I — Circumpolar, Fall and Winter

Suggested Cylinders: Constellation, Deep Sky Objects, Greek Mythology, Starfield

A. Circumpolar constellations

B. Fall constellations

C. Winter constellations

Student Objectives

During and following this program of instruction, the students will be able to:

- Recognize Ursa Major, Ursa Minor, Cassiopeia, Cepheus, Draco, Pegasus, Andromeda, Auriga, Perseus, Cetus, Orion, Taurus, Canis Major, Canis Minor, Lepus, Monoceros, circle them, give the correct name and one nickname if given a star map containing circumpolar, fall and winter constellations.
- Locate those bright stars in each constellation which were pointed out and name them, recognizing names from a prepared list.
- Locate other important objects (galaxies, nebulae and star clusters) which were pointed out in above constellations and label them recognizing names from a prepared list.

XIII. Topic of Study: Mapping the Stars II — Circumpolar, Spring and Summer

Suggested Cylinders: Constellation, Deep Sky Objects, Greek Mythology, Starfield

A. Circumpolar constellations

B. Spring constellations

C. Summer constellations

Student Objectives

During and following this program of instruction, students will be able to:

- Recognize Ursa Major, Ursa Minor, Cassiopeia, Cepheus, Draco, Gemini, Leo, Bootes, Virgo, Cancer, Coma Berenices, Canes Venatici, Corona Borealis, Hercules, Lyra, Cygnus, Aquila, Scorpius, Sagittarius, Vega, Deneb, Altair. They will be able to circle them, give the correct name and one nickname for them (drawing lines to make the figure optional) if given a map containing circumpolar, spring and summer constellations.
- Locate those bright stars in each constellation which were pointed out and name them, recognizing names from a prepared list.
- Locate other important objects (galaxies, nebulae, and star clusters) which were pointed out in above constellations and label them, recognizing names from a prepared list.

XIV. Topic of Study: The Age of Aquarius

A. Compare definitions of astronomy and astrology

B. Define zodiac, where it is located, and how it was set up and is currently changing

C. The 12 constellations of the zodiac — Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricornus, Aquarius, Pisces

D. Conclusion

1. Review manner in which zodiac was set up
2. Examine astrology versus astronomy — ancient times and present

Student Objectives

During and following this program of instruction, students will be able to:

- Differentiate between astronomy and astrology and cite from which it was derived.
- Define zodiac, where it is located, how it was set up and currently changing.
- Observe 12 signs of the zodiac, period of year it governs, brief legend about it.
- Speculate on the future of astronomy over the next couple of decades and centuries.

XV. Topic of Study: Mathematics — As it Relates to Astronomy

Suggested Cylinders: Constellation, Earth, Celestial Coordinates, Starfield

I. Introduction to the Planetarium and Orientation
   A. Definition of astronomy versus astrology
   B. Direction orientation of cardinal points
   C. Sky at North Pole
   D. Latitude by altitude of Polaris, azimuth
   E. Earth Cylinder to locate equator and poles. Recall how latitude is measured
   F. Relate "E" to celestial equator and poles and measure astronomical latitude (declination)
   G. Earth Cylinder to recall longitude measurement
   H. Relate "G" to celestial longitude (right ascension)
   I. Measure several earth locations in latitude and longitude
   J. Measure several celestial objects in declination and right ascension
   K. Students will be able to identify a full moon, new moon and quarter phase moon
   L. Students will successfully locate the cardinal points N, E, S & W

Student Objectives

During and following this program of instruction, students will be able to:

- Recognize and identify the Cardinal Points N, E, S, W.
- Locate the Big and Little Dipper at the North Pole and at your latitude.
- Explain that the height of Polaris above the horizon in degrees is equal to an observer's latitude in northern hemisphere.
- Orally distinguish between star brightness and colors.
- Locate and identify the following additional constellations: Orion and Cassiopeia.
- Explain the difference between terms inferior and superior planets.
- Recognize and name earth's equator and poles.

XVI. Topic of Study: Calculating Time from the Celestial Clock

Suggested Cylinders: Starfield

Student Objectives

During and following this program of instruction, students will be able to:

A. Locate Big Dipper, Little Dipper, "Pointer Stars" and Polaris.
B. Explain relationship of "Pointer Stars" to Polaris.

C. Read “Big Dipper Time” and acquire month number.

D. Do sample time problems using formula: 53 - 2 (M + C) = S where M - month no., S = standard time, and C = time on the “Pointer Sears Clock.”

E. Have students develop why the minus (-) in the formula; why the 2 in the formula; and why the constant 53.

F. Further develop the formula: 53 - 2 (C + 9) = ST where ST = sidereal time.

G. Complete formula development: 53 - 2 (C + M) - ST = RA where GT = Greenwich time and RA = the local hours of right ascension.

XVII. Topic of Study: Geometry of Latitude by the Pole Star

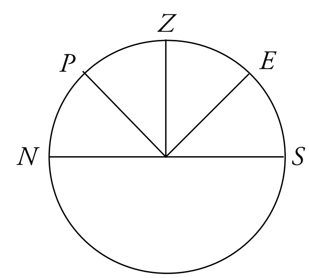
Suggested Cylinders: Starfield

Student Objectives

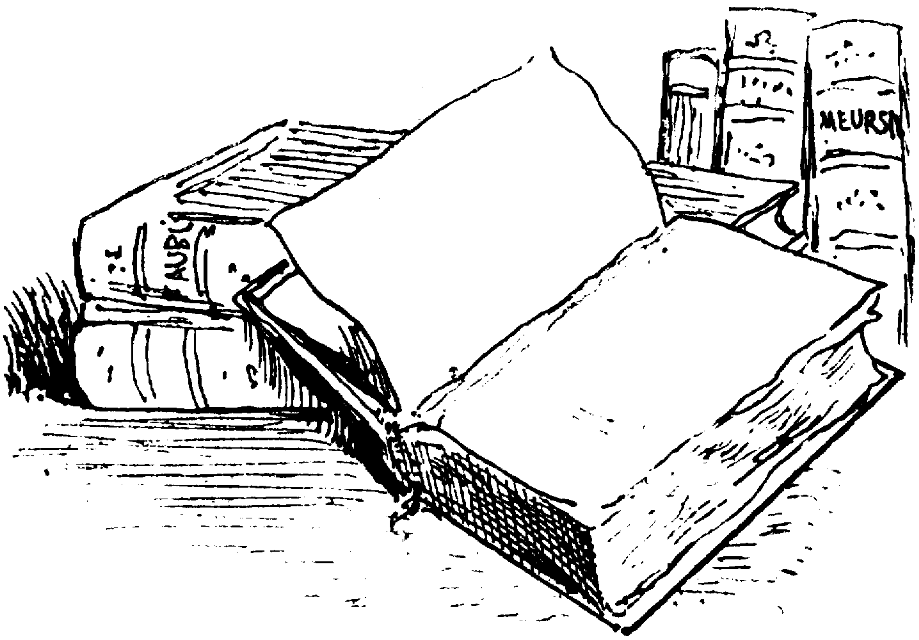
During and following this program of instruction, students will be able to:

- Recite our home latitude; read altitude of Polaris.
- Repeat for 2 other known latitudes.
- Define zenith, celestial equator, celestial poles, horizon, meridian.
- Recite definitions of complementary and supplementary angles.
- Construct, explain and develop relationships among all parts of developed diagram according to geometrical rules for complementary angles:

The angular distance from the equator (F) to the zenith (Z) (along the meridian), is the complement of the distance from Z to the pole (P) since their sum is 90°. The distance from the north point (I) on the horizon to P is the complement of the distance from P to Z. Since complements of the same angle are equal, N-P, the altitude of the pole, is equal to Z-E, the latitude of the observer.



Grades 7-12 Resources



Resources Available from Science First/STARLAB

The following resources used in this section are available from:

Science First/STARLAB, 95 Botsford Place, Buffalo, NY 14216.
Phone: 1-800-537-8703 or 716-874-0133. Fax: 716-874-9853. www.starlab.com

STARLAB Cylinder Guides

1. *A Collection of Curricula for the STARLAB African Mythology Cylinder*
2. "A Current Affair," *A Collection of Curricula for the STARLAB Weather Cylinder*
3. "Go With the Flow," *A Collection of Curricula for the STARLAB Ocean Currents Cylinder*
4. "The Skies of Ancient China I: Information and Activities," *A Collection of Curricula for the STARLAB Ancient Chinese Seasons Cylinder* (The Four Beasts)
5. "The Skies of Ancient China II: Information and Presentations," *A Collection of Curricula for the STARLAB Ancient Chinese Legends Cylinder*
6. *A Collection of Curricula for the STARLAB Biological Cell Cylinder*
7. *A Collection of Curricula for the STARLAB Celestial Coordinates Cylinder*
4. *A Collection of Curricula for the STARLAB Constellation Cylinder*
5. *A Collection of Curricula for the STARLAB Deep Sky Objects Cylinder*
6. *A Collection of Curricula for the STARLAB Earth Cylinder*
7. *A Collection of Curricula for the STARLAB Greek Mythology Cylinder*
8. *A Collection of Curricula for the STARLAB Native American Mythology Cylinder*
10. *A Collection of Curricula for the STARLAB Plate Tectonics Cylinder*
11. *A Collection of Curricula for the STARLAB Starfield Cylinder*

Planetarium Activities for Student Success (PASS)

1. Volume 2, *Activities for the School Planetarium*
2. Volume 6, *Red Planet Mars*
3. Volume 7, *Moons of the Solar System*
4. Volume 8, *Colors and Space*
5. Volume 9, *How Big is the Universe?*
6. Volume 10, *Who "Discovered" America?*
7. Volume 11, *Astronomy of the Americas*
8. Volume 12, *Stonehenge*

Project STAR Hands-on Science Materials (developed by the Harvard Smithsonian Center for Astrophysics)

1. *Where We Are in Space and Time Activity Book*
2. Spectrometer, holographic diffraction grating, refracting telescope and many more hands-on interactive activities

3. Free catalog of materials

Great Explorations in Math and Science (GEMS) series (developed by the Lawrence Hall of Science, University of California, Berkeley)

1. *Color Analyzers*, Teacher's Guide, Grades 5-8.
2. *Earth, Moon and Stars*, Teacher's Guide, Grades 5-9.
3. *Moons of Jupiter*, Teachers Guide, Grades 4-9.

Another Resource:

A Teacher Resource To Enhance Astronomy Education, Project SPICA, Sponsored by the Harvard Smithsonian Center for Astrophysics, Kendall/Hunt Publishing Co., 4050 Westmark Drive, P.O. Box 1840, Dubuque, Iowa 52004-1840.

Grades 7-12 Bibliography

The materials included in this section are a collection of the best resource materials for teaching with a STARLAB Portable Planetarium. They are drawn from the works of many planetarium educators and astronomers and are reproduced here for general educational use. Selected items may be freely photocopied for local distribution to students and others if it serves a legitimate educational need. Otherwise, these materials may not be reproduced except by contractual agreement with the original publishers. These materials are reproduced from these publications:

Astronomy. Monthly magazine. Kalmbach Publishing Co., Waukesha, WI.

Dickinson, Terence and Sam Brown. *The Edmund Sky Guide*. Edmund Scientific Co. New Jersey. 1977.

Marble, Stephen, Ph.D, creator and Marilyn Fowler, Ph.D., editor. *Astronomy: Minds-on the Universe — Supplemental Teaching Activities for Grades K-8*. Southwest Educational Development Laboratory, Austin, Texas.

Pasaachoff, Jay M. *A Field Guide to the Stars and Planets*. Houghton Mifflin Company, Boston. 1992.

Planetarian, Journal of the International Planetarium Society, Los Angeles, CA.

Planetarium Activities for Student Success, Holt Planetarium, Lawrence Hall of Science, University of California, Berkeley, CA 94720. Available from Science First/STARLAB, 1-800-537-8703 or 716-874-0133, www. starlab.com.

Planetarium Handbook 1974. International Society of Planetarium Educators. Contact: Mr. Frank Jettner ISPE Executive Director, Dept. of Astronomy and Space Science, State University of New York at Albany.

Schaaf, Fred. *Seeing the Sky — 100 Projects, Activities, and Explorations in Astronomy*. John Wiley & Sons, Inc., New York. 1990.

Schaaf, Fred. *Seeing the Solar System — Telescopic Projects, Activities, and Explorations in Astronomy*. John Wiley & Sons, Inc., New York. 1991.

Sky & Telescope. Monthly magazine. Sky Publishing Corporation, Cambridge, MA.

Tapes of the Night Sky, Astronomical Society of the Pacific, Contact: Tom Gates, Space Science Center of Foothill Community College, Santa Clara, California. Available from Science First/STARLAB, 1-800-537-8703 or 716-874-0133, www. starlab.com.

Tips for Orientation Activities, Great Lakes Planetarium Association, Contact: Donald O. Knapp, L.S. Noblitt Planetarium, East Senior High School, Columbus, Indiana.

Tips on Developing and Presenting Planetarium Programs, Great Lakes Planetarium Association, Contact: David Hoffman, Director, Reiser Planetarium, Wyoming, Michigan.

Under Roof Dome and Sky, Middle Atlantic Planetarium Society, Contact: Lee Ann A. Henning, Fort Hunt Planetarium, 8428 Fort Hunt Road, Alexandria, VA 22308.

The Universe at Your Fingertips: An Astronomy Activity and Resource Notebook, edited by Andrew Fraknoi, et al., Astronomical Society of the Pacific. Available from Science First/STARLAB, 1-800-537-8703 or 716-874-0133, www. starlab.com.

Where We are in Space and Time. Developed by Project STAR at the Harvard Smithsonian Center for Astrophysics. Available from Science First/ STARLAB, 1-800-537-8703 or 716-874-0133, www. starlab.com.

Note

The following activities are picked up from an older version of the STARLAB User's Manual and although most are not meant specifically for STARLAB, they may be useful as extension activities for upper levels. Some of these activities could be used as supplementary activities to accompany and/or enhance the objectives in the "Planetarium Curriculum Outline for Astronomy" on pages 15 through 27.

Extension Activities for Grades 7 and Beyond

Guide to Using Extension Activities for Grades 7 and Beyond

Introduction

This is a statement of the purpose and content of the activity. It sets the tone of the student investigations to come and briefly describes them. For most activities, planetarium procedures will take about an hour, for others, double sessions or several sessions may need to be arranged. The introduction will alert you to extra time required.

Student Preparation

Content background indicates the science knowledge and skills needed by the student prior to the planetarium experience unless these will be specifically introduced in the classroom activities described. Occasionally included here or in the introduction are suggestions for linking the activity with various science programs.

Facts and Concepts

These are statements of the major ideas that are developed as well as certain well-established facts about the universe that are valuable for permanent retention.

Objectives

The first objective for each activity is the primary or terminal behavioral change the student should be able to demonstrate as a result of the activity. The additional objectives are either supportive or "spin-off" objectives. Supportive objectives are those the student should be able to achieve to meet the terminal objective, while "spin-off" objectives include those the student may accomplish as a result of meeting the terminal objective. If a student achieves the terminal objective but does not accomplish the additional objectives listed, he/she has succeeded. For the student, the lesson may be considered a success.

Materials for the Classroom

This is a listing of the items necessary for the classroom phases of the activity (both pre- and post-planetarium) except for standard classroom items. If certain materials or equipment are commercially produced, the source will be given here or later in the resource section.

Materials for the Planetarium

This is a listing of materials and equipment necessary for the planetarium phase of the activity, other than standard projection equipment assumed to be available in every school planetarium.

Procedures for the Classroom

These are instructions for carrying out activities to be conducted in the classroom before the planetarium investigation. These activities review necessary content background, introduce new concepts as required, stimulate interest, and set the stage for the planetarium experiences. Unless these activities are completed by students, the planetarium investigation will have little meaning or relevance for them. In all instances, the teacher should expand these activities as appropriate and necessary for the group.

Procedures for the Planetarium

This phase of the activity is designed to be inquiry-oriented, action-filled and student-centered. The procedural instructions are given in chronological order. The planetarium director, through his own teaching approach and teaching personality, can enhance this phase. This part of the activity is not meant to stand alone or to be finite in itself; but in partnership with the classroom phases of the activity, it is designed to bring about measurable behavioral growth on the part of students.

Follow-Up Activities

It is through activities back in the classroom that students will analyze their planetarium experiences and integrate new learning into their repertoire of knowledge and skills. The success of the preceding classroom and planetarium activities are dependent on the effectiveness of this follow-up.

Evaluation Suggestions

Some suggestions for evaluating learning and achievement of objectives are set for each activity. The suggestions may be expanded by the classroom teacher and planetarium director in keeping with the objectives of the activity. (This represents a big step forward in planetarium education where previously little effort has been directed toward evaluating either student learning or the success of planetarium.)

Vocabulary

This category includes words that are not in the students' everyday vocabulary but are essential for communicating about the ideas of the activity, and common words used in new ways in the context of the particular topic.

Suggested Resources

Listed here are related readings in textbooks, reference books periodicals (with page numbers given), maps, visuals, and other teaching and learning aids.

Data Sheets

When the activity calls for data sheets, observation sheets, evaluation sheets, etc., these are provided at the end of the activity. Any sheets designed for student use may be extracted from this book and duplicated in class supply.

> **Note**
>
> *There were two purposes for developing these activities: to integrate classroom and planetarium instruction, and to propel the student into the role of active inquirer or learner. We hope you will keep these purposes in mind as you use these lessons.*

Naming the Stars in Constellations

MATERIALS

For the Classroom

- student study sheets (pages 42, 43)
- projector
- slide of one constellation represented diagrammatically on the study sheet (not Ursa Major). The slide should show the constellation as it appears in the night sky.

For the Planetarium

- student worksheets (pages 42, 43)
- pen lights
- pencils
- auxiliary projector
- slide providing circles or other means for outlining the constellations on the dome represented on worksheets
- slide or other means for projecting each constellation alone in its starfield

Note

As students become interested in the stars, they will quickly discover that relatively few have proper names. There's Polaris, of course, at the end of the handle in the Little Dipper, Betelgeuse and Rigel in Orion, Pollux and Castor in Gemini. But do the other stars in these configurations have names?

In the activity to follow, students will find out that they, themselves, can often determine the accepted name for the brighter stars in familiar constellations, provided they can distinguish between degrees of brightness and learn the beginning of the Greek alphabet.

Student Preparation

Students must have enough familiarity with constellations to identify several by name and know their configuration. They must be aware of differences in stellar brightness and must have some knowledge of the Greek alphabet.

Facts and Concepts

Orderly and international nomenclature assists in scientific communication. If astronomers throughout the world are to talk about particular stars, the stars need universal names for purposes of identification. Systems of nomenclature used in science are usually rooted in characteristics which objects (or organisms) possess in common, and differences in these characteristics. An observable characteristic of stars is apparent brightness. The major system for naming stars in constellations makes use of a letter of the Greek alphabet as a prefix to specify the relative brightness of a star. The Greek prefix is followed by the Latin name of the constellation, with the Latin name appearing in its possessive (genitive) form.

Thus the second brightest star in Orion is named:

"β (beta) Orionis" meaning (the) second (brightest) star of Orion.

In most systems there are exceptions to rules, and this is particularly true with systems set up to control language with which names are communicated.

Objectives

- Given an appropriate worksheet and a copy of the Greek alphabet, the student will be able to name certain stars in known constellations.
- The student will be able to state the rules by which stars are generally named.
- The student will be able to identify the constellation figures observed in this activity.
- The student will be able to list by name and letter the first eight letters of the Greek alphabet.

Procedure in the Classroom

1. Project the picture of the constellation, have it identified, and ask students if they can identify any of the stars by proper name. Consider whether there are proper names for all of them.
2. Suggest that the class devise a plan for naming the stars. List methods suggested (perhaps by numbering, using names, or according to color, position or brightness).

3. Let students apply the methods proposed to the stars shown on the screen and decide if the methods are practical.
4. After students discover the problems involved in designing a system for naming stars, distribute the study sheets. Introduce the accepted system for naming stars in constellations and the Greek alphabet.
5. With the class, go through the constellation figures by asking students to determine from the Greek letters the scientific name of each star and its order of brightness which its name indicates. Skip the figure of the Big Dipper.
6. Point out that the Big Dipper is an exception. Another system was used in naming its stars. Students should be able to figure out the system (positional order).

