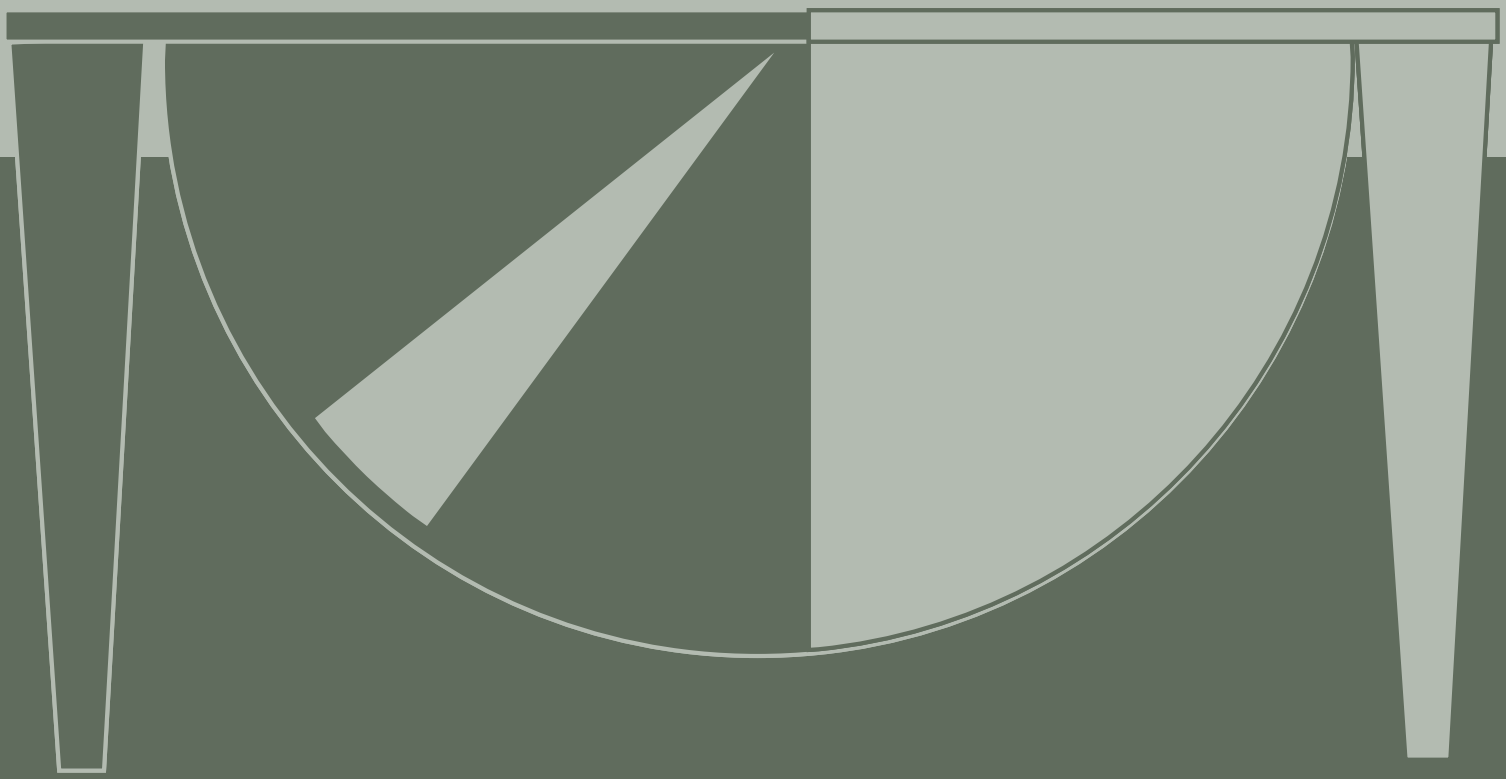
<For Student>

Exploring the Principles of Angbuilgu



Exploring the Principles of Angbuilgu

Integrating Curriculum Unit – Exploration of the Universe : Exploring the Principles of the Sundial

Learning Objectives

1. **I can explain the functions and principles of each structure in Angbuilgu.**
2. **I can create an Angbuilgu model that corresponds to the latitude and measure time.**
3. **I understand and can discuss the concepts of the celestial sphere, time, and calendar.**

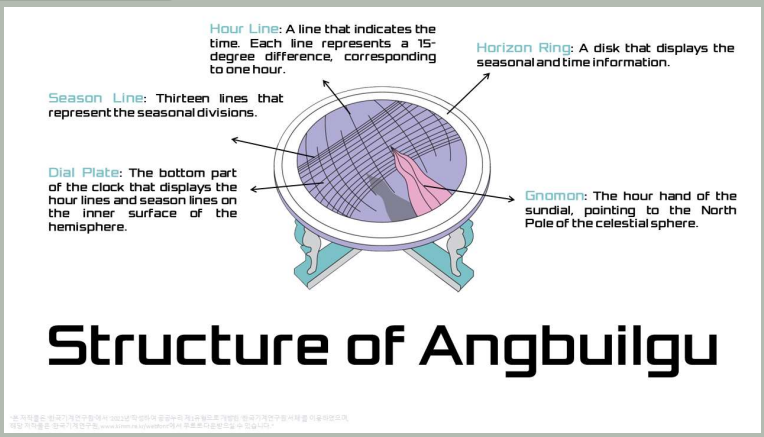
I. Overview

Throughout history, people have created and used various timekeeping devices such as water clocks and hourglasses to measure time. However, these devices had the drawback of not representing a consistent flow of time. In the eyes of ancient people, the most consistent motion they observed was that of celestial bodies, particularly the sun, which displayed regular movements. Therefore, by observing the motion of celestial bodies, especially the sun, people sought to measure time accurately. To make time measurement accessible even to those who found it difficult to determine time based on celestial motion alone, a hemisphere–shaped sundial called "Angbuilgu" was created.

