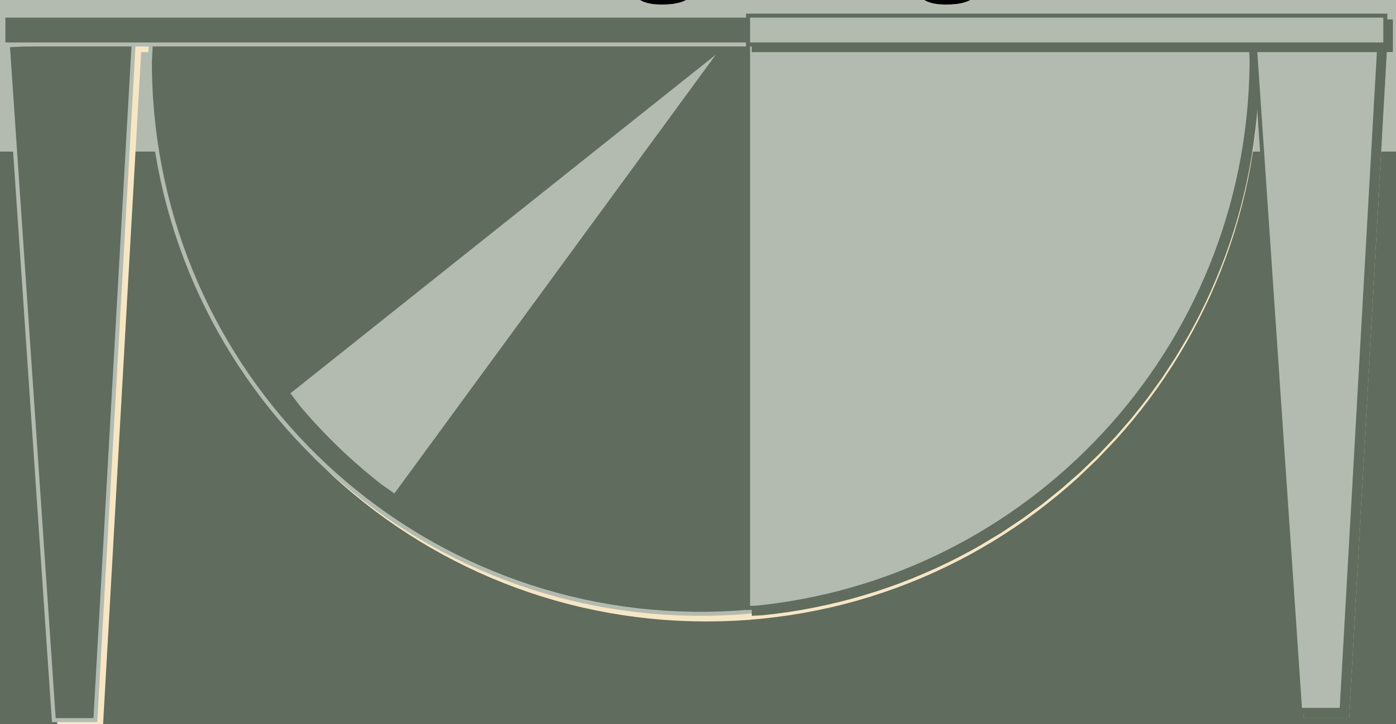
<For Teacher>

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. Postscript

- How did people measure time in the past when there were no mechanical clocks?
- How does Angbuilgu which is a sundial developed during the Joseon Dynasty function?
- What are the characteristics of Angbuilgu?
- If you Wake up in the morning and are given a stick and a sundial, would you be able to estimate the time?

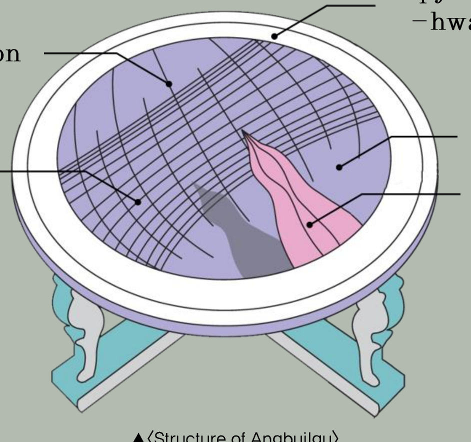
II. Overview

Since ancient times, people have been creating and using various timekeeping devices such as water clocks and hourglasses to measure time. However, these clocks all have the disadvantage of not maintaining a consistent time interval. To the people of the past, the most regular motion they observed was that of celestial bodies, particularly the sun, which rises and sets every day and can be seen for extended periods. Therefore, they used the motion of celestial bodies, especially the sun, to determine the time. Additionally, to make it possible for the common people who had difficulty confirming the time through celestial observations, a hemisphere-shaped sundial called "Angbuilgu" was created.