Procedure in the Planetarium

1. After distributing working materials, turn down the side lights and show the starfield (at full illumination to freshen memories of the star-filled sky. Then turn up side lights until all stars disappear.
2. Now gradually dim side lights until only the brightest star can be seen. Continue dimming until a few more stars appear. Continue further until students recognize that a technique is being used to aid in the differentiation between degrees of brightness.
3. Again show the starfield at full illumination, with side lights low and with all constellations represented on students' worksheets visible. Use an auxiliary slide projector to superimpose circles around the six constellations to be examined.
4. Ask the class to name the constellations and enter the names on their worksheets.
5. Turn up the side lights and then gradually dim them again as in Step 2. At each stop, ask students to point out any newly appearing star(s) in each constellation and to name each, if possible. The first star to appear will be alpha, regardless of the constellation. But from then on, the class must keep track of how many other stars have previously appeared in the constellation and/or notice relative brightness before naming the newly appearing star. Continue until you feel students understand that degrees of brightness serve as the basis for naming stars.
6. Turn off all stars and project on the dome a slide of the real starfield of Orion as it appears in nature. Let students take turns pointing to each star in order of brightness and naming it. Although worksheets will provide the Greek alphabet, the distinction between degrees of brightness will be more difficult now without use of the dimming technique, so allow time for discussion and interaction. Suggest that students fill in their worksheets as the procedure goes along.
7. Repeat the above for all other constellation figures except Ursa Major. You can use the dimming technique again to solve some differences of opinion, but with Cassiopeia and Leo, you may have to provide some of the correct names. Even with just the slide of the constellation's starfield, the dimming technique of increasing and decreasing brightness in the room will help; also compare the real sky photograph of the constellation with its appearance in the planetarium.
8. Project a photograph of Ursa Major with the Big Dipper circled. Ask a student to use a pointer as he/she explains how stars are actually named in this configuration, and how they would be named were not the Big Dipper an exception to the general rule.

Follow-Up Activities

1. Let students take new copies of the worksheets home to identify and name constellations and stars in the night sky.
2. Students might investigate how the system for naming stars is extended when a constellation has more stars than the number of letters in the Greek alphabet.
3. Let students investigate how the constellations and planets received their names.

Vocabulary

Orion
Cassiopeia
Triangulum
Ursa Major
Ursa Minor
Leo
brightness
apparent brightness
magnitude
alpha
beta
gamma
delta
epsilon
zeta
eta
theta

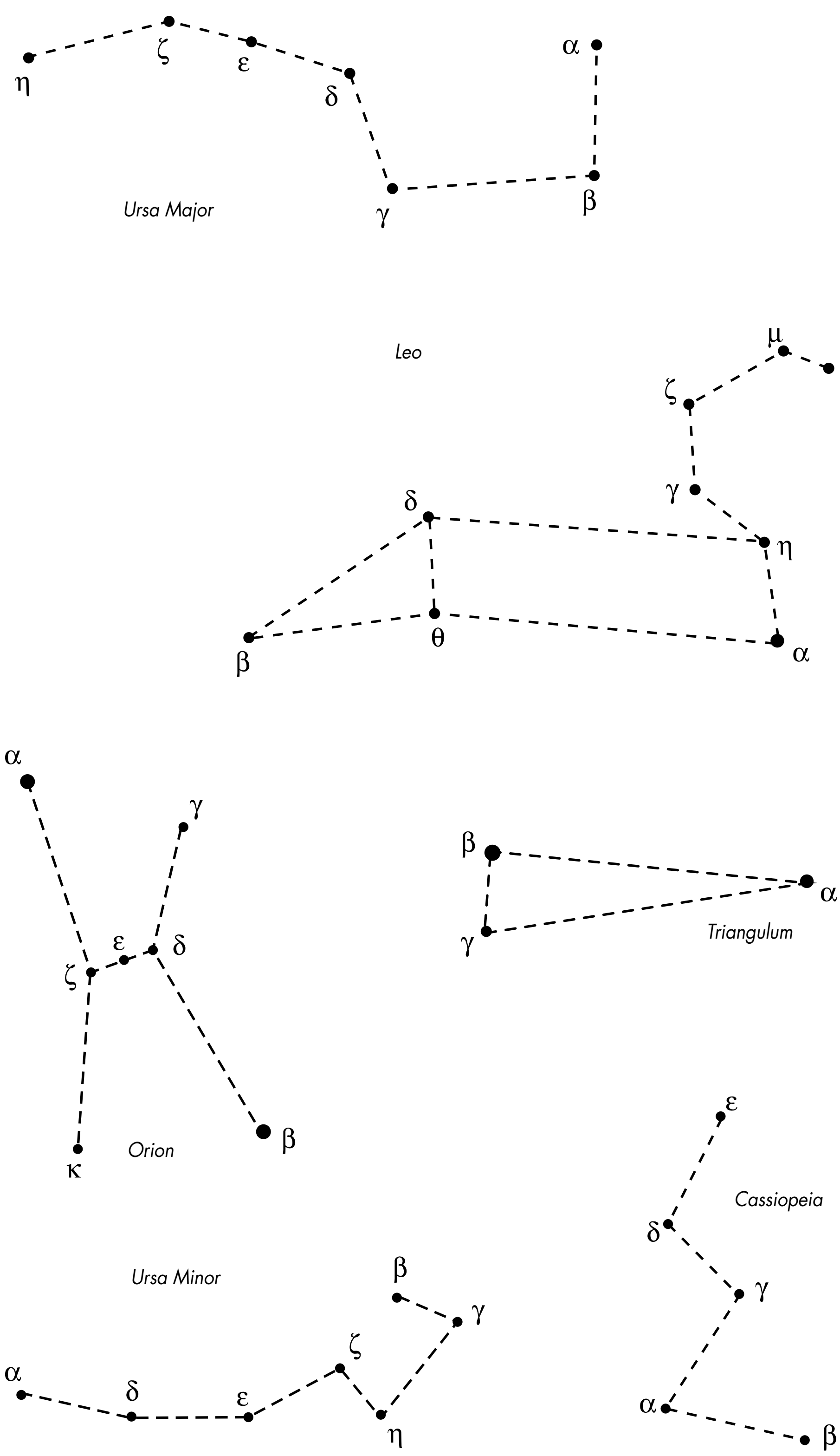
Evaluation Suggestions

Give students diagrams of the constellations studied and a list of their names (or use projection). Ask students to match the names with the constellations. Use portions of Step 7 under the planetarium procedure for evaluation purposes. Ask students to state in writing a rule for naming stars in a constellation. Ask students to list the first eight letters of the Greek alphabet.

Greek Alphabet

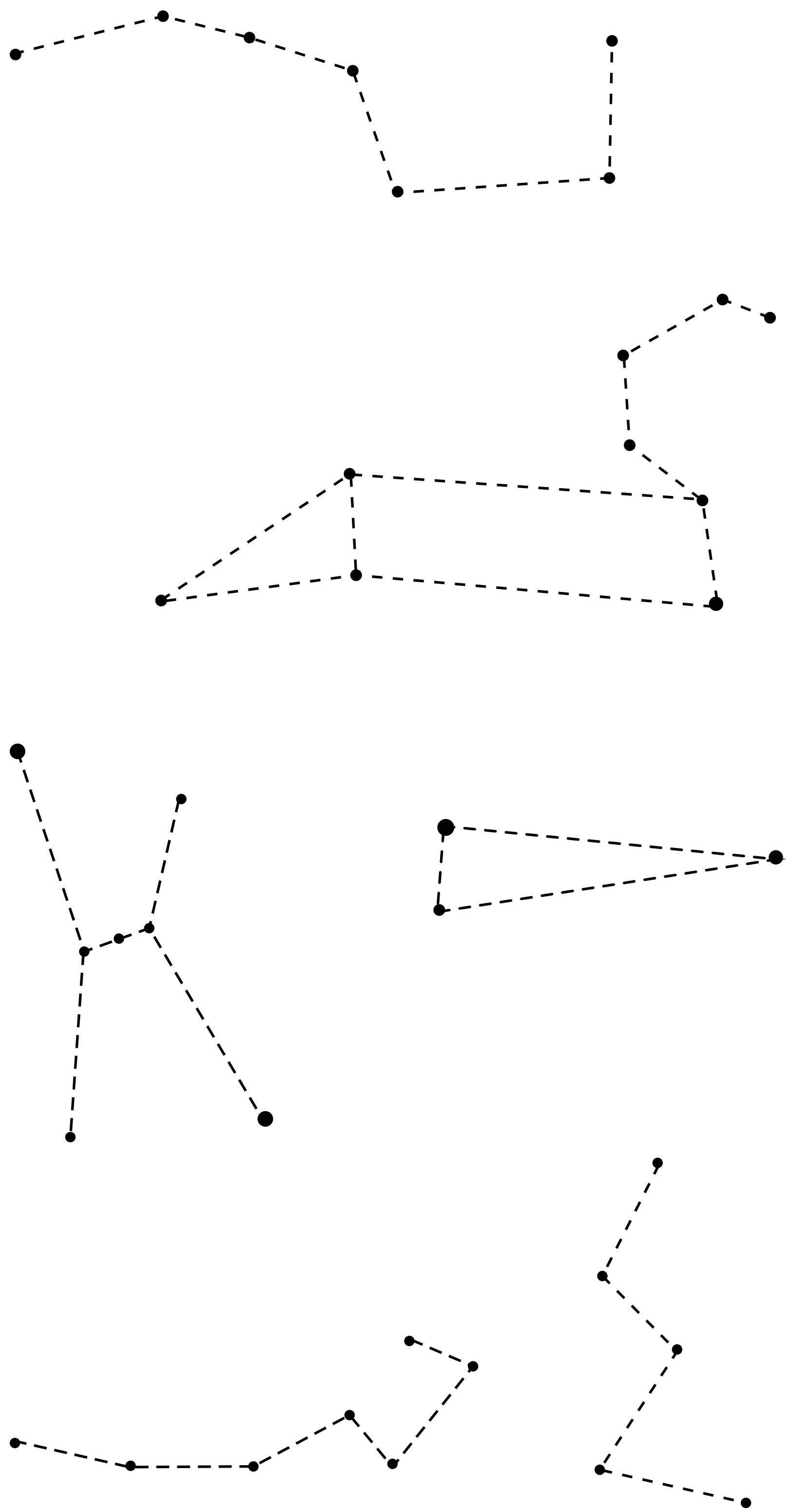
Alpha ...... α
Eta .... η
Nu .... ν
Tau.......... τ
Beta .... β
Theta .... θ
Xi............ ξ
Upsilon .... υ
Gamma ... γ
Iota .... ι
Omicron .. ο
Phi .... φ
Delta .... δ
Kappa ..... κ
Pi............ π
Chi.......... χ
Epsilon .... ε
Lambda ... λ
Rho .... ρ
Psi........... ψ
Zeta .... ζ
Mu .... μ
Sigma...... σ
Omega.... ω

Star Nomenclature Study Sheet



Name____ Date_____________________

Star Nomenclature Worksheet



Greek Alphabet

Alpha ...... α
Eta .... η
Nu .... ν
Tau .... τ
Beta .... β
Theta .... θ
Xi .... ξ
Upsilon .... υ
Gamma ... γ
Iota .... ι
Omicron .. ο
Phi .... φ
Delta .... δ
Kappa ..... κ
Pi .... π
Chi.......... χ
Epsilon .... ε
Lambda ... λ
Rho .... ρ
Psi........... ψ
Zeta .... ζ
Mu .... μ
Sigma...... σ
Omega.... ω

MATERIALS

For the Classroom

- maps and globe
- compass: one for every two students
- hand sextant and astrolabe: one of each for class purposes, one of either for every two students
- eye-safety device

For the Planetarium

- degree markings at 10° intervals around planetarium dome
- planetarium sextant projection device
- at least one compass (perhaps more) and one regular hand sextant
- notepads
- pencils
- pen lights
- data sheet with the following column headings: STAR , DATE , TIME, ALTITUDE , AZIMUTH

Shifting Addresses for Stars

Although the use or altitude and azimuth for designating the location of stars is limited in astronomy, the basic method used (a Cartesian coordinate system) and the measurement techniques employed are common to more sophisticated methods. Students will acquire skills for determining altitude and azimuth coordinates. Experiences in the planetarium will show the limitations of these shifting addresses for stars and will help to develop understanding of star movement.

Student Preparation (Grade level: secondary)

Content background: understanding of ordered pairs and their use in a coordinate system; ability to use longitude-latitude coordinates to find points on a map and globe; understanding of angular measurement and the units used (degrees); preferably acquaintance with a few bright stars.

Facts and Concepts

- A Cartesian coordinate system can be used for locating points on a plane surface.
- A Cartesian coordinate system can be used for locating points on a spherical surface.
- Determination of altitude and azimuth constitutes a Cartesian coordinate system for designating temporary locations of celestial objects from any given point on the earth.

Objectives

Using a projected hand sextant and degree markings around the base of the planetarium dome, the student will be able to determine and record the altitude and azimuth of selected bright stars in the planetarium sky. Given a compass and an astrolabe or hand sextant, the student will be able to determine the altitude-azimuth of the sun in the real sky. The student will be able to express altitude and azimuth in conventional terms.

> **Note**
>
> *Make degree markings with strips of white cardboard 1 inch wide and 12 inches long. Tape at 10° intervals around dome. However, if planetarium is oriented with cardinal points, you may prefer that the students use compasses throughout the activity rather than degree markings.*

Procedures for the Classroom

1. Review the use of ordered pairs in determining location. For example, a student may sit in the fourth seat from the left in the third row; Mountain City, Nevada lies close to the 116th meridian and 42nd parallel.
2. Allow some practice in finding points on a map and globe from given latitudes and longitudes.
3. Ask students to speculate how a coordinate system might be used to designate the location of a star from any given place at any given moment. Press for the answer that the star will have an elevation in relation to the horizon and a direction in relation to compass points.

4. Explain that "altitude," as used in astronomy, is the angular distance of an object measured on a vertical circle from the horizon through the object and toward the zenith. It ranges from 0° to 90°.
5. Using a compass to illustrate, discuss how compass direction, or azimuth, is located from a fixed reference point (north point). Explain rotation from 0° to 360° around the horizon clockwise from north.
6. Review angular measurement with questions such as: How do you find degrees given a section of a circle? What use would a surveyor make of a base line to find the elevation of a hill?
7. Distribute compasses, astrolabes, and/or hand sextants (or materials for making one of the latter two instruments — see pp. 66-67) and help students learn to use them properly. They might practice by determining the altitude and azimuth of selected points inside and outside of the classroom.

Note

It is desirable for students to get acquainted with both an astrolabe and hand sextant.

Procedures for the Planetarium

1. After asking students to work in pairs and passing around the materials they will need, dim side lights and project the planetarium sky (no motion), preset for early evening, date of visit.
2. Determine cardinal points (using compass if planetarium is appropriately oriented), mark on dome, and point out that the horizon is marked at 10° intervals.
3. Ask for suggestions on how to take a good azimuth reading, particularly for stars far above the horizon. A pencil, edge of a sheet of paper, or string with weight attached could be used for lining up horizon degree markings with stars.
4. Point out a bright star and ask several students to determine its altitude from where they are sitting with a regular hand sextant. Discuss their readings with the class and the reason for differences.
5. Project the planetarium sextant, calibrating it with the meridian, and explain use of the projected degrees of altitude. Let students discuss and try out, if possible, the position (center of room) from which a regular hand sextant would need to be used for good accuracy.
6. As you point to several stars, ask the class to determine their azimuth and then altitude, using the projected sextant.
7. Distribute data sheets (described under Materials). Announce the planetarium setting: date and time. Then as you point, one by one, to six bright stars and have them identified by name, ask students to determine their azimuth and, with the aid of the projected sextant, their altitude.
8. Advance daily motion three hours and ask students to repeat the measurements for the same stars. After letting the students locate them (or as many as are still visible), point to them as before so that mistaken identity will not confuse results.
9. Advance daily motion another three hours and repeat Step 8. Then, if time allows, do this again.
10. Discuss the paths of the six stars in terms of both observations and data. Students will note that (a) some of the stars were in the sky longer than others, (b) each star's location, according to altitude-azimuth coordinates changed, more so for some stars than for others. Some students may also have observed that a star low on the horizon as it crossed the meridian was only in the sky a short time.
11. The above procedure might be repeated for the sun and for the moon.

Evaluation Suggestions

Evaluate student performance on the data sheets developed in the planetarium. Give students the altitude-azimuth of selected points outside the classroom and ask them to identify the objects located at the points, using a compass and astrolabe or hand sextant. Ask students to record the position of the sun. Provide them with eye-safety devices to avoid danger to their eyes.

Vocabulary

altitude
azimuth
zenith
horizon
longitude
latitude
north point
astrolabe
sextant
base line

Follow-Up Activities

1. Give the class three sets of altitude-azimuth coordinates four hours apart for several stars and ask students to visualize and describe their movements across the sky.
2. Give students altitude-azimuth coordinates of specific objects in the room and ask them to use an astrolabe or hand sextant to locate and identify the objects.
3. Discuss the limitations of altitude-azimuth coordinates for designating star location. Suggest some readings and reports to the class on how altitude-azimuth is used in navigation.
4. Making altitude-azimuth determinations in the real sky will be interesting for students and will reinforce concepts of diurnal movements of the sun, moon, and stars as seen from earth. Suggest that students use an astrolabe or hand sextant and compass to determine the location and movement of objects in the real sky.

Examining Spheres and Spherical Angles

Note

A planetarium is useful in teaching subjects other than science. For example, when students in mathematics classes are being introduced to the ideas of spherical geometry, the planetarium can provide an excellent setting for experiential development of concepts. In the activity below the students use the planetarium dome to refine their own definitions of the properties of spheres and for developing conclusions about spherical angles.

Although designed particularly for mathematics classes, the activity will be equally useful in science. And, as presented in this activity, spherical geometry need not be limited to advanced groups in high school. The concepts and investigative procedure are well within the ken of junior high school students.

Student Preparations (Grade level: secondary)

Content background: previous experience with the exactitude of definitions in geometry; ability to measure angles on a plane surface.

Facts and Concepts

- The planes of all great circles of a sphere pass through the sphere's center.
- The definitions of the properties of a sphere become more useful when they refer to something in nature.
- Figures and angles on a spherical surface pose special measurement problems.

Objectives

- From their observations in the planetarium, students will be able to formulate verbal and written definitions for the following: sphere, spherical center, great circle, small circle, parallels, axis, equator, meridian, spherical angles.

  Note

  See definitions at end of activity.

- Students will be able to support or refute the premise that the sum of the interior angles of a spherical triangle is equal to or greater than 180°.

Procedures for the Classroom

1. Give each group of three students the materials listed under "classroom" above. They are to use the materials as aids in developing definitions of the nine terms.
2. Suggest that they suspend the bead in the center of a sphere. They can do this by using string, cellophane tape, and the two plastic hemispheres.
3. The students should also cut up the Styrofoam balls for purposes of exploring the terms. Then they can use a grease pencil to illustrate the terms on the plastic sphere.
4. With their own model of each term in front of them, the students should write a definition for each term.

MATERIALS

For the Classroom

- each group of three students should have a listing of the nine terms to be defined
- several Styrofoam balls and instrument to cut them with
- two clear plastic hemispheres that fit together
- string
- one bead
- cellophane tape
- grease pencil

For the Planetarium

- plastic spheres
- list of definitions prepared by students in the classroom
- chalkboard and (if possible), ultraviolet chalk
- folding six-foot ruler (fluorescent, phosphorescent or painted white)
- planetarium projection
- sextant
- pencils
- pen lights
- paper

Procedures for the Planetarium

1. When the students come to the planetarium, they should bring their definitions and models of the celestial sphere. Take up each term in order (sphere, spherical center, great circle, small circle, parallels, axis, equator, meridian, spherical angle) and ask students to present definitions.
2. Turn on the stars, asking the group to look at the sky and to consider it in relation to the plastic sphere with the small bead inside. Ask what the small bead represents (the earth) and help students see that one point on the bead represents the location from which they are viewing the night sky.
3. Go through each term, using planetarium effects to illustrate it (use meridian, coordinates, ecliptic, motion, etc., as needed). Pause after each demonstration for discussion and to let students refine their written definitions. As the class agrees on the best definition, you might write it on a chalkboard with ultraviolet chalk.
4. Play back planetarium effects, asking students to identify what is being illustrated. (At any time students might identify the horizon as a great circle.)
5. Turn attention to the definition of a spherical angle and illustrate one on the dome. To clarify a point often misunderstood about angles, use a six-foot folding ruler. Show students how the ruler can be bent to show any angle; discuss how extending the legs of the ruler doesn't affect the size of the angle.
6. Let students view and identify spherical angles between the ecliptic and horizon, ecliptic and celestial equator, ecliptic and meridian, celestial equator and horizon, etc.
7. Discuss the measurement of spherical angles in the planetarium sky. Then, turn on the planetarium sextant so that the angles mentioned above may be measured. (To check accuracy of the hand sextant, use the meridian.)
8. Construct a triangle on the chalkboard and review the triangle as defined in plane geometry. Then, using the astronomical triangle projector (or a projected triangle), show construction of a spherical triangle.
9. Students should measure the interior angles of the triangle above to draw conclusions concerning the sum of the interior angles of a spherical triangle.
10. In conclusion, cut up a large Styrofoam ball to show the three dimensions of a spherical triangle.

