Chapter 4: Our Bearings in the Sky

Summary

The first part of this chapter describes and explains the daily and yearly motions of the Sun, Moon, and stars, and introduces some simple activities to illustrate them. Students construct and use some additional simple astronomical tools, including the quadrant and gnomon. Since many students have significant misconceptions about the sky motions, hopefully this section of the chapter will be included in some part of your science curriculum. The video "Private Universe" shows how prevalent these misconceptions are even among highly educated adults and is a good introduction to the chapter. (See Resource List for details.) The second part of the chapter addresses the celestial sphere and its coordinate system for accurate locations of celestial objects, and is intended for older students. It is optional and not an essential core element for the remainder of the curriculum.

RESOURCE

Terminology

apogee	libration	quadrant	sidereal time
celestial sphere	limb	revolution	synchronous rotation
declination	maria	right ascension	terminator
gnomon	perigee	rotation	
highlands	precession	sidereal day	

Common Misconceptions

1. *All stars in each constellation are the same distance from the Earth.*
2. *Constellations change due to Earth's rotation.*
3. *The Sun is directly overhead at noon.*
4. *We always see only the same face of the Moon.*
5. *The Moon does not rotate.*
6. *The far side of the Moon is always dark.*

Suggestions for the Poster Pages, Investigations, and Activities

Investigation 4.1a: Understanding the Motions of the Earth-Moon System

The purpose of this investigation is to give students an understanding of the basic motions of rotation and revolution, and to address possible misconceptions about the

Moon. The room needs to be darkened as much as possible, and a bright light source placed in the middle of the room. Have materials such as polystyrene balls available. These work better than Styrofoam, as the contrast between light and dark is much more distinct. Oranges also work well and have a more realistic surface topography. A large orange for the Earth and a ping-pong ball for the Moon will provide a reasonable scale. A small dowel can be glued to the ping-pong ball. Other than pencils to stick into the orange or styrofoam balls, the only additional element you will require is the participation of students themselves. Have them recreate the motions of the Earth-Moon system and show lunar phases. Use a ball the same size as what is used as “the Earth” to represent Venus so the students can experiment with phases for this planet. This is a simple but powerful activity which directly addresses common misconceptions that students have about the Moon.

Investigation 4.1b: Understanding the Motions of Stars and Constellations Across the Sky

If possible, assign this as a nighttime activity. The students will time the appearance of a bright star approximately every five days for a two- to three-week interval. After recording the time for several observations, they can calculate the average difference. The students should determine that their object rises about 4 minutes later each night. The number that the students calculate using this difference is the true rotational period of the Earth. (The rotational period of the Earth is also called a sidereal day; this will be discussed later in the celestial sphere activity.) We use 24 hours for one day/night period and do not deal with the four-minute difference on a daily basis. Instead, it is compensated for by adding an extra day to the calendar and calling that calendar year a leap year. The direction of the apparent star movement is from East to West, and the angle of rising depends upon your latitude. If you are unable to use the nighttime sky, give the students the task of trying to recreate sky motions involving star and constellation motions within the classroom. The students who can use the night sky can then compare their results with the classroom recreations.

Core Activity 4.2: Using a Quadrant to Measure the Motion of the Moon, Stars, and Sun Across the Sky

Students construct their own quadrants to measure the altitude and angular separation of celestial objects. A template for the quadrant is included in the student section. They will also need straws, string, scissors, and small weights such as washers. Three activities are included which allow the students to make observations over long periods of time, enter their data in tables, and use the data to answer questions. There are many other types of observations; the three included are only a representative sampling. If your students are familiar with graphing, they can construct graphs of the observed motions. One example is the activity using Polaris and two stars in Ursa Major. A graph of the movement of these three stars would describe a straight line for Polaris, a steep slope for the star farther away from Polaris, and a more gradual slope for the star closer to Polaris. You may wish to discuss with your students factors that affect the accuracy of the quadrant, and challenge older students to develop and construct a better, more accurate, design. A template for a quadrant is included within the student activity. Two students need to work together for the best results: one student to locate the object and one to hold the string and determine the angle. **NOTE:** The student section tells them **NEVER** to look at the Sun through the straw on the quadrant. They are to point the straw towards the Sun and look at the circle that appears on their hand or on a piece of paper. Students should be reminded to never look at the Sun, either with the unaided eye or through sunglasses, or with binoculars or telescope, as the UV rays from the Sun will permanently damage the eye. An interesting video, "The Sun Dagger," shows how the Anasazi used the Sun to mark the solstices. (See Resource List for details.)

