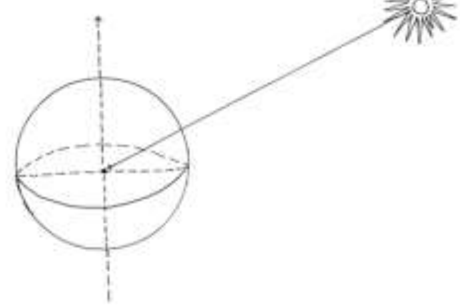
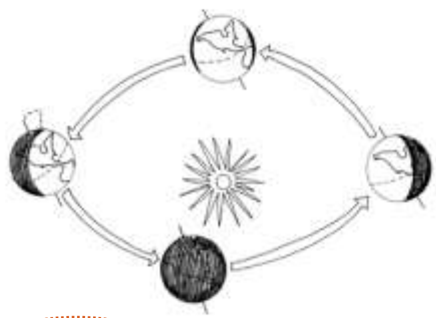
3D Educational Resources





CLINOMETERS - DETERMINING YOUR LOCATION

We have many modern technologies to determine our location. But, what would we do if we did not have our gadgets? One way would be with the Sun. Learn how to do this in this activity!

ONTARIO CURRICULUM LINKS

Through this activity, you and your students will learn how determine the solar altitude (the angle of the Sun above the horizon) using a clinometer. You will then be able to use this value to approximate the latitude where they are found. This activity can be connected to multiple aspects of the Ontario school curriculum, our suggested links is:

- Grade 11: Geography (Introduction to Spatial Technologies)

Note: This activity can only be done on a clear, sunny day at noon.

Grades
10 – 12

Age Range
14 – 17 years

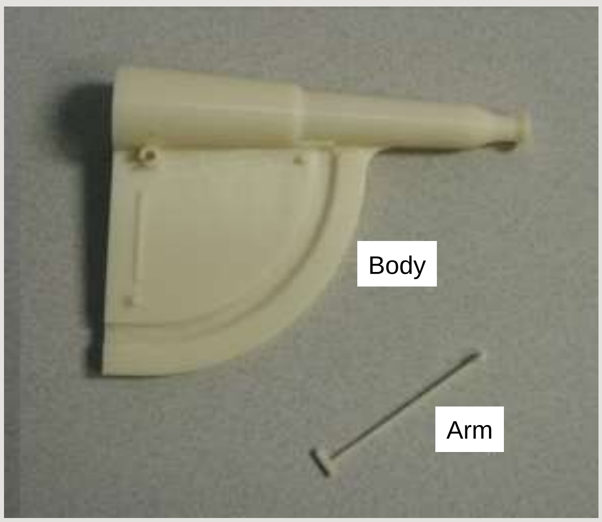
MATERIALS

1 – Glue stick
1 – Calculator
1 – 3D printout of clinometer
1 – Printout of clinometer label
1 – Tape measure (optional)