Evaluation Suggestion

Evaluation may be based on the definitions developed by students.

Follow-Up Activities

1. Offer problems in spherical geometry appropriate to the activity.
2. Discuss constellations as being three-dimensional. The students might make a three-dimensional constellation model, using the directions provided with the activity on parallax in this publication. (In making the model, students will be using a spherical triangle determined by parallax.)
3. Let students investigate the procedures Erastosthenes used to measure the circumference of the earth. If another trip to the planetarium can be scheduled, the sun at noon may be shown for both the latitudes of Alexandria and Syene, and students may use spherical geometry to calculate the circumference of the earth in the same way that Erastosthenes did.

Spherical Geometry: Definitions

The following are examples of acceptable definitions that might be developed by students in the foregoing activity.

- Sphere: Any round solid figure having the surface equally distant from the center at all points.

- Spherical center: A fixed point from which all points on the surface of a round solid figure are equidistant.
- Great circle: A circle of a sphere whose plane passes through the center of the sphere.
- Small circle: Any circle of a sphere whose plane does not pass through the center of the sphere.
- Parallels: Two or more lines which are equidistant at all points and which do not intersect; if two or more planes which intersect a sphere are equidistant, the planes are parallel.
- Axis: An imaginary or real line or point about which an object or sphere rotates.
- Equator: A great circle on a sphere which is equidistant from the points at either end of an axis.
- Meridian: An imaginary line extending from pole to pole which crosses the equator at a right angle; all great circles which contain the axis as their diameter.
- Spherical angle: The angle established by the intersection of two great circles.

Steering by the Stars

MATERIALS

For the Classroom

- world map
- earth globe
- celestial globe
- coordinate star chart
- astrolabe or hand sextant
- compass

For the Planetarium

- planetarium sextant
- star or nautical almanac (for class reference)
- world map with coordinate lines at 15° intervals or less (one per student)
- pencils
- paper
- pen lights
- drawing compasses

In the era of radar and computers, it may come as a shock to students that navigators of ships and planes still use the stars as a basic reference system for determining locations and headings. Why? "The stars are dependable," explained one airline pilot. "Once you get above the clouds at night, they're always there and nothing ever goes wrong with them."

In the following activity, students will use the planetarium stars to learn the basic principles involved in celestial navigation.

Student Preparation (Grade level: secondary)

Content background: understanding of celestial sphere; familiarity with right ascension and declination; prior lesson sidereal time; working knowledge of use of protractor and tools for measuring altitude and azimuth.

Facts and Concepts

The positions of the stars, along with sidereal time, can be used to determine an observer's exact position on the earth.

Objectives

- Using the stars as reference objects, the student will be able to determine his position on earth.
- The student will be able to determine altitude and azimuth.
- The student will be able to plot the navigational triangle on a world map.
- The student will be able to determine a heading.

Procedures for the Classroom

1. The assumptions and principles underlying celestial navigation are the same as those Erastosthenes used in determining the circumference of the earth. Review his method with the class, pointing out that he assumed:
    a. the earth is round
    b. celestial objects are so distant that the direction to any of them from all places on earth must be the same, the apparent differences in the direction of the objects as viewed from earth are caused by the earth's spherical shape
    c. light rays are essentially parallel.

    Emphasize that Erastosthenes knew from geometry that the difference in the angle at which the sun's rays struck the earth at Syene and Alexandria equaled the size of the angle at the earth's center between the two cities. He therefore used a stick to measure the angle of the sun to the vertical in Alexandria at the moment the sun was directly overhead at Syene and found the arc of the angle measured to be 1/50th of a circle. This told him that the distance between Alexandria and Syene was 1/50th of the earth's circumference. The rest was a matter of pacing off stadia between the two towns and multiplying by 50.
2. Ask the class for ideas on what the sky can tell a person about his location on earth. Ideas about the nighttime sky to highlight are that the stars overhead vary with latitude, longitude, and the time of night, and that each of these variables offers a clue to location if other facts are known.
3. Provide for review as needed from the following understandings and skills which

will be used in the planetarium:

a. understanding of the horizon as a primary great circle of the celestial sphere where the sky and earth's surface appear to meet

b. measurement of longitude and latitude, right ascension and declination

c. the relationship of hours of right ascension to longitude and to Greenwich sidereal time

d. measurement of altitude, azimuth, and angles. Through the review use a celestial globe, world map, coordinate star map, astrolabe or sextant, compass, and protractor as needed.

Procedures for the Planetarium

Preset the planetarium for any given date at a latitude and longitude of a location at sea, but neither the latitude nor longitude of home location. Some well-known stars should be no more than 25° to 35° above the horizon. (The latter is important. The stars to be plotted should be at fairly low altitude to allow for a large zenith angle for purposes of better accuracy.) No cardinal points should be visible.

1. Turn on the night sky and ask students to assume they are at sea and need to use the stars to find their way. They may locate the North Star and some familiar constellations. But where exactly are they? In what part of what ocean?
2. Distribute the world maps and ask the class to take part in the following procedures, which are much like those actually used in navigation.
3. The class locates and identifies three familiar bright stars 25° to 35° above the horizon and about 120° apart in azimuth. One student uses the planetarium sextant projector so that others may measure and record the altitude of each star.
4. Using a star atlas or nautical almanac, another student looks up the right ascension (sidereal hour angle for the nautical almanac) and declination of the three stars and reports to the class.
5. The declination of a star gives the latitude of its substellar point (because the celestial equator, from which declination is measured, is simply an extension of the earth's equator from which latitude is measured). The students will need the latitude of the three substellar points for plotting, but you may wish to take time out to discuss how they can determine their own latitude from the declination of one star if it isolated on the meridian.
6. Students next determine the longitude of the substellar points of the three stars, using Greenwich sidereal time (give the class Greenwich sidereal time for the setting). Students know:

   a. that the right ascension of a star coincides with Greenwich sidereal time when the star's substellar point is on the longitude of Greenwich

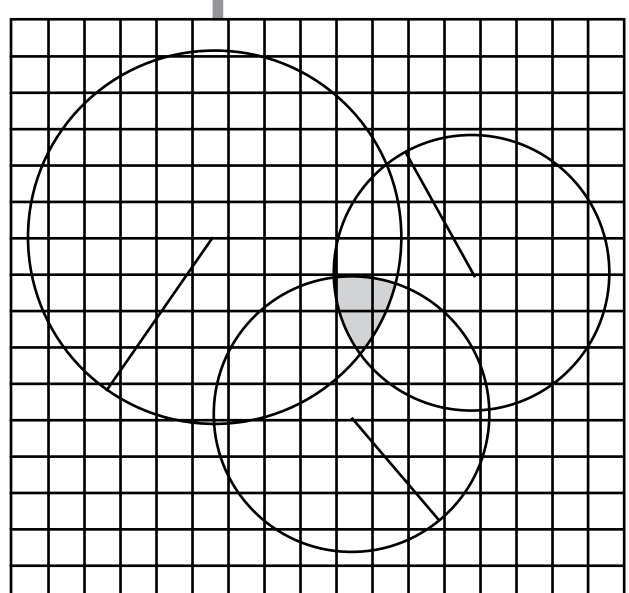
   b. that the earth revolves from west to east at 15° per hour. Therefore, the longitude of a star's substellar point may be found by subtracting Greenwich sidereal time from the right ascension of the star, and multiplying by 15. For example, if the right ascension of a star is 14 hours and it is 0800 Greenwich sidereal time:

   14 - 8 = 6 hours west of Greenwich

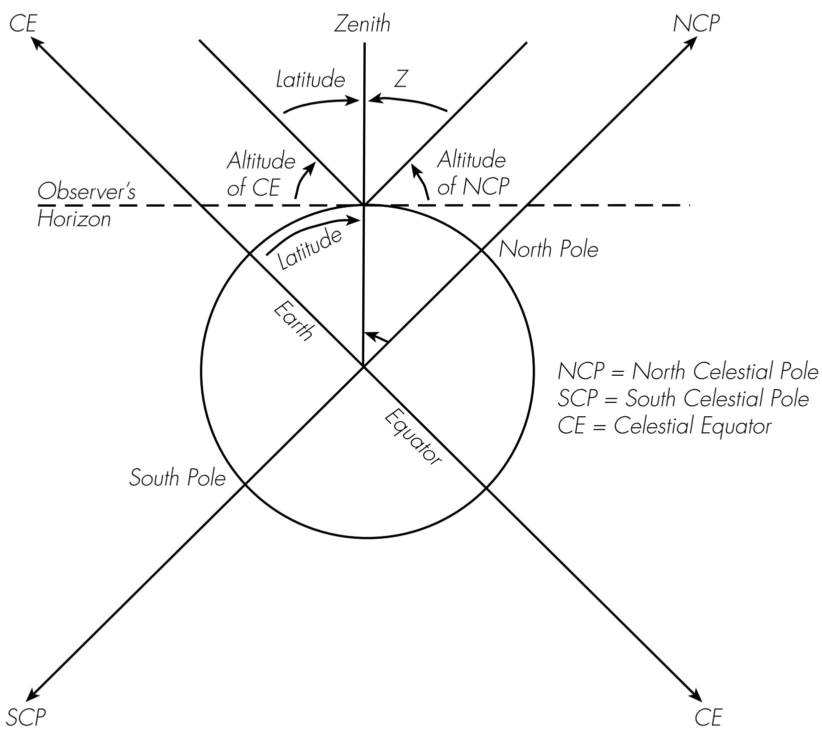
   (a negative number indicates east of Greenwich)

   6 x 15 = 90° west longitude

   (a negative number indicates east longitude)



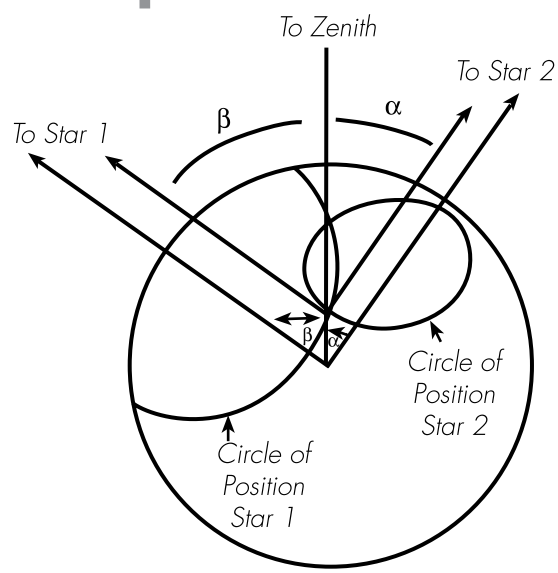
7. After students have found the latitude and longitude of the substellar points of the three stars, they should plot them on their world maps.
8. The next step is for students to determine a zenith angle (the angular distance from the zenith) for each of the three stars. They do this by subtracting the altitude of the star from 90°. They then use the zenith angle of each star as the radius of a "circle of position" which they draw around the star's substellar point as plotted on the map. The latitude scale of the map should be used to measure degrees in constructing each radius.
9. The three circles of position should meet to form a small triangle representing the student's "tour position" at sea, as shown in the figure below. Students should examine what it tells them about their location and consider what else they need to know.
10. The small triangle (shaded area) should tell students where they are on earth within a few degrees. But they must remember that they are at sea and have not yet determined the direction they should head the craft to get to their destination. Now they plot a heading to their destination, drawing a line to that point on the map. To do so, they:
    a. Determine a north-south line. (In the planetarium this can be done with the meridian; aboard ship, it would be done with a compass.)
    b. Measure the azimuth angle between north and the desired heading. This is done by measuring on the map with a protractor and then measuring the same number of degrees around the horizon from the position determined as north. (It may need to be pointed out that both azimuth and bearing are measured clockwise around the horizon from 0° north to 360°.) At this point, the student mariners should mentally head the ship in the determined direction.
11. The above steps complete the procedure for celestial navigation. But explain to students that in practice, once isn't enough. The procedure is repeated over and over again by navigators to keep a ship or an aircraft on course. You might also point out that the planetarium sky hasn't moved, a convenience you have arranged. The stars in the real sky would "move" all the while, a substellar point would be a substellar point only for an instant. Therefore navigators need to take their measurements and make their calculations with speed. How can they do so? They travel (usually) a known course; they know what ocean they are on or over; they have their favorite stars to steer by and know these stars' right ascension and declination. They also have handy instruments to get altitude, a clock set for Greenwich sidereal time, and mathematical tables. Through the night, they get a "fix" from the stars many times, quickly going through procedures comparable to the ones above; during the day, they use the sun and depend on other, but often less satisfactory, methods to steer by.



12. If time permits, move the planetarium sky and let students predetermine their position at sea.

Follow-Up Activities

1. Unless the topic has been well-covered previously, pursue the idea that an observer can determine his own latitude if he finds the declination and altitude of one star located on the meridian. Students know (a) that the celestial equator is directly above the earth's equator at 0° declination; (b) that the celestial poles are an extension of the earth's poles and are 90° from the celestial equator; and (c) that the zenith is 90° above the horizon. Therefore, if a star with a declination of -10° has an altitude of 35°, the celestial equator at the latitude of the observer's location has an altitude of 25°. To obtain his own latitude, the observer subtracts the altitude of the celestial equator from the altitude of the zenith: 90° - 25° = 65°. For class emphasis: 65° is the angular distance of the celestial equator from the zenith point (or the zenith angle). Since the celestial equator's substellar point is the earth's equator, and since the zenith's substellar point is the position of the observer north or south of the equator, the latitude of the observer is the zenith's substellar point of 65°.



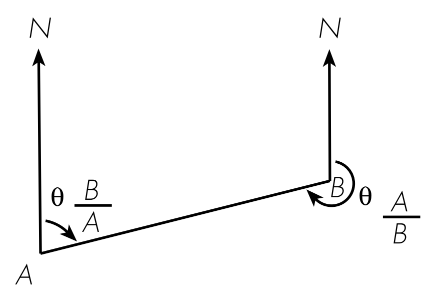
2. Discuss the zenith angles used in plotting the navigational triangle in greater detail. From the diagram below, it should be recognized by students that the zenith angle, Z is 90° minus the observer's latitude, and that it is also 90° minus the altitude of the north celestial pole. Thus the altitude of the north or south celestial pole is equal to the observer's north or south latitude.

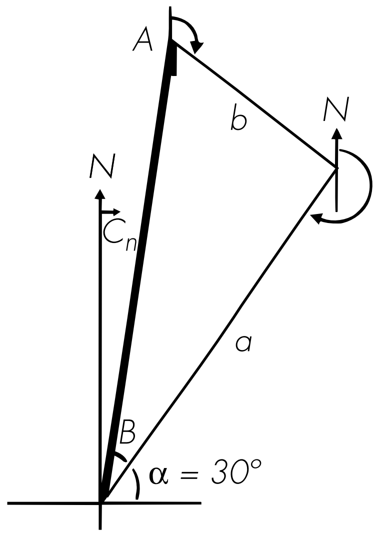
3. Discuss in some depth the principles involved in using three stars to get a "fix." The angle in the sky between the navigator's zenith and a star (the zenith angle) is the same as the angle at the center of the earth between the observer and the star's substellar point. (Mathematically, this is the same principle Erastosthenes used and underlies all determination of location by means of celestial objects.) Having found the zenith angle for one star, the navigator knows his distance in degrees of an arc from the star's substellar point — he is somewhere along the rim of a circle whose center is the substellar point of the star and whose radius is his zenith angle from the star. But the one circle offers possibilities of position that may vary as much as 130° in all directions. By finding his zenith angle for a second star and constructing a second circle of position, the navigator limits the possibilities: the intersections of the two circles define the two places on earth where he may be located. (Two circles often will be enough for a ship's navigator — for instance, one of the possible positions may be on land.) The third circle of position defines a "tour" position in a spherical triangle which contains one of the intersections of the first two circles and which is within all three circles. A drawing (following) may clarify these ideas for students.

4. Students who are interested in sailing may wish to examine in more detail the procedures for plotting course and bearing:

   a. After a north-south line is constructed through the ship's position (that is, the intersection of the circles), the course, C, is measured from the north clockwise to the direction the ship is sailing:

   b. Bearing is also measured clockwise from north. Below the bearing of a ship at A headed toward B is the angle measured clockwise from the north line





Evaluation Suggestions

Give students data and let them repeat the procedures used in the planetarium. The maps prepared by students can serve in part for evaluative purposes.

Vocabulary

horizon
zenith
angle
celestial navigation
right ascension
declination
altitude
navigational triangle
azimuth
longitude
great circle
latitude
circle of position
heading
bearing
"fix"
Greenwich sidereal time

and is the angle B/A (B/A means B relative to A). Likewise the bearing of a ship at A headed toward B is the angle A/B.

c. To provide an example of the computations involved in navigation, present the following problem: A ship sails 15.5 miles on course 124.0°. It then sails 31.3 miles on course 214.0. What course must it then sail to return to its starting point? The sketch below represents the given conditions. We have a right triangle with two legs known.

To find B use:

$$\tan B = \frac{b}{a}$$

$$\tan B = \frac{15.5}{31.3}$$

$$\tan B = 0.4951$$

$$B = 26°20'$$

To find C_n, note that $\alpha = 30°$

Hence $\alpha + B = 30° + 26°20'$

and $C_n = 90° - (\alpha + B)$

or $C_n = 33°40'$

5. To conclude the activity, invite someone familiar and experienced in navigation to talk with the class on celestial and other navigation techniques, and/or conduct an evening session and see if the students are able to obtain their position from observations of the real sky.

Meteor Observation: Getting the Facts

Meteors and meteorites are of value in science for the information they offer about characteristics of the upper atmosphere and the composition of bodies in space. However, meteor observation is of use to students primarily for the opportunities it provides for training and growth in the skills required to make and report observations.

In the following activity, students will be challenged to figure out ways to observe and describe a meteor after seeing one unexpectedly in the planetarium. When other meteors fortuitously cross the planetarium sky, they will be ready to practice specific techniques through which observations may be quantified and reported. (If this activity can be timed for a period of meteor showers in the real sky, so much the better.)

Student Preparation (Grade level: secondary)

Content background: working knowledge of measurement of angles; some familiarity with constellations; ability to use a coordinate star chart.

Facts and Concepts

- Science advances through careful observations and the collection of quantitative data. This means that ways must be found to record and describe sensory impressions quantitatively.
- The observation of meteors requires measuring techniques in order to determine azimuth, altitude, direction of motion, brightness, duration, color, accompanying sounds, and time of observation.
- Meteorites provide information on the composition of bodies in space.

Objectives

- Given appropriate instruments, the student will be able to determine and communicate to others the altitude and azimuth of the beginning and end points of a meteor observed in the planetarium and its angle to the horizon.
- The student will be able to chart the course of a planetarium meteor on a coordinate star chart and to determine, with a protractor, the angle of the meteor trail to the celestial equator.
- The student will be able to provide other such data on a fireball meteor observed in the planetarium as is sought on real fireballs by members of the Network for Analysis of Fireball Trajectories.

Procedures for the Classroom

1. If the students have not had previous experience in making an astrolabe, they should make one. In any event, they should practice using one to determine the altitude of objects outdoors.
2. Familiarize students with the constellations that will be visible in the night sky on the date of the planetarium visit. After showing the shape of the constellation on a constellation chart, ask students to locate the same constellation on a coordinate star chart, giving them the coordinates.