Angbuilgu (仰釜日晷, 앙부일구) was created in the 16th year of King Sejong's reign (1434) by individuals such as Jang Yeong-sil, Yi Cheon, and Kim Jo. The clock face is concave like a cauldron, and the name "Angbuilgu" was given because this cauldron seems to reach up to the sky. Let's take a closer look at the appearance of Angbuilgu on the Detailed Examination. Also, let's explore the principles of Angbuilgu on the next page.

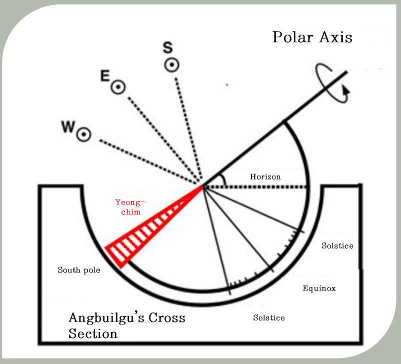
Detailed Examination

The round vessel that makes up Angbuilgu is called the "시반(Siban)," and it serves as the base of the clock. The Siban has lines representing the time and the seasonal divisions, playing a crucial role in timekeeping. By observing the position of the shadow cast on the siban, one can determine both the time and date. 시각선 (Sigakseon), which translates to "time line," are vertical lines used to measure time. The intervals between the 시각선 are 15 minutes. The central 시각선 represents noon, with the western side indicating morning and the eastern side indicating afternoon. 절기선 (Jeolgisun) are horizontal lines representing the seasonal divisions and dates. The topmost 절기선 corresponds to the summer solstice (하지), while the bottommost 절기선 corresponds to the winter solstice (동지). The intervals between the 절기선 are not uniform due to the unequal positions of the ecliptic and the equator. 영침 (Yeongchim) plays a role similar to that of a clock's hour hand. By observing the shadow of the 영침 and its intersection with the 시각선 and 절기선, one can determine the time and date. 지평환 (Jipyeonghwan) is a ring-shaped vessel that contains information about time and date. This system allows people to tell time and date accurately using the sun's shadow and the unique features of Angbuilgu.



▲〈Structure of Angbuilgu〉

Detailed Examination



Indeed, all celestial bodies appear to move around the Earth's axis, parallel to the Earth's equator, completing one full rotation in a day. To project this motion onto the Angbuilgu's Siban, **the Yeongchim must always point towards the Northern Celestial Pole**. However, as you mentioned, the angle between the Earth's equator and the horizon changes with **latitude**. Consequently, the position of the Northern Celestial Pole also changes with latitude. Because of this, when the latitude changes, the positions of not only the Angbuilgu's Yeongchim but also the Jeolgiseon need to be adjusted.

III. Suplies

- 3D Printer
- Compass
- Level

IV. Process

(1) Printing Angbuilgu
Enter the desired location on the website and download the 3D model of Angbuilgu. Use a 3D printer to create an Angbuilgu with dimensions of approximately 18 cm.

(2) Installing Angbuilgu
Place Angbuilgu on a flat surface with no inclination. If the ground is not level, adjust the horizontal alignment of Angbuilgu using a desk or tripod if necessary. Ensure that there are no buildings obstructing the sunlight in the vicinity and conduct the experiment in a spacious and open area.

(3) Aligning with True North
Use a compass to find the Northern Celestial Pole. Align Angbuilgu in the direction of true north that correcting the azimuth based on the long line drawn on the horizon ring (not the line marked with 'N' on Angbuilgu) to match the north indicated by the compass.

(4) Recording
Confirm the position indicated by the end of the shadow cast by the yeongchim and use it to measure the time and date. Record the measured data (time, date) in your experiment log. Also, record the data obtained from the satellite clock (smartphone clock) for comparison (time, date).

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.

V. Result and Discussion

(1)Let's record the measurement values.