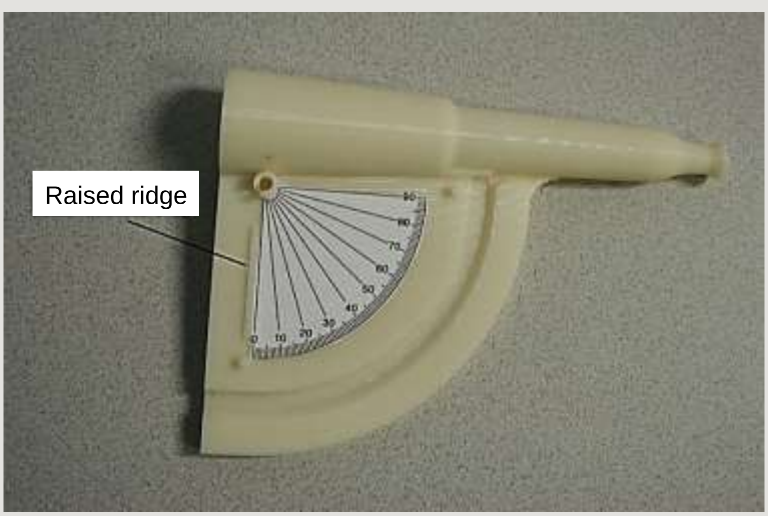
INSTRUCTIONS

Constructing the clinometer

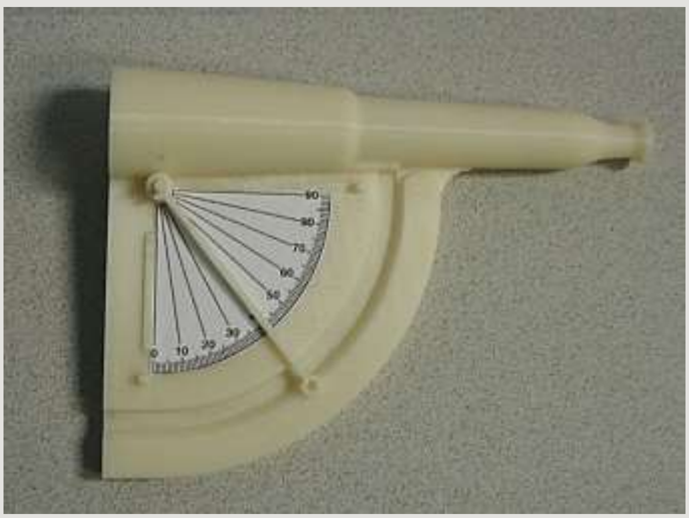
1. The following naming convention will be used in these instructions:



2. Paste the clinometer label on to the body of clinometer with the glue stick. Place the label so that the edge of the “0” line is flat against the raised ridge and the round cut-out portion at the top of the label is flush against the hole (see image below). This ensures that the measurements are accurate.



3. Insert the arm of the clinometer into the hole found on the body of the clinometer. Make sure that the shorter end goes in first. If the arm does not move freely you might have put it in backwards.



Note: If you do not wish to use the arm (or if the arm breaks), an alternate way to do step 3 is to tie a piece of thread around the rim of the hole on the body of the clinometer and, on the other end of the thread, attach a weight (such as a paper clip or washer).

4. As you tilt the clinometer the arm of the clinometer will point down. The number that it points to represents the angle that the clinometer is tilted above the horizon. Try it out! Make sure to hold the clinometer in a way so that the arm does not drag along the surface of the main body.

Determining Latitude

You can use solar altitude (the angle of the Sun above the horizon) to determine the latitude where you and your students are located.

i) Calculating solar altitude

Two potential methods to determine the solar altitude can be found below. The first method is more direct, but more difficult.

Note: For either method, the most important thing to ensure is to not look directly at the Sun. This can cause damage to your eyes.

Solar Altitude 1: The Direct Method

1. Hold the clinometer in front of you in a way that you can see the shadow of the clinometer on the ground. At this point the shadow should be completely solid. To help illustrate this, we’ve included a photo of the shadow on a piece of white plastic (see image below, on the left).

2. Angle the clinometer to allow light to shine through the tub. This is a bit tricky, but when you have succeeded, you should see a small circle of light on the ground in the middle of the clinometer’s shadow (see image above, on the right).

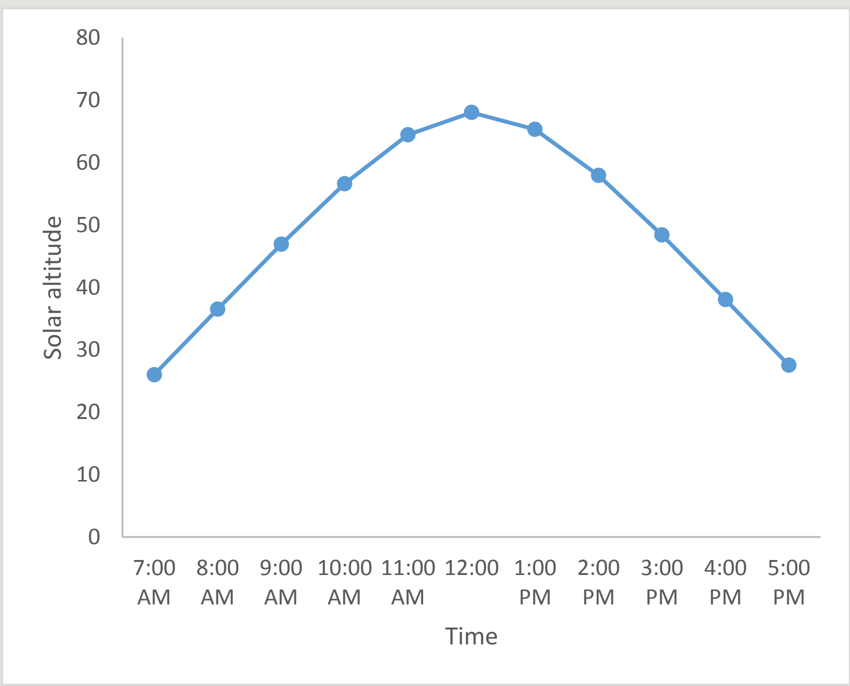
3. Read the angle that the arms points to, this is the solar altitude.