Materials for the Planetarium

1. Turn on the stars for 9 p.m. date of planetarium visit. Let students use the night sky to determine cardinal points, then proceed with the identification of stars and

MATERIALS

For the Classroom

- astrolabes or materials for making them
- constellation charts
- coordinate star chart
- protractor

For the Planetarium

- degree markings around the planetarium dome
- meteor projector (or other projection device or flashlight to simulate a meteor trail on planetarium dome)
- note pads
- pencils
- pen lights
- Fireball Observation Chart: two copies per student
- planetarium sextant projector

constellations. (Be sure to review those that will be in the paths of the meteors to be projected.)

2. As star identification goes on, project the first meteor.
3. Turn up the lights and ask students to record what they saw. Discuss and compare descriptions so that students will note the results (which will undoubtedly come out as conflicting reports, inconsistency in the use of terms, and a scattering of data).
4. Ask the group to consider the types of data that could be collected on a meteor and to jot down a list of observable characteristics as each is agreed upon. Press for mention of the following characteristics and discuss how each might be described and, if possible, measured.
   a. Brightness and color: Students who have seen meteor showers or who have read about them may offer suggestions. Otherwise, ideas may have to await further planetarium experiences.
   b. Location: Where were the beginning and end points of the meteor? Could these be determined in relation to the star background? How might the altitude and azimuth of the beginning and end points be determined?
   c. Angle of meteor trail: Might this be determined in relation to the horizon from the altitude and azimuth of the beginning and end points?
   d. Direction of motion? Might this be determined from the azimuth of the beginning and end points?
   e. Time of night, duration: The observer, of course, would check his watch. He might count to estimate duration, if he had seen many meteors he could make a comparative estimate. Announce the time of the planetarium setting, students will need the information later.
5. Turn on the stars again. Letting students offer suggestions, point out the beginning and end points of the first meteor in reference to constellation background, and show how the planetarium sextant, meridian, and degree markings around the dome can be used to determine azimuth and altitude. As you conclude, offer a few minutes of "waiting time," then:
6. Suddenly project a fireball meteor. It comes as a sudden flash, a trail, a "sonic boom." Ask students to collect their thoughts and try to remember all they can about the meteor, particularly the beginning and end points in reference to the stars.
7. Distribute one copy of the Fireball Observation Chart to each student. Let the class as a whole assemble the requested data, with each student filling in data agreed upon (or his own observations if there are sharp differences of opinion). Explain the chart as one based on a chart in actual use by members of the Network for Analysis of Fireball Trajectories, a group sponsored by the planetarium at Michigan State University, Lansing. Except in this context, some of the questions may strike students as odd; in the context, the questions make sense. Insist that the class answer all. (Students will get a laugh out of the item "Reliability of Observer." Let each evaluate his own reliability.)
8. Use the planetarium sextant and meridian as required for determining "Position in the Sky" and "Angle to Horizontal." Then ask students to note their own latitude and longitude and to consider whether other data might be recorded as to the two above items by an observer at another location.
9. Distribute to students another copy of the Fireball Observation Chart. Inform them that they will be expected to collect data independently for the next fireball seen in the planetarium sky. After turning on the stars and providing a few moments of anticipatory time, project another fireball meteor. Give students opportunity to

fill in the charts, project the planetarium sextant and meridian as needed, then collect the charts for evaluation purposes.

Follow-Up Activities

1. Return the evaluated Observation Charts, discuss, and distribute coordinate star charts. Ask students to plot the trail of the meteor on the chart and to use a protractor to determine its angle to the celestial equator.
2. Let students investigate the dates of the next meteor showers, using The Observer's Handbook. If possible, meteor watches should be planned for those nights, with students again collecting the data called for on the Fireball Observation Chart.
3. Ask students to observe and describe aircraft moving through the sky — an investigation that will require similar observational and communications skills.
4. Assign reading through which students will investigate the relationship of the asteroid belt and comets to meteor showers — and the distinctive terms used to differentiate between objects from space (meteoroid, meteor, meteorite, fireball meteor, bolide).
5. Let students investigate the values of meteors to science.
6. Encourage students to collect and analyze meteor dust. For example, they might collect water from an eaves spout, straining it through muslin. Then they should let the cloth dry and collect particles from it with a magnet. You can explain that what they collect will be micrometeorites, and rust from the gutter. Using a hand glass, they can distinguish between the two — the rust will appear as flakes; the micrometeorites will resemble small grains with ragged edges. (More capable students may also be able to subject the micrometeorites to tests for unknown elements.)

Note

For Fireball Observation Chart, see following page.

Evaluation Suggestion

Student performance may be determined by evaluation of the completed Fireball Observation Chart and by the student's ability to plot the trajectory on a coordinate star chart.

Vocabulary

meteor
trajectory
end point/beginning point
meteoroid
fireball
meteorite
altitude
angle to horizontal
azimuth
micrometeorite
asteroid
comet
bolide

Name____ **Date**________________________

Fireball Observation Chart

Time: ______ (year) ______ (month) ______ (date) ______ (hour) ______ (minute) ______ (second) ______ (time zone)

Weather: ____

Location of observer when fireball was seen: ____________________________

Latitude:______________ Longitude: ______________

Position of fireball in the sky:

First seen:	__________	__________	______________
	azimuth	altitude	star background
End point:	__________	__________	______________
	azimuth	altitude	star background

Angle to horizon: ____

Direction of motion: ____

Duration: ____

Brightness: ____

Color: ____

Sounds: ____

Interval between first seeing fireball and hearing sounds: ________________________

Reliability of observer: ____

Date of interview: ____

This chart is based on the Fireball Observation Chart of Network for Analysis of Fireball Trajectories, Lansing, Michigan.

Parallax: Finding Stellar Distances

Most astronomical distances are so vast that obtaining direct measurements are impossible. In this activity, students will examine parallax through laboratory exercises and investigations in the planetarium. They will explore not only the usefulness of parallax for determining the distance to stars, but also how we depend on it every day for depth perception.

In a final laboratory activity (optional, but recommended), the students will make a three-dimensional model of a constellation. Examination of the model will show them that the three-dimensional configuration is based on the actual distance in light years from each star to the earth, as determined by parallactic shift.

Student Preparation (Grade level: secondary)

Content background: ability to measure angles with an astrolabe or sextant; (preferably) prior experience with technique of triangulation.

Facts and Concepts

- Parallax is the apparent displacement of an object due to a change in the observer's position or point of observation.
- Parallax is directly proportional to the change in the observer's position in relation to the object.
- Depth perception depends on parallax.
- Stellar parallax is an angular shift in the position of a star as viewed from the earth due to changes in the earth's position in its orbit.
- Stellar parallax provides us with a means for indirectly measuring the distance to many stars.

Objectives

- Using direct observations of the apparent shift of a planetarium star due to parallax, the student will be able to use indirect measurements to determine the distance of the star from a known base line.
- The student will be able to use triangulation to determine the height of, or distance to, an object.
- The student will be able to explain (verbally or in writing) the base line used for determining stellar parallax, and will relate this base line to earth motions.

Procedures for the Classroom

1. Let students investigate a simple example of parallactic shift. Ask them to hold up a finger directly in front of them and to look at it alternately with one eye and then the other, keeping the other eye closed. They should note the position of the finger against the background. Then stretching their arm more and less, they should notice whether distance makes the parallactic shift increase or decrease.
2. Use Laboratory Investigation I (Parallax and Depth Perception).
3. Review how the distance to an inaccessible point may be determined by triangulation. Suppose the distance is sought to a mountain peak. This can be determined by setting up two observation stations at A and B, separated by a known distance, the base line, and assuming triangle ABC, with point C representing the top of the mountain. At station A the angle A is observed and measured between the directions to B and C. At station B, the angle B is observed and measured between the directions to A and C.

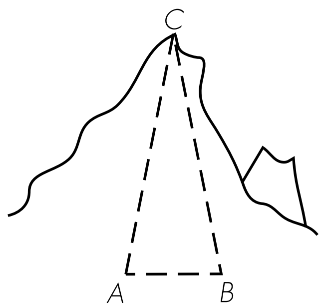
MATERIALS

For the Classroom

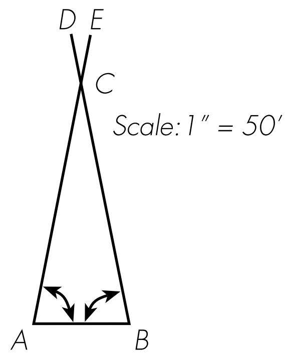
- astrolabes or sextants
- protractor
- additionally, the various materials listed with the two laboratory investigations and copies of the investigations for distribution to students (see end of activity for the two investigations)

For the Planetarium

- light source suspended with black thread from planetarium dome
- astrolabe or sextant
- tape for measuring base line
- pen lights
- paper
- ruler
- protractor
- pencils



Base Line 1000′



Enough information is now available to construct a scale drawing of the triangle ABC. The base line AB is laid out at some convenient scale and lines AE and BD are constructed at angles A and B, using a protractor to measure the angles. The points where lines AE and BD intersect is the object C. The distance to point C from any point on the base line may now be determined by measuring in the drawing and converting to scale. The result is as accurate as the scale of the drawing, with the margin of error increasing as the scale decreases. (Solutions of triangular distance may be much more accurately accomplished through trigonometric function of right angles; this method should be used by students who have the required mathematical background.)

4. Give students opportunity to try out the above method (perhaps determining the distance to the top of a tower) so that they will get practice in setting up a base line, sighting and taking angle measurements, using a protractor to construct angles, and converting to scale (or using trigonometric functions).

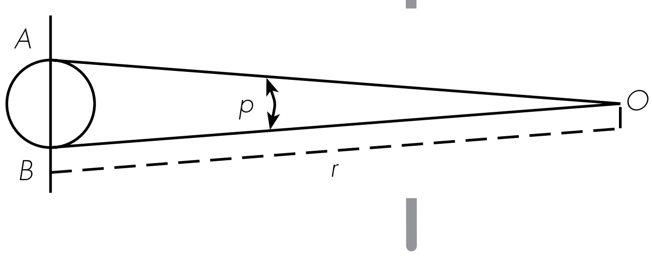
Procedures for the Planetarium

Presetting: Suspend a light source with black thread one or two feet from the center of the planetarium dome. The stars may be set for evening, date of visit.

1. Darken room, turn on stars and the suspended light. Ask students how they might determine the distance to the light.
2. When indirect measurements and triangulation are suggested, students should measure a base line between opposite sides of the planetarium dome and measure the base angle to the suspended object from both ends of the base line. This measurement may be made with an astrolabe or sextant. Then the distance should be found to the suspended light through the method previously used in the classroom.
3. Ask students how they might measure the distance to a star on the dome. (The students should repeat the procedures of Step 2 for one or several stars.)
4. The class should now compare the parallax angle for the suspended light with the parallax angle for the star or stars. Discuss what happens to the parallax angle for more distant objects.
5. Discuss the base line used in astronomy for determining the distance to stars, and ask someone to use an atlas of the heavens or *The Observer's Handbook* to look up the parallax angle for the particular star or stars considered above.

Follow-Up Activities

1. Provide for study and discussion of historical methods for determining the distance to celestial objects. The students might note that the distance to the moon was determined surprisingly accurately by the ancient Greeks through triangulation procedures (two distant points were used as the base line).
2. Present the solution of the astronomical "skinny triangle" as a means for finding the distance to nearby celestial objects (sun, moon, planets). Suppose it is found that the displacement in direction of an object — that is, parallactic shift — as viewed from opposite sides of the earth, is the angle p in the diagram below. Then p is the angle at O subtended by the diameter of the earth.



Imagine a circle centered on O that passes through points A and B on opposite ends of a diameter of the earth. If the distances to O is very large compared with the size of the earth, then the length of the chord AB is very nearly the same as the distance along the arc of the circle from A to B. This arc is in the same ratio to the circumference of the entire circle as the angle p is to 360°. Since the circumference of a circle of radius r is 2πr, we have

$$\frac{AB}{2\pi r} = \frac{p}{360°}$$

By solving the above equation for r (the distance to O), we find

$$r = \frac{360°}{2\pi} \quad \frac{AB}{p}$$

If p is measured in seconds of arc rather than in degrees, it must be divided by 3600 (the number of seconds in 1°) before its value is inserted in the above equation. After the arithmetic, the formula for r becomes

$$r = 206{,}265 \quad \frac{AB}{p \text{ (in seconds)}} \quad .$$

As an example, suppose p is 18 seconds of an arc (about what would be observed for the sun). Since AB, the earth's diameter is 7929 miles,

$$4 = 206{,}265 \quad \frac{7927}{18} \quad = \quad 9.1 \times 10^7 \text{ miles}$$

3. Continue with problems for solution in which the parallax angle is measured from two opposite sides of the earth's orbit. Discuss limitations of parallactic shift and the "skinny triangle" for determining astronomical distance and ask for reports on other methods.
4. Use Laboratory Investigation II (Parallax and the Constellations).

Note

This investigation provides instructions for making three-dimensional models of the Big Dipper and Orion. You can prepare instructions for making models of additional constellations — or students can develop the details themselves — by: (1) determining the distance of each star in light years, (2) devising a scale for light years, such as ¼" = 1 light year, and (3) by plotting the constellation in right ascension and declination to fit the cardboard from which the constellations will be suspended.

See following pages for Laboratory Exercises I and II.

Evaluation Suggestions

Ask students to measure the distance and/or height of various objects, such as to the top of the flagpole, and check on their techniques and mathematical procedures. Ask students to describe verbally, or in writing, procedures for determining the distance to a star on the planetarium dome. Ask students to describe verbally, or in writing, the base line used for determining stellar parallax, and the procedures used. Students' results in Laboratory Investigation II may be used for evaluation purposes.

Vocabulary

parallax
parallax angle
base line
base angle
triangulation

MATERIALS

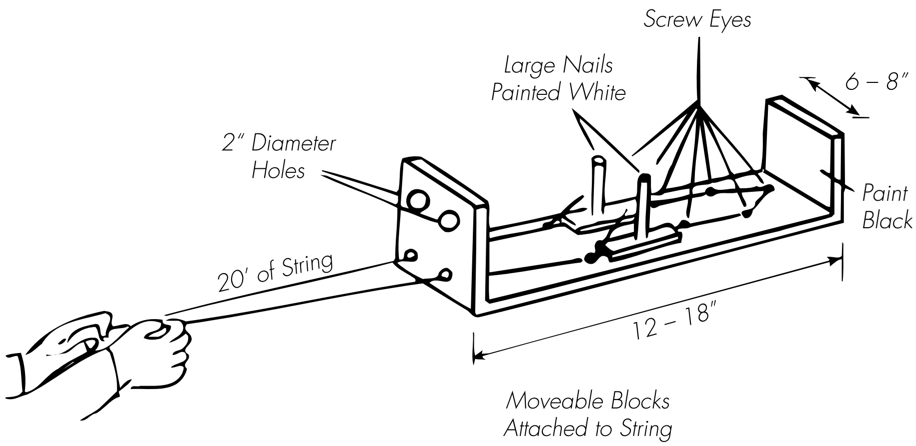
- Frame of wood or cardboard

  If wood, use 1 piece 18″ x 8″ x ¾″, 2 pieces 8″ x 8″ x ¾″, 6 wood screws, 1-¼″ long to assemble frame, 3 screw eyes (string will be threaded through these)

  If cardboard, use a shoebox 12″ to 18″ long, 6″ to 8″ wide, and 6″ to 8″ deep, make loops of string in the positions shown for screw eyes, threading them through the bottom of the cardboard and taping in place on the bottom
- 2 wood blocks, each 2″ x 1″ x ½″
- 2 large nails painted white
- 45-foot length of string
- watch with second hand or stop-watch

Laboratory Investigation I: Parallax and Depth Perception

Depth Perception Device



Construction and Assembly

- Construct apparatus as shown in diagram. Tape or clamp it to the end of a table and thread the string through the screw eyes as shown in the picture. The two ends of the string should extend 20 feet from the apparatus.
- Add a scale along both sides of the apparatus. The scale should not interfere with the movable blocks.

Procedures

Pairs of students are to work together, with one manipulating the strings and the other keeping the record. After one student completes all of Step 1 below, he should keep the record while his partner carries out the same step.

Performance Record Chart

	Time	Units off from Center	Units each peg is off from each other
Trial I			
Trial II			

1. Sit on a chair 20 feet back from the apparatus. Use a tallback chair or sit where you can support your head against the wall, because you need to keep your head in the same position throughout this step. Hold one string in each hand.
   a. Hold your head in a position so that you can look through the two-inch diameter holes and see the nails.
   b. Using both eyes, line up the nails on the wood blocks, as quickly aspossible, in the center of the apparatus. Your partner is to time you and read from the scale how far each nail is off from being in the center of the apparatus and how far the two nails are off from being aligned. He is to record this information for three trials on the chart below.

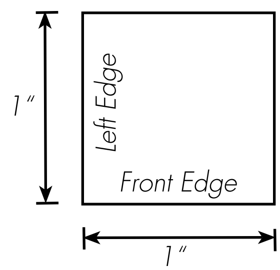
c. Repeat the above procedure, using only your left eye. Try it three times, with your partner recording information.

d. Repeat the above procedure, using only your right eye, three times. Again your partner is to record the results.

2. Did the results differ for each eye?
3. Did the parallax (angle of shift) move uniformly for each eye?
4. Change the color of the backboard (tape colored paper over it) and run the investigation again. Does depth perception improve with color?

MATERIALS

- 1 piece of corrugated cardboard 8″ square
- 1 spool of heavy-duty thread
- scissors
- aluminum foil
- ruler
- pin or heavy needle



Laboratory Investigation II: Parallax and the Constellations

(Three-Dimensional Constellation Models)

A constellation is a chance arrangement of stars as viewed from Earth. If we were to leave the earth in a spaceship and travel to a distant star, the constellations as we know them would no longer be observable. Perhaps the two most famous constellations are Orion, the Hunter, and Ursa Major, the Great Bear (better known as the Big Dipper). How would these constellations appear from other places in space? A three-dimensional model will provide the answer. Choose either of the two constellations and make your model according to the instructions below.

Construction Procedures

1. Label the cardboard as shown at left:
2. Using a ruler and pencil, measure and mark the position of each star in the constellation on the cardboard according to instructions provided in the construction table below. Notice that each star's position has two measurements — one for the left edge of the cardboard and one for the front edge.
3. When you are certain that the star positions are plotted correctly, punch a small hole at each star position on the cardboard, using a needle or scissors point.
4. Cut pieces of thread for each star in the lengths designated in the construction table.
5. Push the thread for each star through its correct hole position in the cardboard, leaving 1 inch of its length to be taped to the top of the cardboard.
6. Roll up small balls of foil to represent the stars. The foil ball for Alpha will be the largest (about ½″ in diameter), the one for Beta will be the next largest, and so forth. Here is the Greek alphabet to assist you:

Alpha .... α	Eta .... η	Nu .... ν	Tau .... τ
Beta .... β	Theta .... θ	Xi .... ξ	Upsilon .... υ
Gamma .... γ	Iota .... ι	Omicron .. o	Phi .... ϕ
Delta .... δ	Kappa ..... κ	Pi .... π	Chi .... χ
Epsilon ..... ε	Lambda ... λ	Rho .... ρ	Psi .... ψ
Zeta .... ζ	Mu .... μ	Sigma...... σ	Omega .... ω

7. With a pin, needle or scissors tip, punch a hole through the center of each foil ball.
8. Pass the free end of the thread through the foil ball, making sure to put the correct size ball on its corresponding thread (again, see construction table) and tape in place.

