Build a Simple Sextant

(teacher's version)

Background:

A sextant is a tool for measuring the angular altitude of a star above the horizon. Primarily, they have been used for navigation. However, the predecessor of the sextant is the astrolabe, which was used up to the end of the 18^{th} century. The earliest known description of an astrolabe is by Johannes Philoponus of Alexandria who lived from 490-566 CE (Current Era). As seen here, the astrolabe was a portable instrument made of copper or bronze, its primary function was to determine the elevation of the Sun or a star and to quickly solve problems of spherical astronomy. Essentially, the astrolabe was a mechanical computer on which a network of azimuths and altitudes dividing the heavens were engraved. Around the rim of the astrolabe, might be inscribed the hours of the day, the days of the year, and the signs of the zodiac. As an altitude device, the astrolabe could also be used to find the height of buildings, or mountains and other topographic features.



Although the oldest astrolabe in Europe dates from about 912 CE, its origins seem to be connected with the armillary sphere (pictured to the right) which was described by Ptolemy in the 2^{nd} century of the current era. Much later, the *sea* astrolabe was introduced about 1460, but did not see general use until the beginning of the 16th century. The use of the sea astrolabe persisted until after 1670, particularly in the fleets of the Spanish and Portuguese, where it was in evidence early into the 18th century.



A contemporary of the astrolabe, which may actually have been a predecessor of the sea astrolabe, was the simple quadrant. Like the sea astrolabe, the mariner's quadrant was adapted from its earlier and more complex astronomical counterpart. In design and function it was remarkably simple. The quadrant consisted of a triangular plate, the point of which was fitted with a plumb bob. Along one edge, were a pair of sighting pin holes. On the lower edge was found a degree scale, over which the plumb bob could hand freely. To use, the observer sighted the celestial object through the pin holes while an assistant read the position of the plumb bob on the scale.



The first real ancestor of the modern-day sextant as a multipurpose nautical instrument was the cross staff or Jacob's staff which was first described by a Jewish scholar named Levi ben Gerson in 1342. The instrument, as its predecessors, was an adaptation from an earlier astronomical surveying device. It consisted of a frame (staff) over 30 inches long with scales engraved on all four sides. Perpendicular to the frame were two or more transoms or "crosses" (hence the name). By lining up the horizon with one end of a cross and the celestial object with the other end, the observer had a simple trigonometric computer.

The cross staff represented a great leap forward in the art and science of navigation, since it embodied all of the functions for recording the altitudes of the sun, stars, moon, and planets, as well as terrestrial sights - a function lacking in the astrolabe and simple quadrant. The next logical step in the evolution of navigation instruments was the development of the backstaff or the Davis quadrant, seen here. The instrument pictured to the right dates from 1760 and is missing some parts.



The sextant pictured to the right, is an

example from the modern era (1820-1920). Just prior to World War II, the long evolution of the sextant culminated in the invention of the ball recording sextant. It is ironic, and perhaps fitting, that the final form of the sextant was not a sextant at all but a much earlier ancestor, the true quadrant. Developed for use at night when no horizon was visible, the recording "sextant" used no reflecting mirror. Rather, the celestial object was viewed directly as with the true quadrant. Instead of using a plumb bob, a liquid-damped steel ball recorded the altitude of the object on a screen. A drum micrometer was used to determine the precise altitude reading. Because of its size, easy reading, and nighttime capability, the recording sextant found favor with airplane navigators, leading to "aircraft sextants" built on the same principle.



Our simple sextant will not be nearly as complicated as the ones pictured above, but will hopefully enable the students to take part in a discovery of their universe as did the earliest developers of the astrolabe.

<u>Purpose:</u> To measure the height (altitude) of a celestial object above the horizon. To observe the apparent motion of stars, the Moon, planets, or comets by noting changes in altitude over a period of time.

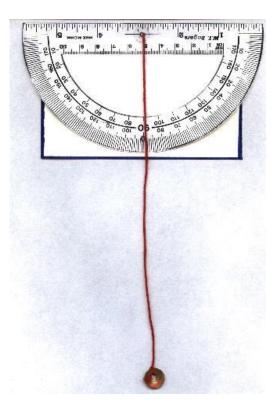
Materials:

30 cm wooden ruler (smaller is ok, but must be at least 16 cm long) protractor tape string washer or paper clips compass (for determining directions)

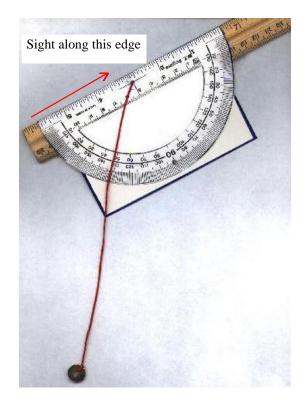
Procedure:

Part I:

a) Tie a washer or three paper clips to one end of the string. Tie or tape the string to the midpoint of the protractor, so that the string falls across the 90 mark. The string is called a plumb line.



- b) Tape the protractor to the ruler to within an inch of the end of the ruler.
- c) Sight an object by placing your eye at one end of the ruler. The protractor will be upside down and the plumb line will hang down as seen in the picture.



d) Let your partner determine where the plumb line falls on the protractor. Reading the inner set of numbers on the protractor (0° to 90°), record this number on your data sheet; this is the zenith angle. Subtract this angle from 90° and you have found the object's altitude angle, or the height in degrees, of the object above the horizon.

Object	Zenith Angle	Altitude Angle	
		(90°-zenith angle)	

Part II: Observing Celestial Objects

- 1. When viewing any celestial object at night, find an area away from lights, trees, etc., that will reduce vision.
- 2. Use a compass or Polaris to find north, then find east, west, and south. Locate the celestial object in the sky (a comet, star, the Moon, or a planet) and record its compass direction.
- 3. Sight the object along the edge of the sextant (ruler) to determine its altitude. Record the angle indicated by the plumb line.
- 4. Using the data chart, record the date and time of the observation. Keep a log for several weeks' time to emphasize the celestial object's motion.

DATA							
Object:							
Observation	Date	Time	Compass Direction	Zenith Angle	Altitude Angle		
	(22-09-1998)	(8:30 p.m. CST)	(e.g., NW, SW)	(e.g., 30°)	(e.g., 60°)		
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

POST-LAB: <u>Questions:</u>

1. What does the change in position of a star in one night indicate?

2. How did a star appear to move in a 3-4 hour period (e.g., north to south, east to west)?

3. What does the change in position of a star at a particular time of night, over a period of days or weeks, indicate?

Answers:

- 1. The motion of a star during one night is due to the motion of the Earth as it rotates.
- 2. The star appeared to move from east to west.
- 3. A Star in a different position at 10 p.m. on one date to 10 p.m. on subsequent date indicates that the Earth moves around the Sun (revolutionary motion), constantly changing stellar background throughout the year.