Solar Altitude 2: The Indirect Method

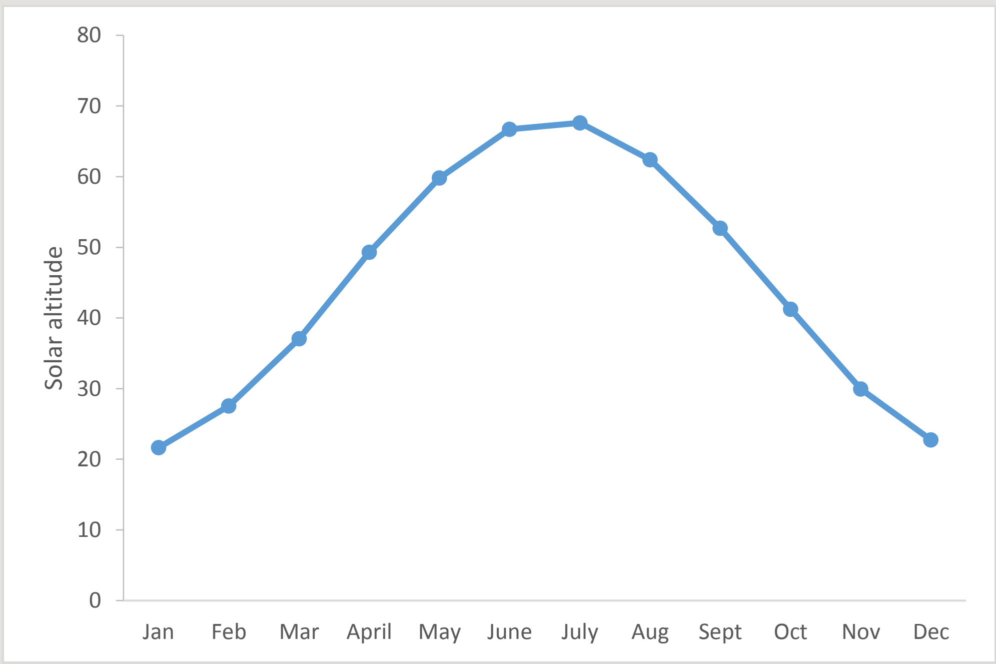
1. Find something that is standing up relatively straight and casting a shadow (such as a tree or sign post).
2. Measure the length of the shadow.
3. Determine the height of the object using the methodology found in the “Clinometers – How high is that?” activity (either the “Simple” or “Advanced” one is fine), which is found on the same website where you obtained this activity.
   Note: Do not do this measurement while standing at the tip of the object’s shadow. If you do this, you will likely be looking directly at the Sun.
4. Use the equation below to determine the solar altitude:

$$\text{Solar altitude} = \tan^{-1} (\text{Height of object} \div \text{Length of shadow})$$

Try this! Have your students determine the solar altitude throughout the day. If you plot these points (time being one variable and solar altitude being the other), you can see how the Sun’s position changes. A typical graph can be found below:



Try this! Have your students determine the solar altitude at noon each day (or each week or each month) for a period of time. These values will show the impact of the Earth's orbit on the solar altitude. For instance, you can find a graph of the solar altitude of the first day of each month for Ottawa, Canada below.



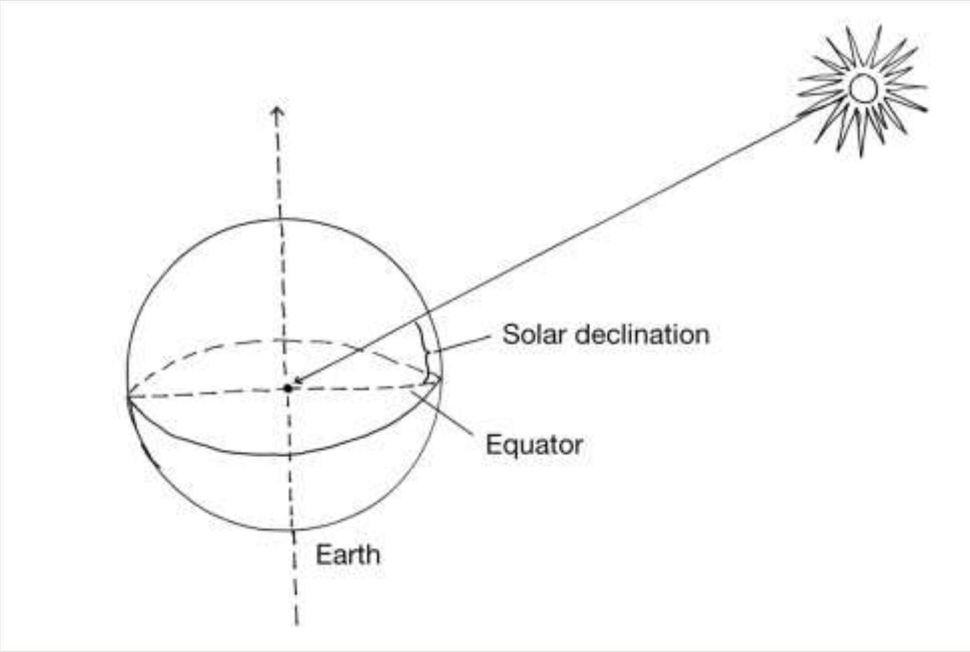
ii) Latitude calculation

Calculate your latitude using the follow equation:

Latitude = 90 - Solar altitude +/- Declination

Note: A positive value indicates a latitude in the Northern hemisphere, while a negative value indicates a latitude in the Southern Hemisphere.