Investigative Procedures

1. Hold the cardboard horizontal with the floor, view the constellation at eye level, and record its appearance.
2. Hold the cardboard horizontal with the floor but over the head, view the constellation from underneath, and record its appearance.
3. Hold the cardboard so that the front edge is vertical with the floor, view the constellation, and record its appearance.
4. Hold the cardboard so that the left edge is vertical with the floor, view the constellation, and record its appearance.
5. Try to relate your observations to your view of the constellation from earth, to a view of it from other points in the universe, and to parallactic shift.
6. Try to relate your observations to the movement of the earth in space and to the parallactic shift that results from earth's motion in space. The parallax angle for each star is given in the last column of the construction table. You can convert parallax angle to distance in light years as shown below:

$$\text{Distance (in parsecs)} = \frac{1}{\pi} \text{ (parallax sec of arc)}$$

Example

Star's parallax = 0".007

$$\text{Distance (parsecs)} = \frac{1}{.007} = 142.9$$

1 parsec = 3.263 light years

D (light years) = light yr/parsec x distance (parsecs)

$D = 3.265 \times 142.9$

D = 466.4 light years

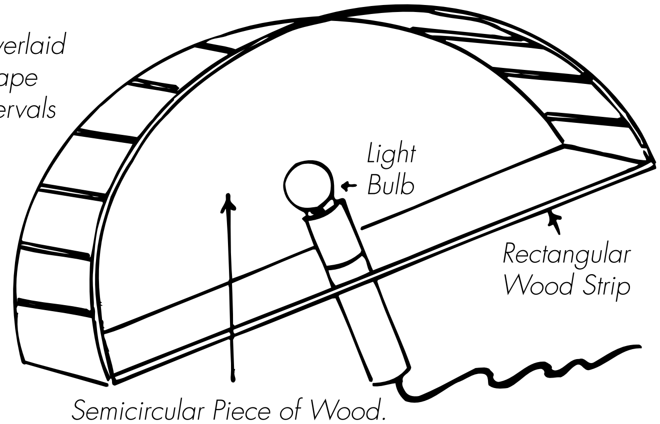
MATERIALS

- 2 pieces of thin wood cut in semicircles
- 1 strip of thin wood the length of diameter of semicircles
- 1 strip of clear plastic the length of circumference of semicircles and width of the wood strip
- black tape
- good glue and/or small screws
- tube for white light and plug
- light source

Planetarium Hand Sextant

Directions

Put together as pictured below, adhering small strips of black tape at spaced intervals across the plastic strip for the light to shine through and project degree lines on the dome. The width of the tape should be chosen to represent 5° or 10° increments.



Instructions for use

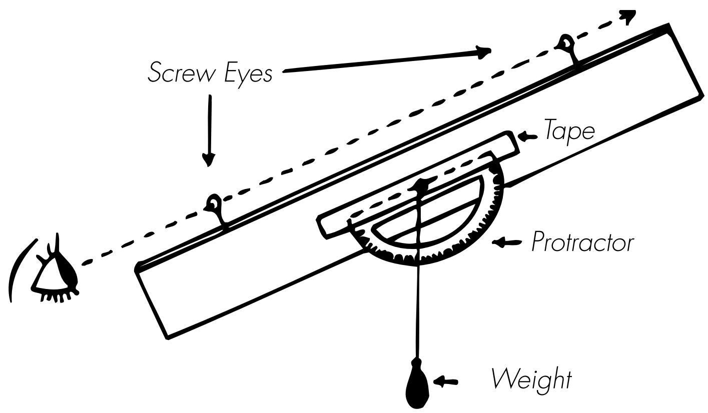
In measuring altitude, use the planetarium sextant as near to the center of the planetarium as possible. It may also be used to measure azimuth, but the means suggested below are easier and no one needs to hold the sextant.

Varieties of Student-made Astrolabes

Two types of student-made astrolabes are pictured below (although there are many other varieties).

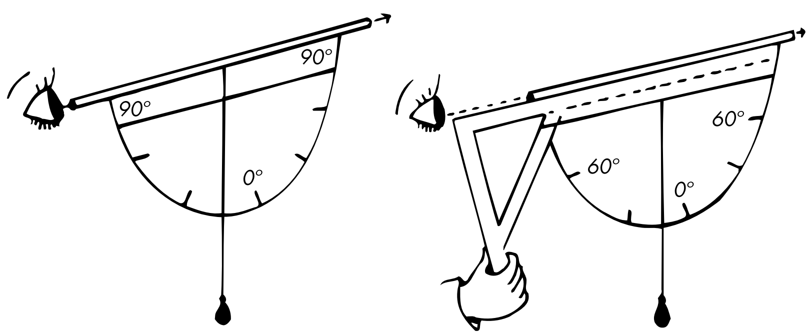
Type A

Construct and use as pictured.



Type B

Construct and use as pictured.



MATERIALS

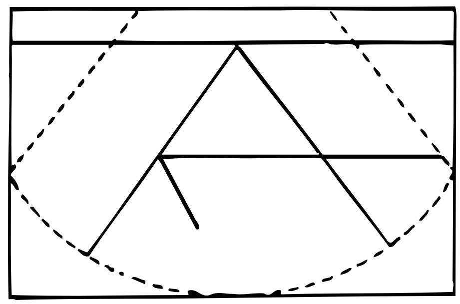
- straight piece of plywood
- 2 screw eyes
- protractor
- string
- weight
- adhesive tape (for affixing protractor)
- thumbtack

MATERIALS

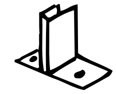
- heavy cardboard marked off in degrees as shown
- string suspended as pictured, drawn through hole and knotted on the back of the astrolabe
- weight
- straw for sighting device
- (refinement) lorgnette-type holder of wood or cardboard

Student-Made Sextant

Materials



Plywood marked as shown and cut on dashed lines

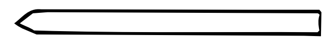


Four mirror holders

Two mirrors

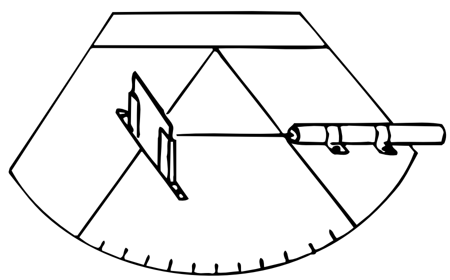
Two holders for sighting tube

Sighting tube

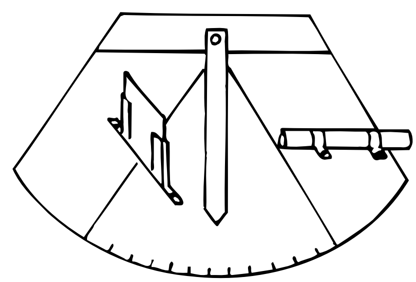


Plywood arrow

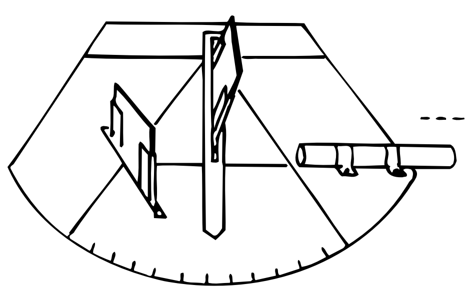
Construction



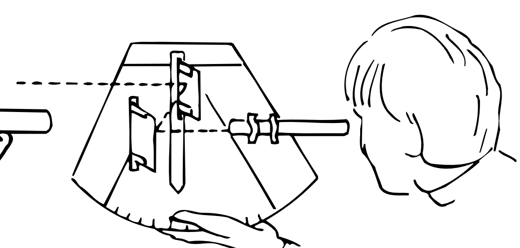
1. First view



2. Second view



3. Third view

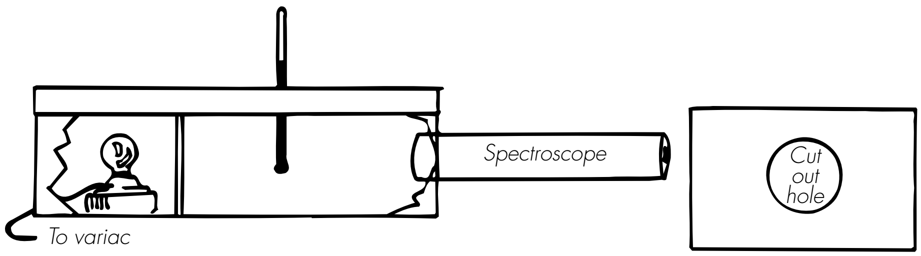


4. Use

Apparatus for Observing Temperature–Color Relationships

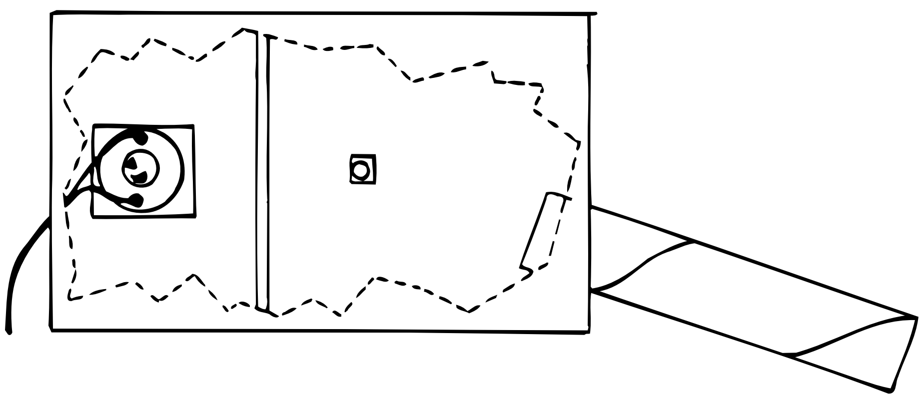
Construct as shown in the following pictures:

Side View:



Note

Divider has small opening;end view of divider.



Top View:

Directions for Use

The thermometer must be in the light beam produced through the opening in the partition. As one student uses the calibrated rheostat to reduce the bulb in brilliance, another student records temperature changes as shown on the thermometer, while a third student looks through the spectroscope and records color bands.

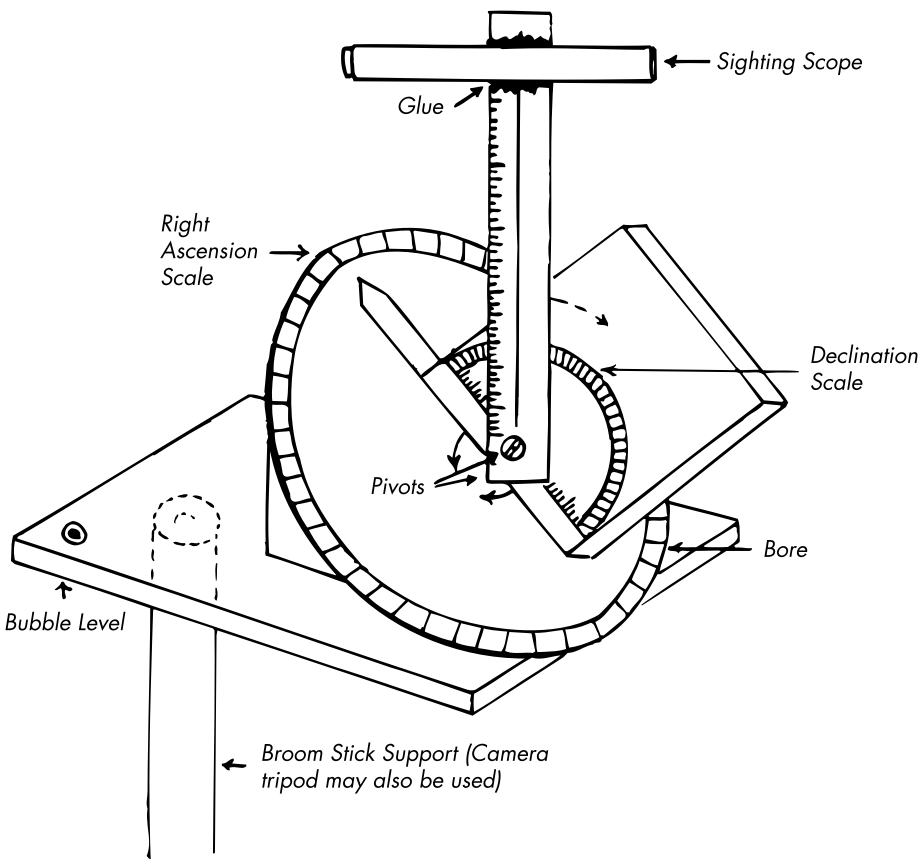
MATERIALS

- incandescent bulb
- calibrated rheostat or variac
- partitioned box with slit in partition
- thermometer
- spectroscope

If only an uncalibrated rheostat or variac is available, put a paper plate around the control knob and mark degrees on the plate, using a protractor.

Equatorial Coordinate Star Finder

The drawing below shows materials, construction, and use.



Safety Devices for Viewing the Sun

Eye-Safety Device for the Viewing Sun

When students are doing investigations that require viewing the sun, it's best to do more than caution them against looking directly at it. Materials should be made available which they can use for observing the sun without running the risk of eye damage. Ordinary sun glasses are not sufficient protection. However the following methods are considered safe.

Indirect Method

Instructions

Punch a small hole into the cardboard, and hold it so that the sun is at the viewer's back. The sun's rays can then be focused through the hole onto the white paper, showing safely the sun's disc.

MATERIALS

- piece of cardboard
- sheet of white paper

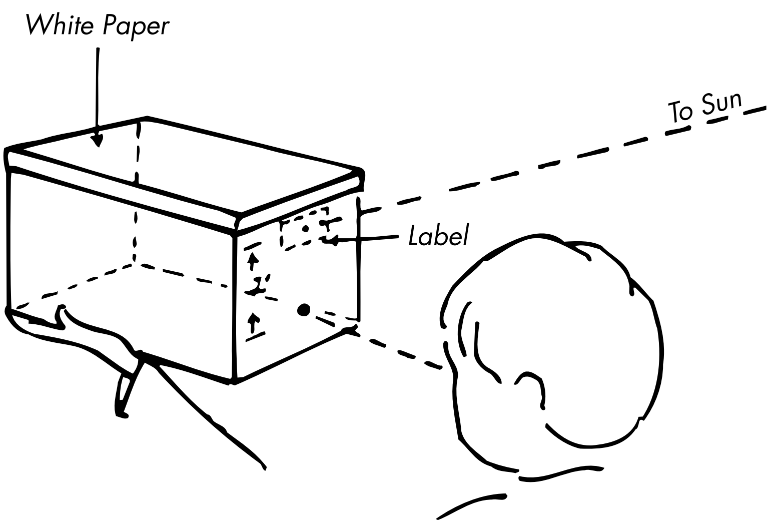
Pinhole Camera Method

Instructions

Paste the paper inside one end of the box. Punch two holes on a vertical line about a foot apart in the opposite end. Place the label over the top hole and pierce it with a pin. Then seal all the box seams so that no extra light enters. The observer stands with his back to the sun, looking through the bottom hole. The box should be moved around slightly until the sun's image comes through the pinhole and appears on the paper.

MATERIALS

- Cardboard carton with a lid (a box or a long tube can be modified for use)
- piece of white paper
- gummed label



Telescopic Observations

If you are planning to view the sun with a telescope, be certain that it is equipped with a reliable solar filter. Check the filter before using it, making sure that it has no cracks or scratches. Under no circumstances should you look through the telescope without the proper filter. Similarly, do not look through binoculars or into a mirror to view the sun.

A projection system can be set up using your telescope or binoculars to view the sun. By orienting the instrument so that it points in the direction of the sun, you can project the image of the sun on a piece of paper or cardboard held in front of the eyepiece.

DO NOT LOOK THROUGH THE EYEPIECE. Many instruments will be damaged if pointed at the sun too long, so check with the manufacturer of your instrument before taking a chance.

Note

DO NOT use the Project STAR Refracting Telescope (manufactured by Science First/STARLAB) for viewing the sun. It has no protective filters and would not be safe for this purpose.

Bibiliography for Extension Activities

Chamberlain, Von Del, Functioning as a Member of the Network for Analysis of Fireball Trajectories*, Michigan State University, 1969. pp. 1-8.*

Hamburg, Michael, Astronomy Made Simple*, Doubleday Books, 1993. 237 pp.*

Harvard Project Physics, New York, Holt, Rinehart, and Winston, 1970.

Investigating the Earth*, 4th edition, Earth Science Curriculum Project (ESCP), Boston, Houghton Mifflin Company, 1987. An earth science text for junior high school students, funded by the National Science Foundation.*

Morrison, David, Sidney C. Wolf, Andrew Fraknoi, Abell's Exploration of the Universe*, Saunders College Publishing, Philadelphia, many editions. An astronomy text for college students. Page numbers in Suggested Resources refer to first edition unless otherwise noted.*

Zim, Herbert Spencer, Stars: A Guide to the Constellations, Sun, Moon, Planets, and Other Features of the Heavens*, Golden Books Publishing Co., 1985. 160 pp.*

Annotated Periodical Bibiliography for Extension Activities

The American Ephemeris and Nautical Almanac, Washington D.C., Government Printing Office. Published annually. Regularly contains the following in addition to other information:

"Eclipses of the Sun and Moon." Charts, maps, and narrative describing the eclipses occurring in the current year.

"Heliocentric Ephemerides of Major Planets." A chart of the information described by the title.

"Mean Places of 1,078 Stars." A chart containing the name, magnitude, spectral class, and position of 1,078 stars.

"Moon: Right Ascension, Declination and Horizontal Parallax for Each Hour." A chart containing the information described by the title.

"Sun-Ephemeris for OhE.T. Precession and Nutation in Longitude: Obliquity." A chart of the information described by the title.

"Sunrise and Sunset: Twilight." A chart of the information suggested by the title.

The Maryland Academy of Sciences Graphic Time Table of the Heavens, Watson, Paul S. A chart depicting the heavenly events of the current year, published annually by the Maryland Academy of Sciences, 7 W. Mulberry St., Baltimore, MD.

The Observer's Handbook, Toronto, Royal Astronomical Society of Canada. Published annually. Regularly offers the following in addition to other information:

"Eclipses During...[the current year]." A chart and map of the year's eclipses.

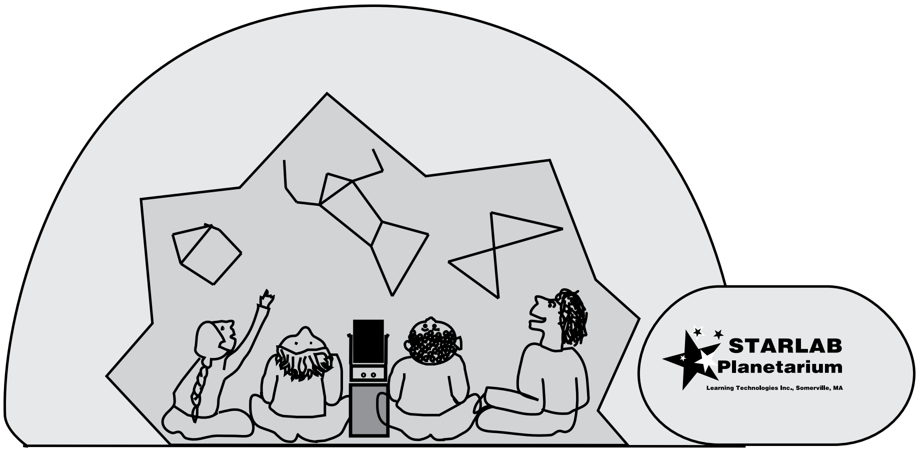
"The Brightest Stars," MacRae, Donald A. A chart containing nine items of information about 286 stars plus their location.

"Meteors, Fireballs and Meteorites," Millman, Peter M. A chart and narrative describing the occurrence of these phenomena.

"Times of Rising and Setting of the Sun and Moon." A chart of the information suggested by the title.

Sky and Telescope, Cambridge, Mass., Sky Publishing Corporation. Monthly periodical.

Stars & Skies



An E.S.E.A. Title IV Project, 1979.

The Stars & Skies project was originally developed in 1979. The activities in this section have been culled from the original document and updated by Gary D. Kratzer. These activities should be especially useful to the beginning STARLAB user. The elementary section is divided according to grade level. Each section contains suggested student objectives, background information, and planetarium activities. This section also contains supplemental activities to be used as pre- or post-planetarium visits. Refer to the Appendix (located at the end of the Grades 7-9 section) includes scripts and directions for construction of support equipment.