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Core Activity 4.3: Why Constellations Appear in Different Places in the Sky at Different Times of the Year

This is a simple, highly visual activity, which reinforces the concepts of rotation and revolution. Students can be required to take into account the clockwise rotation of the Earth, cardinal directions, and degrees of movement each month of the Earth around the Sun (~30). Simple drawings of the constellations can be replaced by any art form, and the Zodiac can be Western or from any other culture. The related mythologies can also be discussed. Have students hold up large sheets of paper, or cloth sheets to hide the six constellations not visible during the daytime sky. It would be more realistic if they were painted or dyed blue to represent the sky. (A diagram is included in the student pages.)

Ask students why stars cannot be seen during the day. You may also have a student represent the Moon in this model, and ask when stars can be seen from the Moon. Most people think that, seen from the Moon, the sky is black and filled with stars; however, the far side alternately faces towards and away from the Sun, and the side facing Earth is affected by "Earthshine," which washes out part of the sky.

NOTE: An excellent visual model to help students understand star motions is a clear plastic umbrella with some of the major constellations glued to the inside in approximately correct positions. (The cloth from an old umbrella can be removed and replaced with clear plastic.)

Poster Page: Abe Lincoln and the Almanac Trial

Besides the examples listed on the poster page, there are several historical associations with lunar phenomena, such as the first voyage of Christopher Columbus, and the Boston Tea Party. Also, bright comets and solar eclipses have influenced the course of history on several occasions. Solar eclipses played a part in the lives of Einstein, Nat Turner, and the Shawnee Indian Tecumseh, among others; comets were influential in the lives of Montezuma and the Aztecs, the Roman emperor Nero, and the Millerite cult in the northeastern United States. Paintings, poems, and stories, which include astronomical phenomena can be checked for accuracy, just as with the Almanac Trial. There are several software programs which will accurately display all aspects of the night sky for any date and time. (See Resource List for details.)

RESOURCE

Core Activity 4.4: The Rotating Earth and the Sun's Apparent Motion Across the Sky

a. Shadow Stick Astronomy

This activity demonstrates that the Sun casts shadows of different lengths and different angles as the Earth rotates. Measurements need to be taken every half hour all day long, so choose a sunny day. The activity can either take place outdoors, or indoors next to a large south-facing window. Students can use the quadrants they made for Activity 4.2 above.

If they have not constructed quadrants, they can measure the length of the shadow and divide that number by the measured length of the stick. The angle equal to the resulting ratio can be read from Table 4.1, included within the student activity. More advanced students can use right-angle trigonometry instead of using the table.

b. Shadows on a Sphere

This activity is an excellent reinforcement of the shadow stick activity above. You can use ready-made spheres or make your own by cutting off the round bottoms of 2-liter plastic soda bottles. The only difficulty with this method is that sometimes the glue used to put the dark flat bottom onto the round clear bottom is difficult to remove. Inexpensive plastic spheres can be obtained from Project Star (see Resource List for details) or from party-supply or novelty stores. RESOURCE

The results are a reflection of the shadow stick activity above—high in the middle and low on the ends, whereas the shadow stick reveals a dip in the middle and high ends. The shape of the shadows on the sphere is an excellent lead-in to the celestial sphere. Redoing this activity throughout the year will show students the changing altitude of the Sun. If a student is going on vacation in a different latitude, they could perform this activity, or the previous activity using the gnomon (described in Part (a) above), and compare their results with local graphs for the same day.

Core Activity 4.5: Constellation Plots

This activity uses the HOA constellations (Ursa Major, Cepheus, Cassiopeia, Cygnus, Auriga) and Ursa Minor. All except Cygnus and Auriga are circumpolar for upper latitudes in the northern hemisphere. You may wish to have your students plot constellations which correlate with your location. If so, sky charts for your area can be found via software programs (see Resource List for details), local colleges and universities, and local amateur astronomy groups. Plotting on polar coordinate paper is a graphing activity rarely encountered in the classroom, and the celestial sphere coordinate system is reinforced by using the right ascension and declination coordinates to plot constellations. *A completed graph is included to show what the student plots should look like.*

RESOURCE

Variable stars, by convention, are designated on maps by an open circle. If your students are going to observe the variable star in Cepheus (delta Cephei), this is an excellent introduction to the location of this constellation. Cygnus includes W Cyg, another AAVSO (the American Association of Variable Star Observers) program variable star. Also W Cyg is the variable star used in the slide set which the students will be using to learn the skill of magnitude estimation in Chapter 6. This is an excellent lead-in activity for Activity 4.6, which follows. Chapter 5 addresses some of the mythologies corresponding with these constellations. Some extension activities follow, and there are many more possibilities.