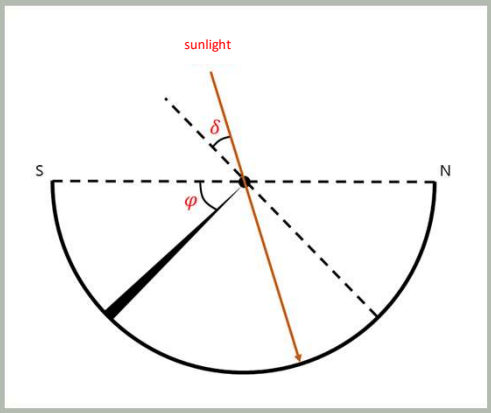
Angbuilgu (앙부일구) was developed in the 16th year of King Sejong's reign (1434) by Jang Yeong–sil, Yi Cheon, Kim Jo, and others. Its appearance resembles a concave clock face, shaped like a cauldron, symbolizing the cauldron reaching towards the sky. Angbuilgu exhibits the following characteristics.

Detailed Examination

The base of the sundial, which serves as the bottom part of the clock, has a rounded shape and is divided by a total of 7 vertical lines and 13 horizontal lines. The 7 vertical lines represent the hour lines and indicate the time based on the position of the shadow throughout the day. Each hour difference is marked with a 15–degree variance from the center of the sphere. The seasonal lines represent the 24 solar terms, with the topmost line indicating the winter solstice (dongji) and the bottommost line representing the summer solstice (haji). On top of the sundial's base, there is a horizontal plate extended from the seasonal lines, which displays the solar terms corresponding to each seasonal line and the latitudes where the sundial can be used.
The gnomon, or shadow–casting object, plays a role in creating a shadow on the surface of the base. By reading the surrounding seasonal and hour lines based on the position of the shadow's end caused by the gnomon blocking the sunlight, one can determine both the solar term (date) and the time.



Detailed Examination



The gnomon of the sundial is designed to point towards the celestial pole, which is the north celestial pole. Therefore, when extended, the gnomon forms an angle with the horizontal plane that is equal to the latitude (φ). When sunlight falls onto the sundial, it enters at an angle δ with respect to the plane perpendicular to the gnomon. As a result, the seasonal lines are drawn on the plane perpendicular to the gnomon, inclined by the daily declination value of the sun for each of the 24 solar terms.

II. Suplies

- 3D Printer
- Compass
- Level

III. Process

(1)Printing the Sundial
Generate an Angbuilgu model that corresponds to the desired latitude. Enter the desired location on a website and create the model, printing the Angbuilgu to a size of about 18cm.

(2)Installation of the Sundial
Place the Angbuilgu on a flat surface without any slope. If the ground is not level, use a desk or tripod to adjust the horizontal position of the Angbuilgu. Conduct the experiment in a spacious area without any buildings obstructing the sunlight.

(3)Alignment with True North
Use a compass to determine the direction of the magnetic North Pole. Align the Angbuilgu towards true north, correcting the declination by matching the long line extending to the horizon (not the line marked with "N") with the north indicated by the compass. Ensure that the gnomon points towards the celestial North Pole.

(4)Recording the Readings
Observe the position of the shadow's end on the sundial's surface, which is created by the gnomon blocking the sunlight, and determine the time accordingly. Record the time indicated by the sundial as well as the time obtained from a satellite clock (e.g., smartphone clock). Repeat the measurements approximately three times at regular intervals.

CHECK!

- Ensure that the Angbuilgu is accurately installed by using a level to achieve proper horizontal alignment. (o, x)
- Install the Angbuilgu gnomon in a way that it points towards the celestial North Pole. (o, x)
- Securely fix the Angbuilgu during the measurements to prevent any changes in its designated position. (o, x)
- Not following the above precautions may result in significant errors in the readings.

IV. Result and Discussion

(1)Let's record the measurement values and also note the corresponding solar terms and Time

latitude		longitude		Declination	
YYYY		MM		DD	

	1	2	3
The time observed using the Angbuilgu.			
The time confirmed using the satellite clock.			

(2) When recording the measurement values, did the solar terms appear consistently? If not, let's analyze

(3) What could be the reasons for the discrepancy between the time observed using the Angbuilgu sundial and the time confirmed using the satellite clock?

(4) Let's compare the time observed using the Angbuilgu sundial, corrected for the equation of time based on the annual publication of the Korean Astronomical Observatory, with the time confirmed using the satellite clock. (As of the production date in 2023, refer to the '2023 Astronomical Ephemeris (pg. 96–101)' available at https://www.kasi.re.kr/kor/publication/post/publication?clsf_cd=pub005 for the equation of time table.)

(5) Is the time difference still evident as observed in (4)? If there is a difference, let's consider the reasons behind it, brainstorm potential methods of adjustment, and discuss them.