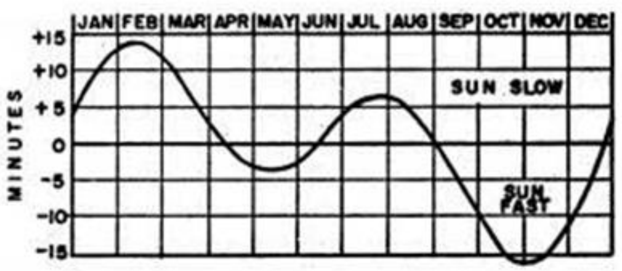
Latitude	
Longitude	
Declination	

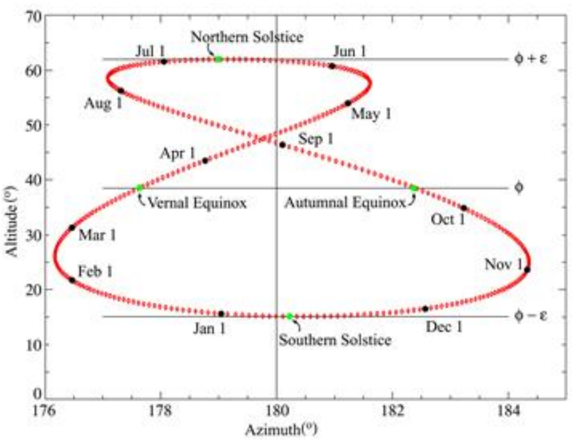
Date	
Time	

Time measured by Angbuilgu	
Date measured by Angbuilgu	

(2) Is there a difference between the values measured through Angbuilgu and those confirmed using a smartphone clock? If differences exist, explain the reasons using the concept of Equation of time.

The difference between the dates measured through Angbuilgu and those confirmed using a smartphone clock is expected to be minimal. However, there can be a significant disparity in the displayed time. The primary reason for this discrepancy is the concept of the "equation of time." The equation of time represents the disparity between mean solar time and apparent solar time. The time system we commonly employ is based on mean solar time, whereas the time system ascertainable through Angbuilgu relies on apparent solar time. This difference arises because our timekeeping system is rooted in mean solar time, whereas Angbuilgu's measurement system is based on apparent solar time. The cause of this discrepancy can be attributed to the fact that the plane of the Earth's orbit (the ecliptic) is not perfectly aligned with the equator, and the Earth's orbital path is not a perfect circle.





A graph displaying the monthly equation of time values (left) and an analemma curve (right). The horizontal component of the analemma curve represents the equation of time.

(3) Let's compare the time determined using Angbuilgu, adjusted for Equation of time based on the almanac published by the Korea Astronomy and Space Science Institute, with the time confirmed using a smartphone clock.

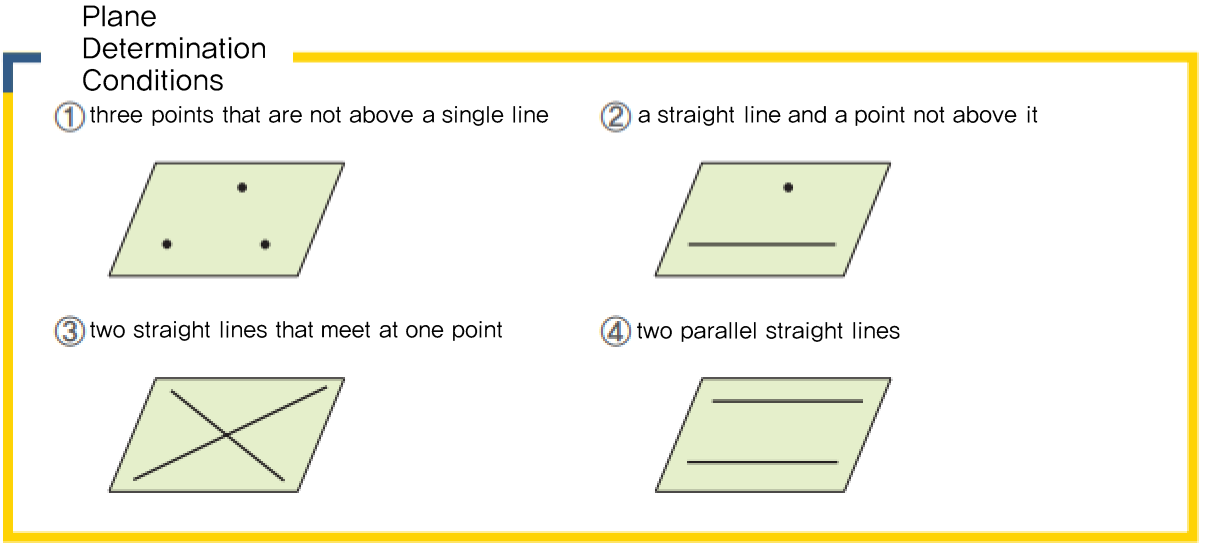
The equation of time can be calculated as (solar time – mean solar time). Therefore, by subtracting the equation of time from the time observed using the Angbuilgu sundial, we can obtain the mean solar time value.