Revised by Gary D. Kratzer, 1997

STARLAB Activities for Grades 7 to 9 (plus Appendix)

Grades 7-9 Objectives

Objectives

The student should be able to:

1. Identify the following phases of the moon: first crescent, first quarter, waxing gibbous, full, waning gibbous, last quarter, last crescent.
2. Identify and position a slide image of any phase of the moon, given the time of day.
3. Identify the approximate time of day by viewing a slide image of the rising moon.
4. Identify the major areas of highlands and "seas" on the surface of the moon on a projected image of the full moon.
5. Identify, from a projected slide image, the following major surface features of the moon:
    a. The craters: Copernicus, Plato, Archimedes.
    b. Any other features selected by the teacher.
6. Visually differentiate between 1st, 2nd, 3rd, and 4th magnitude stars.
7. Make a direct correlation between star color and increasing star temperature.
8. Give a numerical estimate for the amount of apparent stellar motion per two minutes.
9. Give a numerical estimate for the amount of "drift" of the 10 o'clock position of any given star along the ecliptic.
10. Look at the night sky and tell which season it is.
11. Locate the 15 brightest stars in the sky throughout the year at your local latitude.
12. Identify 14 constellations containing the 15 brightest stars at your local latitude.
13. Demonstrate an understanding of why Venus sometimes appears as the "morning star" and as the "evening star" at other times.

Moon Phase Identification, Activity I

Objective

The student should be able to identify the following phases of the moon: first crescent, first quarter, waxing gibbous, full, waning gibbous, last quarter, last crescent.

Background Information

The changing shape of the moon is one of the most conspicuous of the celestial phenomena. As the moon revolves around the earth we see increasing and decreasing amounts of the moon. The time interval between two successive new moons is called a synodic month which is a little over 29½ days.

During the first half of the synodic month the amount of the moon visible from earth increases each night. The moon is said to be waxing. During the second half of the synodic month, the amount of the moon visible from the earth becomes less each night. The moon is then said to be waning.

At the beginning of the synodic month the sun and moon rise and set together. The moon can therefore not be seen. This is a ***new moon***. Each night the moon rises and sets about 50 minutes later.

One night after the new moon, the sun sets and the moon will still be above the horizon in the west. The moon will appear as a thin crescent. This phase is called ***first crescent***. On the second night after the new moon, the moon will set about 100 minutes after the sun. The crescent will appear thicker than the night before. The points of the crescent are always away from the sun (to your left during the first half of the synodic month). About ¼ of the way through the synodic month (about seven days after new moon) the moon rises at noon and sets at midnight. By this time, half of the moon is visible from earth. This phase is called ***first quarter***. About ten days after new moon, the moon rises in the middle of the afternoon. More than half of the moon is visible. This phase is called ***waxing gibbous***. About halfway through the synodic month (about 14 days after new moon) the moon rises at about sunset. The entire side of the moon toward the earth is visible. This is called a ***full moon***. About 18 days after the new moon, the moon rises about 10 p.m. Over half of the moon is visible. This phase is called ***waning gibbous***. Three quarters of the way through the synodic month (about 22 days after the new moon) the moon rises at about midnight. Half of the moon is visible. This phase is called ***last quarter*** or ***third quarter***. About 26 days after the new moon, the moon rises at about 4 a.m. It is crescent-shaped again; however, the cusps point to the right (away from the sun).

The synodic month ends and begins with new moon.

Procedure 1

- In the STARLAB set up the projector and Starfield Cylinder to project various moon phases or use the slide projector and the ecliptic slide projector mount to project the slides of the moon phases. If your slide projector is equipped with a zoom lens, adjust the image size for realism.
- Begin with new moon. Tell the students that the sun and moon rise and set together in this phase. Ask why the moon can't be seen. Point out that the moon is very close to the sun and it's lit side is away from the earth.
- Mention that the new moon causes solar eclipses when it comes between us and the sun so we know it is there even if we can't see it.

MATERIALS

- STARLAB Portable Planetarium
- Projector
- Starfield Cylinder
- moon phases

Optional

- ecliptic slide projector mount
- 35 mm slide projector
- moon phase slide set

- Project the waxing crescent slide in its position at sundown.
- Point out that the moon rose about fifty minutes after sunrise and therefore will set about fifty minutes after sunset being visible for about fifty minutes in the west. Note that the cusps are pointing away from the sun or toward the east as seen from our hemisphere.
- Suggestion: A rheostat-controlled light can be used to simulate day and night and to make it easier to comprehend the passage of time between phases. A student can be used to operate this device.
- Continue to project the phases in order, emphasizing that the portion of the moon which is seen from the earth is getting larger each night. At full moon emphasize that the moon rises about the same time the sun sets, and that we are now through the waxing half of the lunar month.
- Continue to show the phases pointing out the part of the moon which we can see from the earth is becoming smaller each night during the waning half of the lunar month. Note that the cusps of the moon point toward the west during the waning phases. After the last crescent is shown, point out that the sun has now "overtaken" the moon and they will again rise and set together. Ask the students the name of this phase.
- Now have the students tell you where to project the phases as you run through a lunar month. Students should be able to give the approximate position of the moon at sundown for the first half of the lunar month and the approximate rising time of the moon for the second half of the month.

Procedure 2

- In the STARLAB, have a team of students project the phases of the moon to demonstrate a lunar month. The position of the moon at sundown works well for the waxing phases. Moonrise time works well for the waning phases.
- This is accomplished in STARLAB by placing all of the moon phases on the Starfield Cylinder in order.
- Place the first waxing crescent on the first hole to the right of the sun (depends on the month you are observng). No projector is needed on the 6th hole for the position of the full moon. The rest of the waning moon phase projectors will fit in order and will be to the left of the sun position.
- Remember: the lighted side of the moon always faces the sun!

Moon Phase Position, Activity 2

Objective

The student should be able to identify and position a projected or slide image of any phase of the moon, given the time of the day and the equipment supplied with the STARLAB Portable Planetarium.

Background Information

See background information for Activity 1.

Procedure

- In the STARLAB, use the Starfield Cylinder with moon phases or a slide projector and the ecliptic slide projector mount to project the phases of the moon in random order. Give the students the approximate time of the day and have them identify the phase which is being projected.
- Remind the students that the direction the cusps are pointing is an important key to their identification.
- Have the students identify the phase of the moon by shape and the direction the cusps are pointing.

MATERIALS

- STARLAB Portable Planetarium
- Projector
- Starfield Cylinder

Optional

- ecliptic slide projector mount
- 35 mm slide projector
- moon phase slide set

MATERIALS

- STARLAB Portable Planetarium
- Projector
- Starfield Cylinder
- moon phases
- ecliptic slide projector mount
- 35 mm slide projector
- moon phase slide set

Time of Day, Activity 3

Objective

The student should be able to identify the approximate time of day by viewing a projected image or slide image of the rising moon, given the equipment provided with the STARLAB Portable Planetarium.

Background Information

See background information for Activity 1.

Procedure

In the STARLAB Portable Planetarium use the slide projector and ecliptic slide projector mount to project the phases of the moon in random order. Position the projector for moonrise and ask the students the approximate time of the day. Also ask if the moon could really be seen in this position.

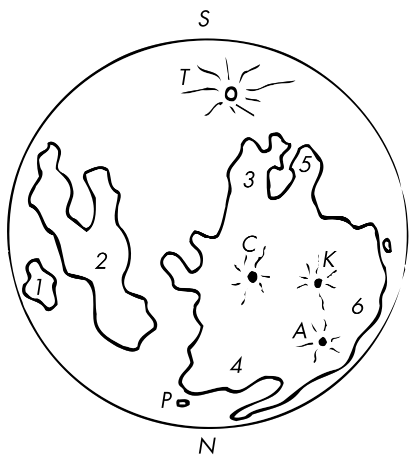
Surface of the Moon, Activity 4

Objective

The student should be able to identify the major areas of highlands and "seas" on the surface of the moon on a projected image of the full moon.

Background Information

Two sketches of the moon are provided below to aid in the identification of lunar features from the projection slide. They may also be used as a guide when observing the moon through a telescope. The first sketch shows the actual moon position is with the North Pole in the standard "up" position. The second sketch is of the inverted telescopic view. Since almost all lunar observations are made with a telescope, it is suggested that the inverted view be used with students.



1. Sea of Crises
2. Sea of Tranquillity
3. Sea of Clouds
4. Sea of Rains
5. Ocean of Storms

A. Aristarchus
C. Copernicus
K. Kepler
P. Plato
T. Tycho

Procedure

Project the slide of the full moon. (This may be done in the classroom or in the STARLAB at the teacher's discretion). Point out the highlands and lowlands on the photograph. Emphasize that this photograph was taken through a telescope and is therefore inverted and much larger than what is seen with the naked eye. Point out that the highlands and lowlands may be seen without a telescope and are quite clear with a pair of binoculars. Suggest that the students observe the moon the next time it is in favorable phase. Discuss the reason why the lowlands are called "seas." Ask the students if they can explain where some of the names of the "seas" came from.

MATERIALS

- STARLAB Portable Planetarium
- Projector
- ecliptic slide projector mount
- 35 mm slide projector
- full moon slide

MATERIALS

- STARLAB Portable Planetarium
- Projector
- ecliptic slide projector mount
- 35 mm slide projector
- full moon slide

Moon Features, Activity 5

Objective

The student should be able to identify, from a projected slide image, the following major surface features of the moon: the craters (Copernicus, Plato, Archimedes) and any other features selected by the teacher.

Background Information

Mapping the Moon — The first maps of the moon date back to those made by Galileo. In 1610 Galileo observed the moon with his telescope and mapped some of the details which were revealed. Galileo thought that the large dark areas of the moon were seas. His naming of the "seas" is still with us today. Galileo also recognized the mountainous areas of the moon. In about 1651, J.B. Riccioli began the practice of naming craters after scholars, giving us many of the present crater names. In 1935, the International Astronomical Union published Named Lunar Formations which was a catalog containing about 6,000 lunar features. With the advent of satellites our knowledge of the moon leaped forward. In 1959, the Russian satellite, Lunik III, sent the first pictures of the far side of the moon back to earth. Information about the moon has been accumulating at a staggering rate ever since. The accomplishments of the United States manned space programs has eclipsed much of the early speculative work about the moon and we now have direct evidence to support many observations. NASA makes a wide variety of materials available to schools including actual samples of moon rocks.

Lunar Mountains — Three ranges of lunar mountains are found along the west side of Mare Imbrium. Unlike many lunar features these mountains somewhat resemble our mountains here on earth. Some of the peaks in this area may rise as high as 20,000 feet based on shadow measurement techniques. Lunar mountains as well as other features do not show the effect of weathering and therefore are much different from what we see here on earth.

Lunar Seas — The large dark areas of the moon are called seas or maria. This name was first given them by Galileo and has endured even though the "seas" are actually plains.

Lunar Craters — The nearly circular craters of the moon are probably the most unique of the moon's geographical features. The number of craters probably exceeds 30,000. They range in size from just a few feet across to over 150 miles across. There is still much debate among scientists concerning the origin of the craters.

Procedure

- Show the students the slide of the full moon which has the major geographic features labeled. Have them make a sketch showing the approximate location of the major features.
- Explain to the students that most moon observations are made through telescopes which invert the image which we see, and therefore what we see is really upside down. Explain that to make observation easier, many moon maps are drawn just as they are seen through the telescope, even though it is really upside down.
- Point out key geographic features such as the craters, Copernicus, Plato, and Archimedes. Explain that other features may be found using these easy-to-find features as points of reference. Ask where the names of the craters came from.
- Have the students locate the features studied above.

- If at all possible, have the students look at the moon through a telescope. If this is not possible, have the students look at the moon through a pair of binoculars. Some of the geographic features can be seen. Remind the students that binoculars don't invert the image so the moon will appear in the same position as it does with the naked eye.

MATERIALS

- STARLAB Portable Planetarium
- Variable Light Source (see Appendix for plans)

The Magnitude of Stars, Activity 6

Objective

The student should be able to visually differentiate between 1st, 2nd, 3rd, and 4th magnitude stars.

Background Information

What causes the stars to vary in brightness from one star to another? Besides local weather conditions, especially wispy cirrus clouds which indiscriminately veil some stars but not others, stars may be uniformly brighter or fainter due to particulate pollution, or the background light produced by cities or a combination of both. In the country, one can see stars that are 2.5 times fainter than those seen in the city sky — a good reason to head to the country for stargazing!

All the factors mentioned above are earthbound sources of star brightness variation which must have inspired the familiar "Twinkle, Twinkle Little Star." Viewed from earth orbit, however, the stars do not twinkle. Now what accounts for the variation in star brightness? Casual observation of a bright, conspicuous star and a nearby faint star makes it impossible to tell whether the brighter of the two stars is simply much closer to us than the faint star or whether the brighter star is more distant but much larger in diameter. Star distances vary from 4.3 light years for the star nearest the earth to over 4 billion light years for the most distant objects we can see. A light year is 5,880,000,000,000 miles, which is the distance light travels in one year.

The diameter of visible stars can vary from dwarf stars, which are about the size of the earth, to stars with diameters of 1 to 2 billion miles. These very large super giant stars would swallow up our star, the sun, and all the planets out to Saturn, if placed at the center of our solar system.

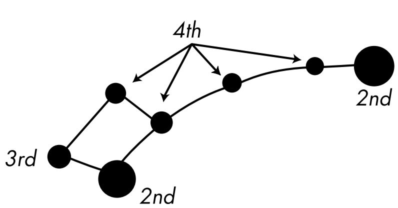
Because stellar distances from the earth and stellar diameters encompass such a huge range of distances and diameters, it is not at all surprising that some stars are so bright, while others are so faint. To complicate matters, stars have an absolute brightness and a relative brightness. The relative brightness is exactly what we see at night. If all stars were placed the same distance from the earth, then we could view their absolute brightness, which might be surprising because some close bright stars would be fainter and some distant faint stars would be much brighter.

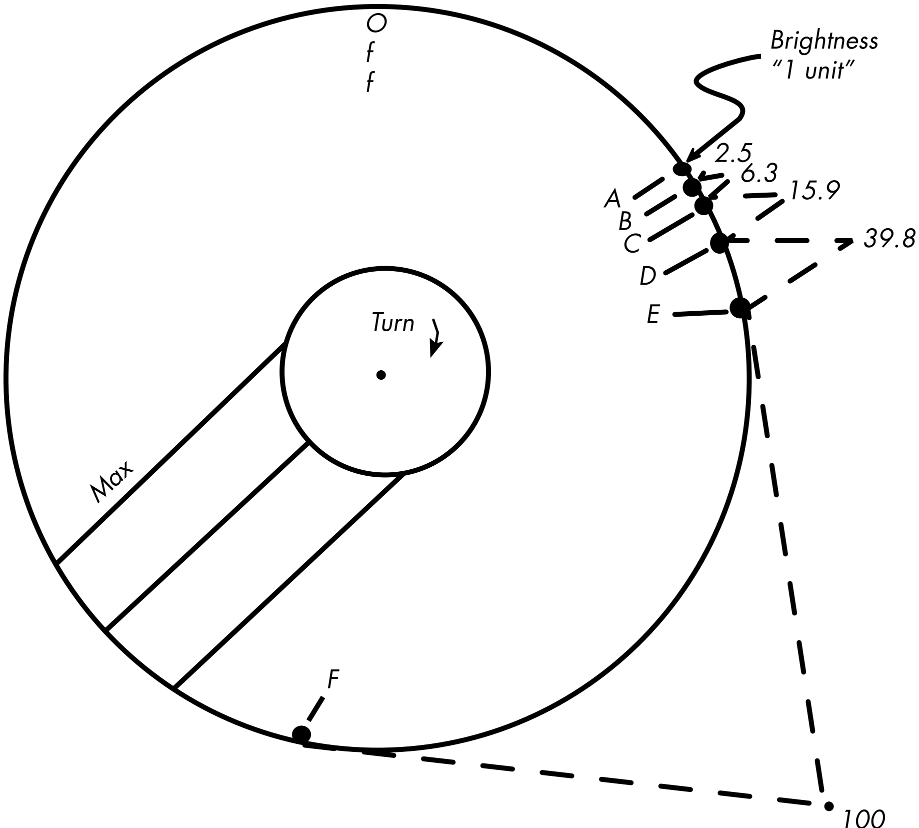
Procedure

- Spend some time discussing star brightness with your students, trying to draw out the factors that influence star brightness mentioned in the background material. A good technique might be to set the night sky to any arbitrary position then slowly turn up the side lights while asking students to explain why the stars are fading from view. This should lead naturally to a discussion of other factors influencing stellar brightness.
- Slowly dim down the projector. The faint stars should disappear first, followed in order by brighter stars, until just the brightest stars remain. You should practice this in the planetarium to find a constellation which "behaves" well with the dimmer switch. A good candidate is the Little Dipper.

Note

The diagram here shows why the Little Dipper is difficult to find sometimes, especially in city light. The four 4th magnitude stars are at the limit of "see-ability" in city light.





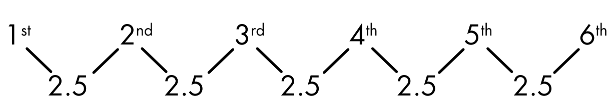
Extension Activity

It is possible to teach about star brightness by using a simple-to-build variable light source which can have many uses in the planetarium. Detailed plans for the variable light source can be found in the Appendix of this booklet. The dial for this homemade instrument is shown here.

- Turn the control on the unit to max., leaving it there for several minutes to warm up. Next "test" your students' eyesight (and your dexterity) by slowly turning down the control to letter A . If you push too far beyond A, the light will go out and you will have to start at F again. Now with the light just barely visible, move the control to B. The light intensity is now 2.5 times greater, the same change in brightness between the faintest stars we can see and the next brightest stars. Again move the control to C and state that now the light is 2.5 times brighter than it was at B and 6.3 times brighter than the first position A.
- Now challenge students to tell you when to stop as you make the bulb brighter so that the bulb will be 2.5 times brighter than the previous position C. At D the bulb is 2.5 times brighter than C and 15.9 times brighter than A. Continue this procedure until you have turned to F. Now the bulb is 100 times brighter than it was at A.
- Explain that there are 6 positions of brightness and 5 changes which have taken place. Each change is called 1 magnitude. An Englishman named N. R. Pogson proposed in the late 1800s that the six (6) magnitudes of stars visible to the naked eye under the best viewing conditions should represent a change of 100 units of brightness. This means that the 5 changes in magnitude from 6th to 1st magnitude stars should span 100 units. The question now becomes, "What number raised to the 5th power is 100?"

  $X^5 = 100$

  $X = 2.5119$



This is why if you call the faintest bulb reading 1 unit then 5 changes of magnitude later, the bulb is (2.5119)5 or 100 times brighter.

Here are some interesting magnitude comparisons, based on the visual magnitudes listed below.

- Sun: -26.7
- Full moon: -12.5
- Venus: - 4.3
- Sirius (the brightest star): -1.4
- The faintest star seen with no telescope, under the best conditions: +6

$$\frac{sun}{moon} = \frac{(2.5119)^{26.7}}{(2.5119)^{12.5}} = (2.5119)^{14.2} = 478{,}670$$

The sun is almost 500,000 times brighter than the full moon.

Note

Since the brighter the object, the smaller the magnitude number, very bright objects must have negative magnitudes.

$$\frac{\text{Brightest star}}{\text{Faintest star}} = \frac{(2.5119)^{1.4}}{(2.5119)^{6}} = (2.5119)^{7.4} = 912$$

The brightest star is almost 1,000 times brighter than the faintest star. The important thing to remember is that each magnitude is a change of 2.5 compared to the previous one.

Use a calculator to quickly make other similar comparison calculations. The important thing to remember is that each magnitude is a change of 2.5 compared to the previous one.

Star Color and Temperature, Activity 7

A student should be able to make a direct correlation between star color and increasing star temperature.

Background Information

In the early 1900s two men, Ejar Hertzsprung and Henry Russell plotted a graph of the absolute magnitude of a star versus its color. The resulting diagram called the H-R diagram has been used for 70 years to draw conclusions about the surface temperatures of stars. Listed below is a qualitative description of this relationship.

Color	***Surface Temperature***
Greenish White	*62,000° F*
Bluish	*44,000° F*
White	*20,000° F*
Yellowish White	*12,200° F*
Yellow	*10,000° F*
Orange Yellow	*7,000° F*
Orange	*4,900° F*
Orange Red	*4,200° F*

Procedure 1

By turning the variable light source up to maximum then slowly decreasing the brightness, students should be able to see some color changes. To maximize this activity, the large 4½" diameter 60-watt frosted bulb should be replaced with a regular or clear 100-watt bulb. Although colors ranging from "white" to orange can be seen, this does not mean that the temperatures range from 20,000° F to 4,200° F. The tungsten filament in the bulb melts at 6,100° F! The range of colors from the bulb is characteristic of heavy elements, however most stars are composed of the first six elements, especially hydrogen. The real point to this exercise is that the whiter it is, the hotter it is, something most students know intuitively.