Extension Activities

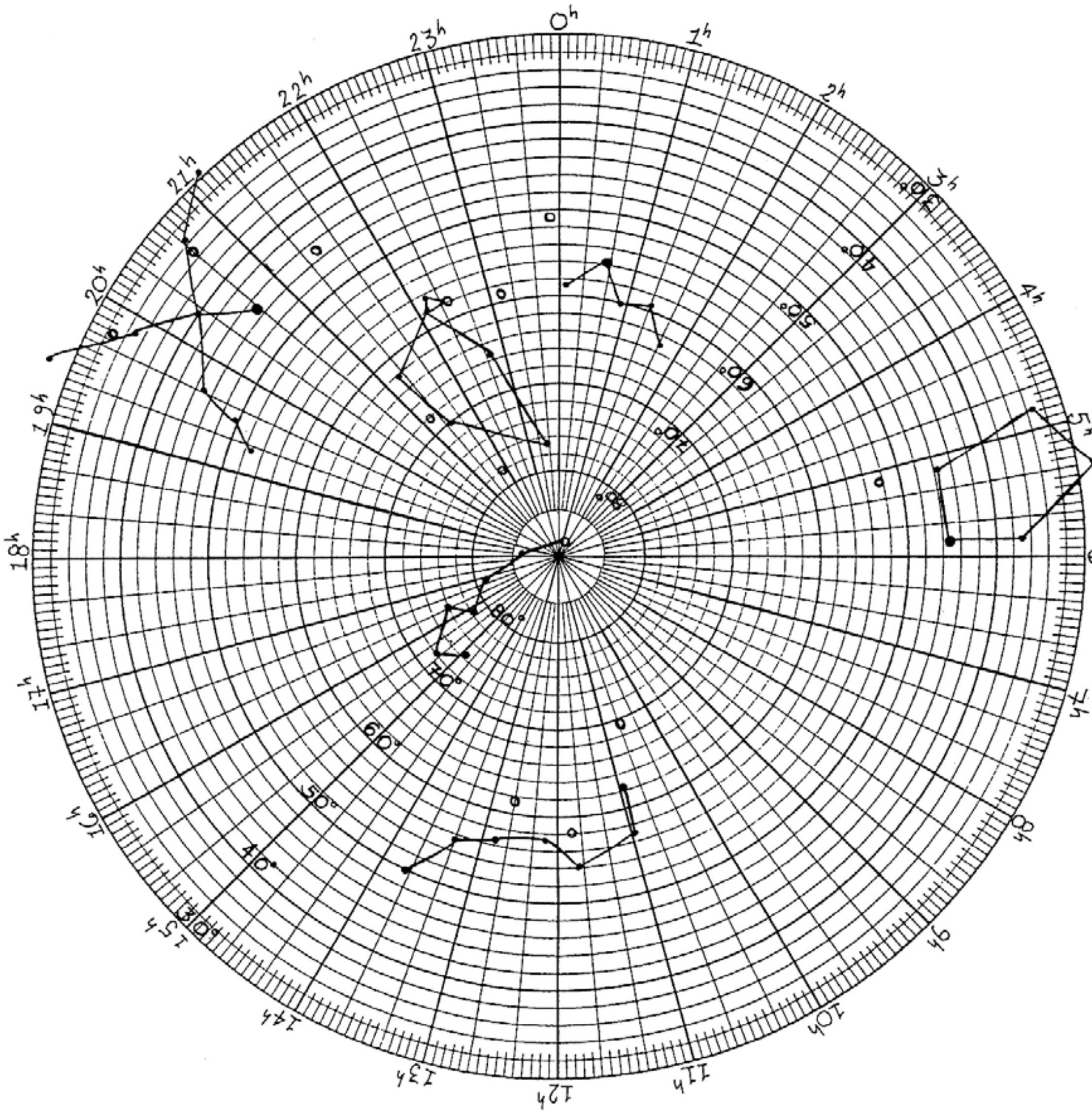
1. The stars have strange-sounding names. What are the origins of these names? Who named the stars? What do the names mean in the English language? What is the historical significance of the origin of the names for the stars? Why do different cultures have different names for the stars?

2. What is the mythology associated with these constellations for the different cultures, i.e., Greek, Roman, Chinese, American Indian, and so on? What are the advantages of using our own mythologies? Why don't we use the myths of other cultures?

3. Construct a polar coordinate graph for the circumpolar constellations for someone living south of –40 degrees latitude in the southern hemisphere.

4. At what latitudes on the Earth are there no circumpolar constellations? At these latitudes, how can one determine North by looking at the sky?

5. Would you still see the same constellation patterns that we see from Earth from the Moon? Mars? Pluto? The nearest star? (The stars are so far away that the same patterns would be visible from the nearest stars.)