(4) Is the time difference still evident as observed in (3)? If there is a difference, let's consider the reasons, brainstorm potential methods of adjustment, and discuss them.

The difference still exists because South Korea operates in the UTC+9 time zone. The time zones are based on a system where for every 15 degrees of longitude increase to the east of the Greenwich Observatory, you add 1 hour to the time. This system uses the meridian passing through Greenwich, England, as the reference point for Coordinated Universal Time (UTC). However, South Korea, despite being closer to UTC+8.5 based on its longitude (127 degrees east), uses UTC+9 based on the meridian at 135 degrees east. This is why there is still a difference between the time displayed on a smartphone and the time adjusted for the equation of time using Angbuilgu. By correcting for this longitude difference, you can align the time measured with Angbuilgu to the same time as that displayed on a smartphone clock, eliminating the discrepancy.

(5) What are the advantages of changing the support base of Angbuilgu into a tripod shape, and how can this be related to mathematical principles?

The existing angbuilgu pedestal is in the form of two rectangular parallelepiped overlapping. This type of angbuilgu is difficult to level if it is not printed perfectly flat when 3D printed. However, if you change it to a tripod shape, it becomes easier to level because there is only one plane on which the angbuilgu can stand according to the plane determination conditions.

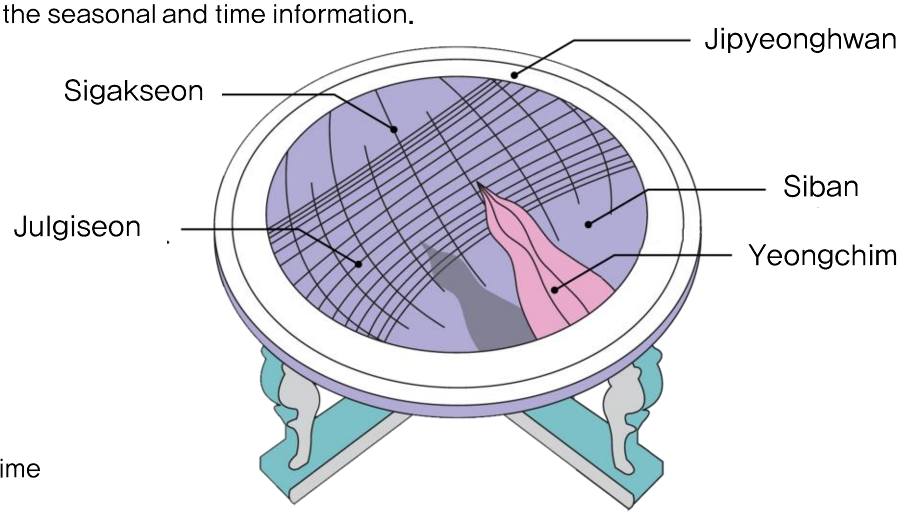


Various plane determination conditions represented. The tripod shape of Angbuilgu is based on the use of condition ①.

VI. Summary

Overview

- Angbuilgu: A sundial in the shape of a hemisphere that can estimate time based on the movement of the Sun.
- Sigakseon: A line that indicates the time. Each line represents a 15–degree difference, corresponding to one hour.
- Jeolgiseon: Thirteen lines that represent the seasonal divisions.
- Siban: The bottom part of the clock that displays the hour lines and season lines on the inner surface of the hemisphere.
- Yeongchim: The hour hand of the sundial, pointing to the North Pole of the celestial sphere.
- jipyeonhawn: A disk that displays the seasonal and time information.



Materials
•3D printer
•Compass
•Spirit level Procedure

Process
(1) Print the sundial.
(2) Install the sundial.
(3) Align it with true north.
(4) Record the data.

Results and Discussion
(1) Record the measurement values.
(2,3) Understanding the Equation of time
(4) Understanding the Standard time
(5) Understanding and Applying the Plane Determination Conditions to Angbuilgu