Procedure 2

- If a high voltage source and some gas discharge tubes are available, it is possible for students to see firsthand, the bands of light in an element's spectrum. If you have never operated this instrument, it is best to get some help from a physics or chemistry teacher. Do not let the "high voltage" part of the name scare you.
- The shock obtained by purposely touching both contacts is much more like a good "scuff across the rug in the winter" shock.
- It can come as a real surprise to students to realize that the elements found on earth are the same ones found in the stars, and that the spectrum of the star light is what tells us which elements are present.
- Besides the voltage source and discharge tubes, you also need a piece of diffraction grating. Diffraction grating is a small piece of clear plastic with 10,000 to

MATERIALS

- STARLAB Portable Planetarium
- Variable Light Source with star magnitude calibrations
- 100-watt clear bulb

Optional

- High-voltage source
- gas discharge tubes
- diffraction grating

13,000 evenly spaced parallel scratches per inch. The "scratched plastic" does exactly what a prism does. White light is broken up into its colors. (Diffraction grating is available in a variety of sizes from Science First/STARLAB at 1-800-537-8703, www.starlab.com.)

- When looking through the grating, look off to either side of the bulb to see the spectrum.
- After years of observing stars and the spectra of their light, it became obvious that the spectra fell into categories or types. The spectral type and the color are shown in the following chart.

Spectral Class	***Visual Color***
O	*Greenish-white*
B	*Bluish*
A	*White*
F	*Yellow-white*
G	*Yellow*
K	*Orange-yellow*
M	*Orange*
N	*Orange-red*

Apparent Stellar Motion, Activity 8

MATERIALS

- STARLAB Portable Planetarium
- Projector
- Starfield Cylinder
- Variable Light Source (optional)

Objective

The student should be able to give a numerical estimate for the amount of apparent stellar motion per 2 minutes.

Background Information

If you timed how long it took for a given constellation to return to its original position in the sky from one night to another, it would take 23 hours and 56 minutes or 1,436 minutes. Since the star "circled around" the earth once during that time, it covered 360°. Any star appears to move $^{1}/_{1,436}$ of 360° in one minute. This is $^{360}/_{1,436}$ or .25°.

A quarter of a degree per minute is difficult to grasp, however .5° per 2 minutes is easier to understand because the full moon has an angular diameter of .5°. So simply stated, any star or constellation along the ecliptic moves westward about the diameter of the full moon every 2 minutes through the night and day. Stars and constellations toward Polaris from the ecliptic, cover less distance even though they too "move" at .5° per 2 minutes.

It is useful to think of a rotating wheel to help with this concept. All points on the wheel sweep out the same angle in 2 minutes, however, it is obvious that all points do not cover the same distance. Because many well-known constellations "move" through the sky along the ecliptic, the "moon's width measure" in 2 minutes is useful, even if it does not work for stars closer to Polaris.

Procedure

- An easy way for students to grasp the nightly "movement" of the stars is to time-lapse the night. If you assume that you are looking at the night sky when it's spring or fall, there would be 60 x 60 x 12 or 43,000 seconds of night on a given evening. By making things happen 10,000 times faster, the night would only last 43 seconds. During this 43 second night, a star just rising as "night" starts should set at dawn 43 seconds later. The Starfield Cylinder on the projector will accommodate this movement easily. With practice using the daily motion switch, you should be able to move the cylinder uniformly so that your reference star rises at sunset and 10 seconds later is exactly southeast. Twenty seconds after sunset, the star should be at its maximum height in the sky due south. At 30 seconds, the star should be exactly southwest, and at 40 seconds, it should be setting just as dawn breaks.
- As you become skillful, you may want to use the variable light source to simulate the setting and rising sun, otherwise, a capable student can control the sun at your direction.

  Note

  Remember: every 10 seconds of daily motion in STARLAB, equals 1 hour of apparent sky motion.

Star Drift, Activity 9

Objective

The student should be able to give a numerical estimate for the amount of "drift" of the 10 o'clock position of any given star along the ecliptic.

Background Information

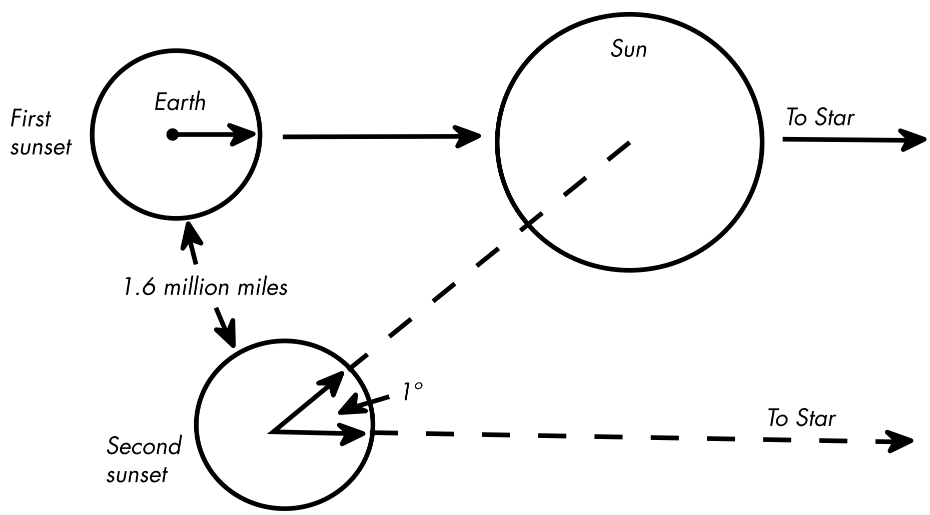
The whole parade of constellations seems to pivot around Polaris, and in the course of 1 year, a given constellation returns to the exact position where it was first sighted. This means that in 365 nights, any given star moves in a complete circle, 360° about Polaris. The amount of nightly "drift" is therefore 360°/360 nights or .986° per night westward.

It is close enough to say that the stars drift westward 1° per night during a 12-hour night, a star just rising at sunset would cover 180° of sky and set 12 hours later at sunrise. The next night, at the same time, the same star would be 1° west of its previous rising location. It would now only have to travel 179° and would set in slightly less than 12 hours.

Since on this second night the star covers only $^{179}/_{180}$ of the previous night's journey, it also only takes $^{179}/_{180}$ of 12 hours or 11.93 hours to set. The difference, .07 hours (or about 4 minutes) is the amount by which the star rises and sets earlier each night.

Assuming a 12-hour night, it would take: $\dfrac{\text{12 hours/night x 60 min./hour}}{\text{4 minutes}}$

or 180 nights for a constellation just rising in the east at sunset to slowly work its way across the sky so that it was just setting at sunrise. Here are some actual star observations to support this idea. At 10:00 p.m. CST, Feb. 15th, the constellation Virgo rises due east at sunset and on August 14th, 180 days later, Virgo is on the western horizon at 9:00 CSDT (10 p.m. CST) at sunset. During this time, all the stars have completed half of their yearly arcs just as Virgo has. The reason for this 1° drift each night is best explained by a diagram.



At the first sunset, if you see a bright star and fix its position, then the next day when the star is in the exact same position, the sun will still be above the horizon. The earth will have to turn through 1° more before 24 hours has lapsed. Stated simply, the stars "circle" overhead once in 23 hours, 56 minutes, while the sun circles overhead once in 24 hours, 0 minutes. The 24-hour day is called a solar day, of course, and the 23-hour, 56-minute "day" is called a sidereal day. Because even the nearest star is so far away, viewing a star from two different points on the earth's orbit 1 day apart (1.6 million miles) does not make any difference in the direction of sight. The lines of sight are parallel. From the drawing it is obvious that 1 day does make a difference in the direction of the sun's center.

Procedure

By coordinating the Variable Light Source (representing the sun) with the Starfield Cylinder on the STARLAB projector, the rapid passage of time can be simulated. Position a conspicuous constellation such as Orion so that it is due south. Then turn up the Variable Light Source to maximum simulating sunrise. While the "sun" is still up, advance the cylinder westward about 1°, then dim the sun. Orion should now be a little west of south. By repeating this pattern 18 times within about 3 to 4 minutes, Orion will have moved one tenth of the way across the sky and the passage of about 3 weeks of time will have taken place. Although the coordination of sun and starlight might seem complicated, this is the sequence we see. To simply sweep Orion across the sky is something no one sees. If necessary, a competent student can run the sun for you.

MATERIALS

- STARLAB Portable Planetarium
- Projector
- Starfield Cylinder
- Constellation Cylinder

Season Identification, Activity 10

Objective

The student should be able to look at the night sky and tell which season it is.

Background Information

The seasonal passage of time is an important concept and an easy one to demonstrate with the STARLAB Portable Planetarium. Stars and constellations along the ecliptic are visible about 6 months from rising to setting. Constellations below the ecliptic are visible less than 6 months and constellations above the ecliptic towards the pole star are visible for more than 6 months. Any constellation which is within the circle swept out by the holding end of the handle of the Big Dipper will be visible year-round. These constellations are called circumpolar. All of this will seem much more real by working with a Star Finder. (See the K-6 section of this book.)

It should be mentioned that the generalizations above apply to 40° north latitude observing but substitution of your latitude is recommended. All the visible stars at the North Pole are visible continuously throughout the year. They are called circumpolar constellations. At the equator, all constellations are visible for 6 months. Since the North Star is right on the horizon, circumpolar constellations have no meaning. At latitude of 40° north, we have some of each.

Procedure

- Pick a conspicuous constellation like Orion. Set the projector so that all of the constellation is just visible at 40° north. The date corresponds to October 21 for 10 p.m. viewing. Now slowly rotate the cylinder until Orion is just about to set in the west. This date corresponds to April 15. The total time passage was 183 days, almost 6 months exactly.
- Now back up to Orion's rising position again, then advance the cylinder a little more westward until Canis Major is just in view. This corresponds to December 3rd for 10 p.m. viewing. Again advancing the cylinder westward, stop just before Canis Major sets. The date is now April 5th. The total time passage has been about 123 days, considerably short of 6 months. This shortened visibility becomes shorter for constellations closer to the horizon at 40° north.
- Now again set Orion at its rising position (October 21 for 10 p.m. viewing), but this time, rotate the Starfield Cylinder eastward until the Pleiades (the Seven Sisters) are just rising. This corresponds to August 10th at 10 p.m. Now rotate the cylinder westward until the Pleiades are just ready to set. This is now April 30th at 10 p.m. The total time lapsed is 263 days.
- The point to make here is that as the seasons progress, new constellations rise, are seen for about 6 months and set if they are close to the ecliptic. Constellations close to the pole star are visible longer and constellations close to the horizon, are visible for less time.
- Now repeat this same activity for North Pole observing and equator observing. Orion is a good constellation to follow each time.
- For our latitude, there is a simple way to tell at a glance what season it is. If you view the Big Dipper continuously at 10 p.m. throughout the year, you would find that in the fall, the same two stars of the Big Dipper which point to the North Star, also point exactly south. In winter, the same two stars in the Big Dipper point west at 10 p.m. In the spring the two Dipper stars point north, and in sum-

mer they point east. The planetarium projector with the Starfield or Constellation Cylinders will show this nicely. A good memory device to help students remember this is:

In the spring, birds fly north and the pointer stars point north.

In the fall, birds fly south and the pointer stars point south.

In winter, the pointer stars point west . . . W for winter.

In summer, the pointers point east.

MATERIALS

- STARLAB Portable Planetarium
- Projector
- Constellation Cylinder

Vocabulary

Relative magnitude — measures how much brighter the star is as compared to Polaris

Star Brightness 1, Activity 11

Objective

The student should know where to find the 15 brightest stars in the sky throughout the year at latitude 40° north.

Background Information

Some stars within 50 light years from us seem especially bright. Several good references list bright stars and information about them. *A Field Guide to the Stars and Planets* by Donald Menzel is especially good. The table below has been compiled from several sources including the one mentioned above. Besides the visual brightness, the brightness compared to Polaris has been calculated. Since Polaris is always visible, whenever the other 15 bright stars become visible, visual comparisons can then be made with calculated comparisons at hand to supplement direct visual comparison.

15 of the brightest stars visible at 40° north latitude with brightness comparisons made relative to Polaris.

Constellation	*Star*	*Visual Magnitude*	*Relative Magnitude*	*Light Years from Earth*
Canis Major	Sirius	-1.4	25	8.7
Bootes	Arturus	-.1	7.7	38
Lyra	Vega	0.0	7.0	27
Auriga	Capella	.1	6.4	46
Orion	Rigel	.2	5.9	500
Canis Major	Procyon	.4	4.9	11
Aquila	Altair	.7	3.7	16
Orion	Betelgeuse	.7	3.7	300
Taurus	Aldebaran	.9	3.1	64
Scorpius	Antares	.9	3.1	230
Virgo	Spica	1.0	2.8	190
Gemini	Pollux	1.1	2.6	33
Pisces Austrinus	Fomalitaut	1.2	2.3	23
Cygnus	Deneb	1.3	2.1	650
Leo	Regulus	1.4	1.9	78
Ursa Minor	Polaris	2.1	1.0	470

Note

The category "Light Years from Earth" was taken from ***A Field Guide to the Stars and Planets****, 1964 edition by Donald H. Menzel.*

Procedure

- The task of getting to know 15 bright stars can seem like senseless busy work, however, it is a worthwhile skill to learn because it allows an observer to navigate by eye, a desired path through the night sky. This skill is rather like the ability to drive around town by using familiar landmarks.
- A real key to helping students remember these 15 bright stars is to invent a multitude of games that stress quick recall. Repetition is an important strategy. Examples of some games include:
- Game 1: Position a constellation along the due south meridian and ask "What is the brightest star in this constellation?"
- Game 2: Have students come up to the projector one at a time. Tell them the name of a bright star, then ask them to move the Constellation Cylinder or Starfield Cylinder on the projector until the constellation containing the bright star is due south. With a arrow pointer, they should try to point to the bright star.
- Game 3: Try identifying the constellation containing the bright star by what the constellation is supposed to represent. For example: "I'm thinking of the name of the bright star in the Swan." Ask them to name the star.
- Game 4: Your turn to invent one!

MATERIALS

- STARLAB Portable Planetarium
- Projector
- Starfield, Greek Mythology or Constellation Cylinders
- Do it Yourself Star Finder

Star Brightness 2, Activity 12

Objective

The student should be able to identify 14 constellations containing the 15 brightest stars, at your latitude.

Background Information

There are certainly many choices and preferences when it comes to which constellations to remember. Altogether, there are 88 constellations in the combined hemispheres, roughly 44 in each.

A reasonable place to start is with the most noticeable stars and the constellations of which they are a part. For 40° north, for example, the constellations containing the 15 brightest stars are:

1. Canis Major
2. Bootes
3. Lyra
4. Auriga
5. Orion
6. Canis Minor
7. Aquila
8. Taurus
9. Scorpius
10. Virgo
11. Gemini
12. Pisces Austrinus
13. Cygnus
14. Leo

For this reason, it is suggested that students get to know these, since observation throughout the year will mean seeing at least one bright star in each.

Procedure

- Using a Star Fnder ahead of time (available from Science First/STARLAB, 1-800-537-8703 or www.starlab.com), should make it easier to locate the previously mentioned 14 constellations. By using the Constellation Cylinder which has lines that connect each star in a constellation, students should be able to match a constellation name with its namesake. For example, by using the Constellation Cylinder rather than the Starfield Cylinder, students should be able to visualize a lion for Leo. If available, place the Greek Mythology Cylinder on the projector to allow the students to visualize the mythological characters.
- After having located the 14 constellations on the cylinder, use the Starfield Cylinder to try to find the 14 constellations (without the aid of lines to help identify the figures).

  Note

  It is recommended that as many different games as possible be constructed which emphasize repetition in the location and name of these 14 constellations. Representative games are written in the activity connected with concept.

The Planet, Venus, Activity 13

Objective

The student should be able to demonstrate an understanding of why Venus appears as the "morning star" sometimes and as the "evening star" at other times.

Background Information

Venus is an inferior planet — one that is between the earth and the sun. Because it is inferior, Venus will appear to move back and forth near the sun. Venus will also show phases similar to those of the moon. When Venus is on the far side of the sun it will appear as "full Venus." When Venus is between the sun and the moon it is in the "new Venus" phase and is not visible from the earth.

Venus is seen either as the "morning star" or "evening star." Because of its nearness to the sun, Venus is seen only shortly before or shortly after sundown. When seen in the morning just before sunrise Venus is called the "morning star." When seen in the evening just after sunset it is called the "evening star." Venus appears as the "evening star" when it is east of the sun and the "morning star" when it is west of the sun.

Procedure

- Set the Variable Light Source on the east side of the planetarium at the point where the ecliptic meets the horizon. Tell the students that the light will act as the sun. When you have the light off it will represent the sun just below the horizon; when the light is on it will be just above the horizon. Ask the students how far Venus will appear from the sun. (They should have the concept that Venus is quite close to the sun.) Explain that Venus is never more than 48° from the sun. To help the students understand the relationship between degrees and what they see, explain that the apparent diameter of the sun is about ½ degree and that from horizon to horizon is about 180°.
- Project Venus using the Venus planet projector or show a slide of Venus just a little above the horizon in the east with the "sun" (Variable Light Source) in the off position. Remind the students that the sun is just below the horizon and therefore can't be seen yet. Ask the students if the projected planet is west of the sun (between the observer and the sun) or east of the sun (on the far side of the sun). The students should determine that the image of Venus is west of the sun. If the students have difficulty with this idea, move the projected image to the east of the sun position. The students should see that the image is on the floor (below the horizon) and couldn't be seen.
- With the planet image just above the eastern horizon, slowly turn up the side lamps to simulate sunrise. Ask why Venus can't be seen during the day. Also ask why Venus can't be seen when its orbit causes it to appear very close to the sun.
- Now move the Variable Light Source to the west side of the planetarium where the ecliptic intersects the horizon. Explain that when the light source is off it represents the sun just after sunset. When the light source is on it represents the sun just before sunset.
- With the light source off, position the projected image of Venus just above the western horizon. Ask the students if Venus is now east of the sun (between them and the sun) or west of the sun (on the other side of the sun). They should determine that Venus is now east of the sun or between them and the sun.
- Now turn on the side lamps or variable light source and ask why Venus can't be seen before sunset. Ask why Venus can be seen only a short time after sunset.

MATERIALS

- STARLAB Portable Planetarium
- Projector
- Venus planet projector
- ecliptic slide projector mount
- 35 mm slide projector
- planet slides
- Variable Light Source

Appendix for Stars & Skies

Constellation Locator Script

Procedure

The STARLAB Projector with the Starfield Cylinder should be set for viewing on about January 15, 9 p.m. Read the following script as you point things out in the dome.

The easiest place to begin a study of constellation location and identification is with the North Star, also called Polaris. Polaris is not especially bright, but it is one of the easiest stars in the sky to locate.

First, look for the Big Dipper (Ursa Major) in the northern sky. Find the "pointer stars" that make up the outer side of the bowl. Then follow the imaginary line joining them until you come to the nearest moderately bright star — Polaris. Polaris is the end star in the handle of the Little Dipper.

Now look again for the Big Dipper. This common star grouping falls within the constellation Ursa Major, the Big Bear. It is a circumpolar constellation that can be seen throughout the year in the northern sky. The Big Dipper makes up the tail of the Big Bear and the rear portion of his body. Extend to two fainter stars west of the pointer stars to complete the front portion of his body and beyond that to one star for his nose. An even fainter star makes up his beady little eye. Just off of the body stars are the front and rear legs of the Big Bear, although local sky conditions may prevent you from seeing those stars.

Now look at the three stars making up the handle of the Big Dipper or tail of the Big Bear. The middle star of the handle is called Mizar and the dimmer companion is called Alcor. This pair of stars was used by armies long ago as a test for eyesight. If you could detect the companion to Mizar, your eyes were good enough.