Completed graph for the Core Activity 4.5 constellation plot

Activity 4.6: Plotting the Actual Positions of the Planets

This activity reinforces the concepts of rotation and the celestial coordinate system, especially right ascension (RA). Students construct a model by plotting the current celestial coordinates of the Sun and planets. It is a “geocentric” model, using polar coordinate paper with the Earth located in the center, and requires a sophisticated understanding of celestial motions for students to be successful in answering the questions. The right ascension and declination coordinates of the Sun and planets can be obtained from several astronomical handbooks or other sources, such as *Sky & Telescope.* This activity can be accomplished on paper; however, if the outermost planets are to be plotted, the paper must have a minimum diameter of 60 cm (2 ft).

If a paper model is used (scale of 1 cm = 1 AU), the scale indicated in the activity and the right ascension (RA) coordinates of the planets and Sun are used. However, if this becomes an outdoor activity, declination can also be plotted. The outdoor approach is strongly recommended, using a scale of 1 meter = 1 AU. The students can cut out lengths of string proportional to the planets’ distance from Earth. Then a marker or picture can be placed at these positions to represent the planets or the Sun. Elevated markers can be used to represent declination coordinates (keeping in mind that the declinations vary from –23.5 degrees to +23.5 degrees).

Distances to Mercury and Venus may be larger than 1 AU if their positions are on the other side of the Sun with respect to Earth (superior conjunction). The students can take turns standing in the center on the “Earth” and rotating counterclockwise to determine night and day, and note visibility of constellations and planets. The constellations can also be placed around the outside of the planets, with Pisces located at 0 hours right ascension. This activity helps students understand the concept of a sidereal day.

Explanations about why Mercury and Venus are visible only during morning or early evening can be made by noting that the RA of the two are always close to the Sun; as the Earth rotates counterclockwise, they are either able to see the two planets just after they lose sight of the Sun (dusk), just before they see the Sun (dawn), or not at all if the planets are too close to the Sun.

NOTE: This is a *geocentric* model of the Solar System, with Earth located at its center. It represents the positions of planets and the Sun as they appear to observers on Earth. Once again, you can reinforce both the usefulness and distortions of models with your students.

Poster Page: Astrology or Astronomy? (Horoscopes and Precession)

You can use this issue as a stimulus for discussions and research, as pseudoscience affects important aspects of our culture. Horoscopes are one of the most prolific an enduring aspects of pseudoscience. The general population tends to confuse astrology with astronomy. It is mistakenly thought that astronomy evolved from astrology, and that therefore astrology is a true science. Actually, judicial astrology did not appear until 600 BC, long after the Babylonian astronomers had developed their astronomical tables, calendars, star charts, and lunar eclipse theory. Astrology became a dominant force during the reign of the Roman Empire, and with the fall of the empire, astrology ended in the Western world for 500 years. The Arabs acquired astrology when they took over Greek culture; astrology had developed in Greece during the Hellenistic period.

In the early medieval period, astrology was reintroduced to the Western world through Arabic medicine. Astrology also became associated with alchemy, mathematics, and astronomy. Astrology had a devastating influence on medicine of the time, for physicians ceased making diagnoses from symptoms and case histories and relied on horoscopes to tell them why the patient was ill, what drugs to prescribe, and the favorable time to apply remedies. Astrology also hindered the development of chemistry. It was only after alchemy had been purged of astrology and other superstitions that chemistry became a separate discipline. Furthermore, astronomers were often forced to earn their living by astrology while carrying on legitimate science as best they could.

Interestingly, astrology has flourished in periods of high scientific development rather than in low periods, and also during periods when religion and philosophy were unpopular. The Reformation and Roman Catholic Counter-Reformation were instrumental in ending the power of astrology in the 1600's. In our time, astrology has again become popular with the public, and recent polls show that 60% of the population believes in some aspect of pseudoscientific phenomena.

Students can take opinion surveys, and also survey the existing materials associated with astrology. Horoscopes and psychic hotlines have targeted females as their primary audience. These articles appear in women's magazines, not *Field and Stream,* and women's magazines are found in grocery stores, drug stores, and doctor's offices—places that women visit more frequently than do men. Why are the articles found in women's magazines? Is it because astrology deals with emotional issues and women are perceived as being more emotional than men? Is it because women as a group are not as scientifically literate as men? What psychological issues cause people to believe such fraudulence? What needs are being fulfilled by these flights from reality? These issues are complex and interrelated and have no simple answers.

NOTE: Another major claim of astrologers is that planetary alignments are important events and can influence humanity. Activity 4.6 shows that the planets all have different inclinations to the plane of the Solar System, and that even though sometimes the planets *seem* to be aligned, in actuality they are not.