Let's now find the pointer stars again at the far end of the bowl of the Big Dipper. Follow the imaginary line through these stars, and you will locate the North Star again. Polaris is the end star in the handle of the Little Dipper. The Little Dipper is the circumpolar constellation called Ursa Minor. Ursa Minor, also called the Small Bear, can be seen throughout the year in the northern sky. The tail of the Small Bear is the handle of the Little Dipper, and the body of the bear is the cup of the Little Dipper. Note that the Big and Little Dipper open somewhat toward each other, so when one is dumping its contents, the other is catching it and so on.

Next, let's locate the constellation of Cassiopeia, shaped something like a "w" with its five brightest stars. Start again from the Big Dipper, but this time from the star that joins the bowl and the handle. Again draw an imaginary line from this bowl-handle star through Polaris and on beyond Polaris for about 5 additional "pointer star" lengths, and you will find Cassiopeia, the Queen. Use your imagination to see her sitting on her throne. She can be found high in the autumn evening skies. In summer, Cassiopeia is located in the northeastern sky, and in the winter, she is found in the northwestern sky.

Located close to Cassiopeia, the Queen, is Cepheus, the King. The top side of the "w" of Cassiopeia points to Cepheus. The stars of Cepheus are not very bright, so look closely. Two shapes are distinctive in Cepheus. The constellation is made up of a triangle and a square put together. The triangle represents the top portion of the king including his shoulders and head. The square symbolizes the body and legs of

Cepheus. In winter evening skies, Cepheus is right side up in the northwest. Cepheus is also said to look like a house located between Cassiopeia and the head of Draco, the Dragon.

Draco, the Dragon wraps its long tail around Ursa Minor in the northern sky. The stars between the Big and Little Dippers are the end of the dragon's tail. The tail curves halfway around the cup of the Little Dipper. The main body of the dragon begins and extends to the diamond-shaped head of the dragon. The legs are dim stars connected to the body of the dragon. None of the stars are very bright, so look closely.

Leaving the northern sky and facing south, we find the most magnificent of the constellations. Orion, the Hunter, can be found in the southern sky throughout the winter. Look for Betelgeuse and Rigel, the two brightest stars with the three fainter stars at the belt halfway between the two. Betelgeuse is higher in the sky than Rigel. When you find the basic shape, look for the detail of Orion in the fainter stars close by. Orion is standing in the sky facing us. Betelgeuse makes up his right shoulder. Rigel is his left foot. Look for his left shoulder and right foot to complete the main part of his body. A faint dagger hangs from his belt. His left arm is extended, and he is holding a lion's skin. Holding a club, his right arm extends up from Betelgeuse.

Once we have become familiar with Orion we can use the stars of this constellation to locate others. Locate the three stars forming Orion's belt.

Now follow the line suggested by these three stars to the southeastern sky. They lead to the very bright star, Sirius, the most apparently bright star of the night skies. Sirius is the bright star in the constellation Canis Major or Big Dog. Sirius is the heart of the Big Dog. Once you find it, look for the legs and head to complete the picture. Canis Major, one of Orion's hunting dogs, is facing his master to the west.

Let us return again now to the Big Dipper. If we use the pointer stars, but form an imaginary line the other way, opposite in direction from the North Pole star, Polaris, we come to Leo, the Lion. Remember two shapes when looking for the Lion. A backward question mark or sickle make up the mane of the Lion. The dot of the backward question mark is the bright blue star, Regulus. Southeast of the backward question mark are three stars which form a triangle. These make up the back end of the Lion. No stars represent Leo's face or legs, so be sure to use your imagination to add the rest. Leo appears to be standing on his tail early in the evening when he first appears or rises; as the night passes toward morning, he rotates and appears to stand on his head.

Pegasus, the Winged Horse, is also seen this time of year high in the western sky. There are no bright first magnitude stars in Pegasus, but a rectangle of stars is easy to spot. The rectangle is called "The Great Square of Pegasus." Many refer to the Great Square as the baseball diamond of the skies. First base is the star in the northeastern corner. Second base is the star in the southeastern corner. Third base is the star in the southwestern corner. Pegasus is upside-down in the sky. The head extends out from the body to the southwest. The front legs extend to the northwest.

The beautiful maiden, Andromeda, shares the northeastern star of the Great Square with Pegasus. Located in Andromeda is the most distant object that can be seen with the unaided eye. It is called the Great Andromeda Nebula. This object is the closest neighboring spiral galaxy to the Milky Way Galaxy. If you have difficulty locating the Andromeda Galaxy, try using the baseball diamond. If you form an imaginary line from third base to first base, that's a start. Now extend that line for an equal distance in the same direction. Well, maybe bend the line just a little back toward home plate. Not very much.

We want to wish you good viewing and may the stars put a new twinkle in your eye.

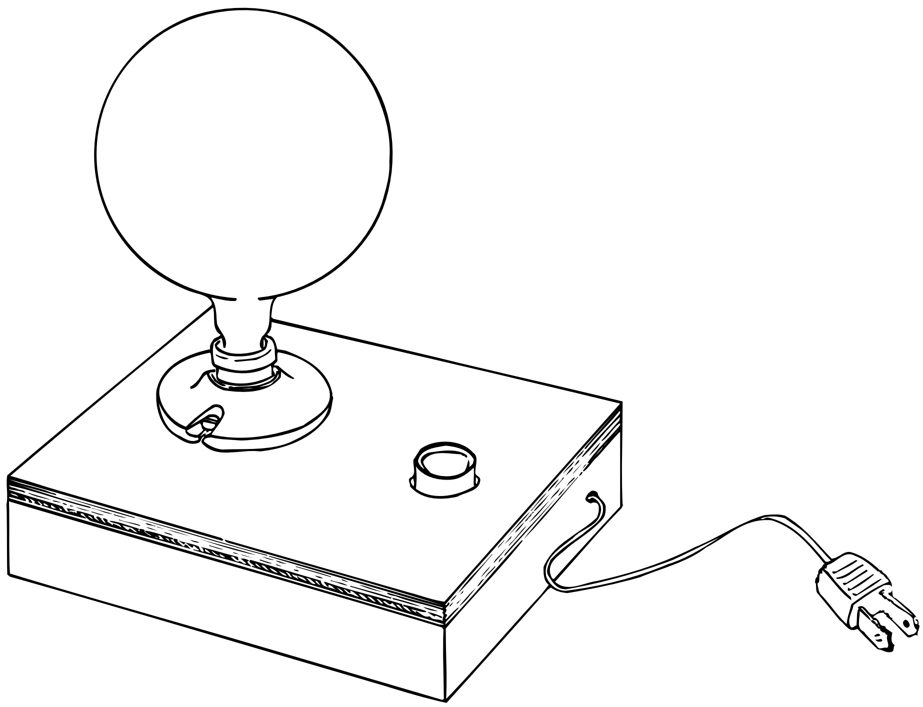
MATERIALS

- 1 incandescent dimmer switch (600-watt capacity)
- 1 plastic or porcelain light socket
- 1 60-watt decorator light bulb (approximately 4½" diameter)
- 1 6′ piece of electrical cord with standard plug
- 1 metal rectangular junction box to house switch
- 1 base box: 8" x 12" x 2" deep. (1" x 2" sides with ¼" plywood top recommended)

Directions for the Construction of the Variable Light Source (or Sun Simulator)

The Sun Simulator is designed to simulate the phenomenon of dawn and dusk, thereby illustrating the idea that stars and other celestial bodies are constantly present yet not visible due to the more intense light of the sun.

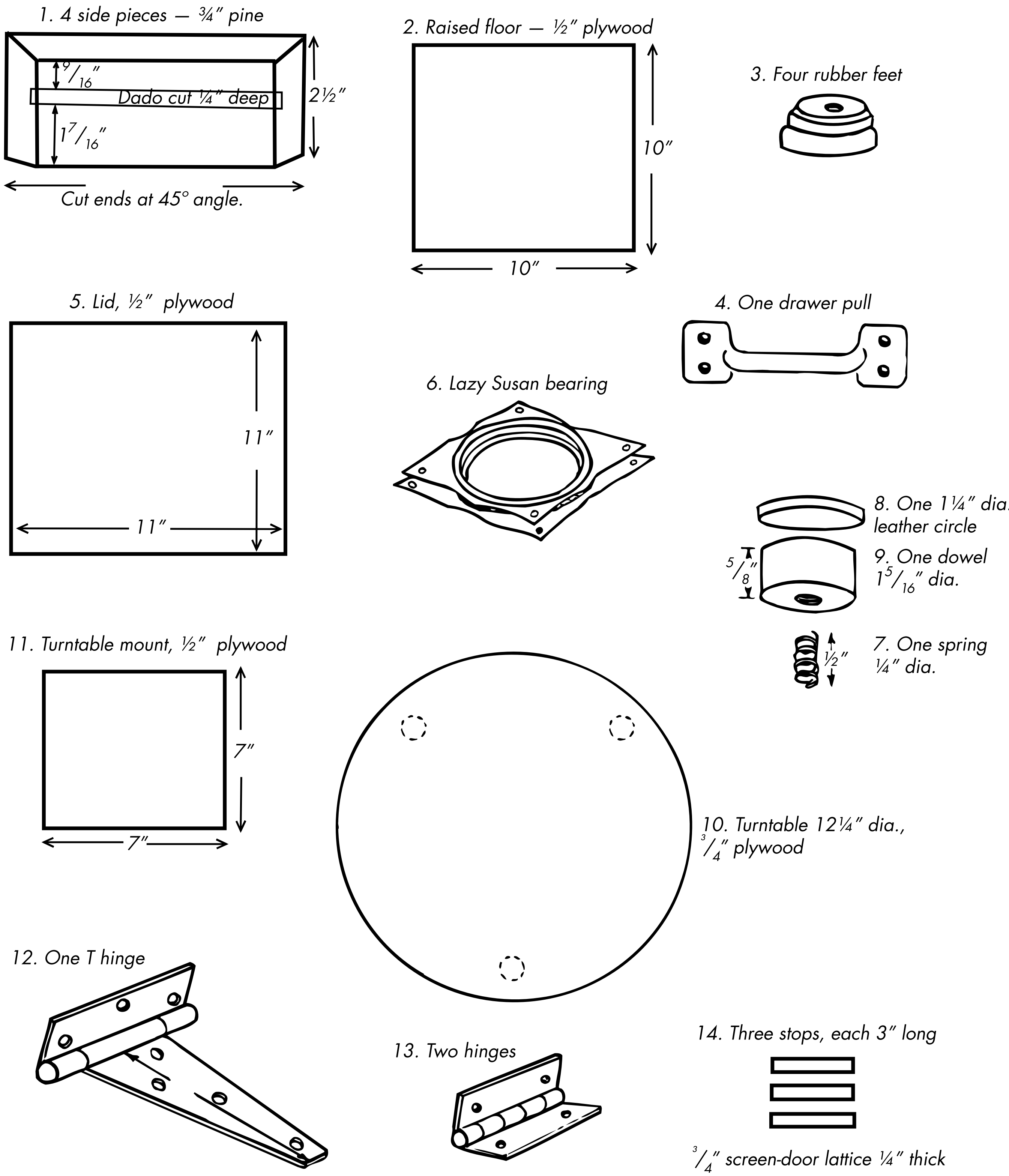
Assemble the base box. Drill a 1¼ " diameter hole 3" from one end of the box. Hole will be slightly larger than the size of the switch knob. Drill a similar hole in the base box approximately 3" in from the opposite end of the base box. Mount the dimmer switch on the underside of the box with dimmer knob protruding through the hole. Wire the cord to the switch wires and connect these wires to the socket. Mount the socket on the top side of the base box using screws provided. Secure bulb in socket and use as directed.



Note

If dimmer switch does not give adequate control, insert a 100-ohm, 20-watt resistor in series between the switch and the socket.

Parts List for the Ecliptic Slide Projector Mount



Directions for the Construction of an Ecliptic Slide Projector Mount

The Ecliptic Slide Projection Mount allows the use of a standard projector to project images of the moon and planets along the ecliptic. This capability allows the student to experience the phenomenon of moon phases, planetary motion, as well as changes in position above the horizon during the various seasons of the year.

- Cut four box side pieces (1) of ¾″ pine, 2½″ wide x 11″ long — each end cut at 45° angles.
- Make dado cuts the length of each piece, ½″ wide and ¼″ deep as on parts list.
- Cut one raised floor (2) piece of ½″ plywood to 10″ x 10″ size.
- Assemble the box base as shown in Fig 1 & Fig 2. Glue and nail all four corners, enclosing the raised floor in the dado cuts as you assemble the sides.

  Note

  The raised floor of the base box is closer to the top edge.

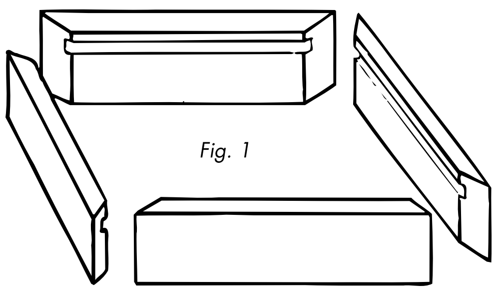


Fig. 1

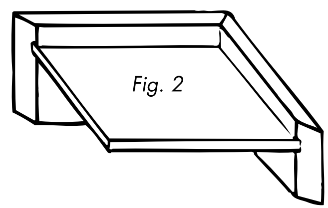


Fig. 2

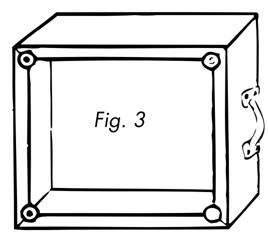


Fig. 3

- Attach the four rubber feet (3) to the bottom corners with screws. Attach the drawer pull (4) near the top edge of one side, centered from side to side. See Fig. 3. Remember — the raised floor of the base is closer to the top.
- Cut one turntable mount (11) of ½″ plywood, size 7″ x 7.″ Center the lazy susan bearing (6) on turntable mount. Mark and start screw holes, then remove. Set mount aside.
- Cut one lid (5) of ½″ plywood, size 11″ x 11.″ Attach the lazy susan bearing to the lid, ¾″ from one edge and centered side to side, with four screws — Fig. 4.
- Fix spring (7) to lid with one screw. Place 2″ from back edge, center from side to side. Fig. 4. Cut one piece of $^{15}/_{16}$″ dowel (9) to $^{5}/_{8}$″ long for drag assembly. Cut a circle of leather (8) and glue to one end of the dowel. using $^{3}/_{8}$″ drill bit, drill hole in the other end of the dowel ¼″ deep. Hole in dowel fits over spring on the lid, Fig. 4.
- Cut a circle 12¼″ diameter out of ¾″ plywood for turntable (10).
- Drill 1″ diameter holes, ¼″ deep in top side of turntable as shown in Fig. 5, to fit the feet of the carousel slide projector that will be used on your turntable.
- Center the turntable mount (11) on underside of the turntable (10). Be sure your starter holes for screws are exposed. Glue and tack together, Fig. 6.

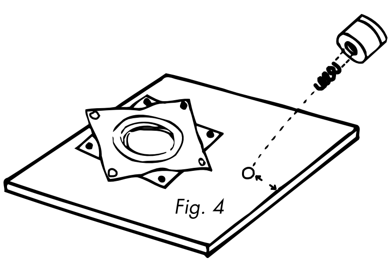


Fig. 4

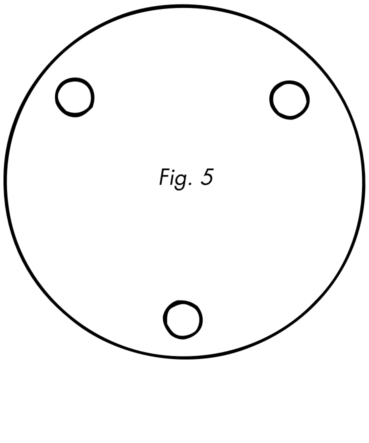
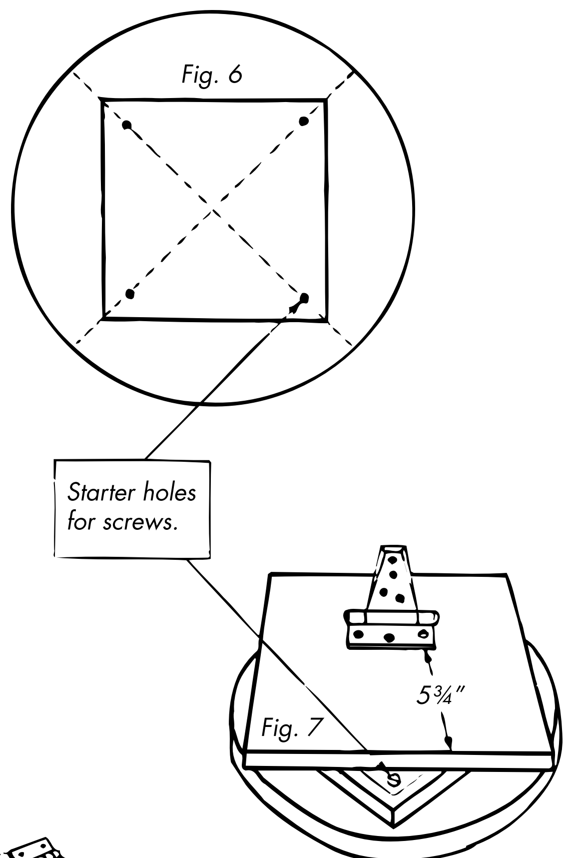
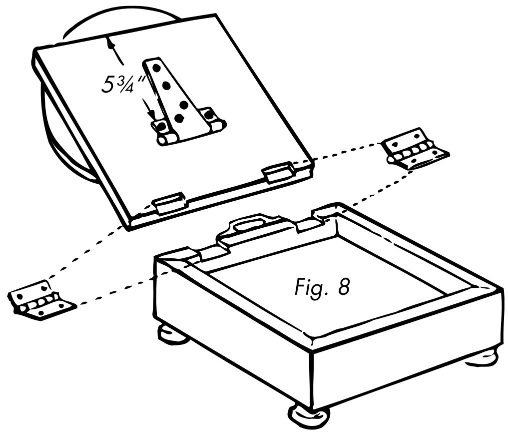
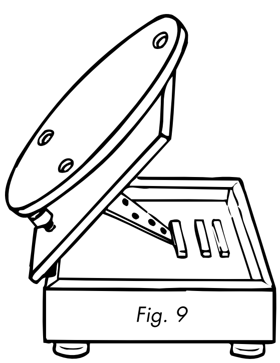


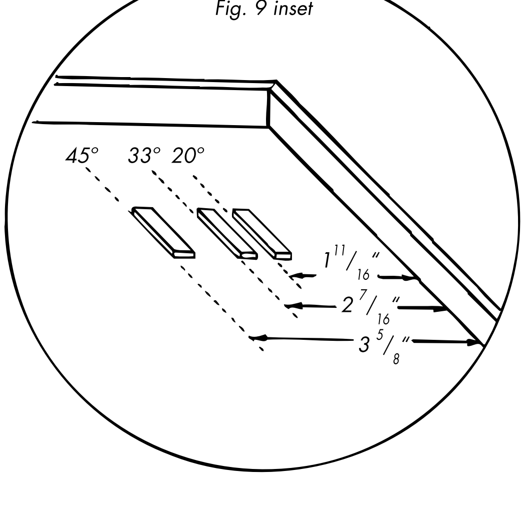
Fig. 5

- Attach the turntable assembly to the top of the lazy susan bearing as shown, Fig. 7. The bearing was set close to one edge of the lid to enable you to insert screws one at a time over this edge when attaching this side of the bearing to the turntable assembly.
- Screw the T-hinge (12) to the underside of the lid, 5¾″ from the opening edge, centered side to side. See Fig. 7 & 8.
- Install hinges (13). Inset the hinges flush. See Fig. 8, lid will be installed so that the turntable assembly is offset over the front (or opening edge) of the box base. The drawer pull will be on the back of the box (hinged side).
- Cut three pieces of lattice each 3″ long. Glue and tack the 3 pieces to the raised floor of the box base, inside the box as shown in Fig. 9 and Fig. 9 inset. Place the stops at appropriate measurements to arrive at the proper degree settings of 45°, 33°, and 20°. The approximate measurements are shown in Fig. 9 inset, but you should check to be sure these measurements give you the proper angle or degree settings.









Install latch on front opening of box. Fig. 10