Declination (specifically solar declination) is the angle that the Sun makes with the plane formed by the equator (see image below).



Declination is impacted by the tilt of the Earth and its rotation around the Sun. It is positive when the Sun is north of the equator and negative when it is south. To estimate the declination for your day, you can use the equation below:

Declination (in degrees) = -23.45 x cos(360 ÷ 365 x (DOY + 10))

DOY is the day of year number. So for January 1, DOY = 1, January 15 DOY = 15. For February 1, DOY = 32, since there are the 31 day of January plus the first day of February. A DOY calendar can be found here:

esrl.noaa.gov/gmd/grad/neubrew/Calendar.jsp

Whether or not you add or subtract the declination depends on the time of the year and your position on the Earth. If you are in the Northern Hemisphere and the Sun is to the south of you at midday, then you will be adding the declination (this will always be the case if you are in **Canada**). Note: When declination is negative you will be in fact subtracting it (since you will be adding a negative number). Conversely, if you are in the Southern Hemisphere and the Sun is to the north of you, you will be subtracting the declination.

If you are in the Northern Hemisphere and the Sun is to the north of you (this will only happen if you are at a low latitude during the summer), you will subtract the declination. But the latitude that you obtain will be negative, so you will need to take its absolute value (make the value positive). Similarly, if you are in the Southern Hemisphere and the Sun is to the south of you, will you add the declination and then take the absolute value of the latitude.

Latitude example calculation:

Location: Ottawa, Canada
Date and time: June 1, 2018 at noon

Latitude = 90 - Solar altitude +/- Declination

a) Measured solar altitude = 67 degrees

b) Declination = -23.45 x cos(360 ÷ 365 x (DOY + 10))

For June 1, 2018, the DOY is 152

$$\begin{aligned}\text{Declination} &= -23.45 \times \cos(360 \div 365 \times (152 + 10)) \\ &= -23.45 \times \cos(159.78) \\ &= 22\end{aligned}$$

c) Latitude = 90 - Solar altitude +/- Declination
Since we are in Canada, we will be adding the declination

$$\begin{aligned}\text{Latitude} &= 90 - \text{Solar altitude} + \text{Declination} \\ &= 90 - 67 + 22 \\ &= 45\end{aligned}$$

Since the value is positive, we calculated a latitude of 45˚ N for Ottawa, Canada, which is the correct value.

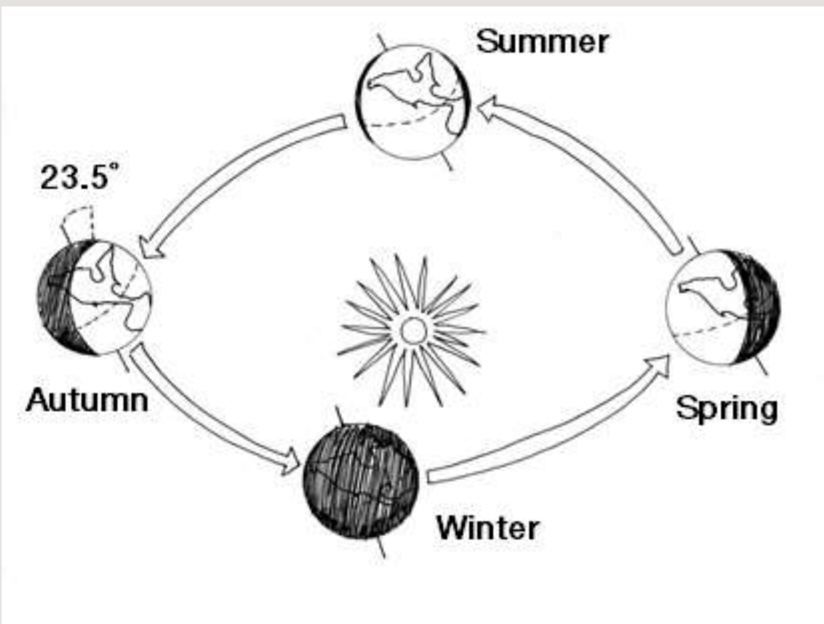
SCIENTIFIC EXPLANATION

Solar altitude changes during the day

The Earth's rotation is what causes us to have day and night. As one side of the planet rotates toward the Sun, more of it is exposed to the Sun, causing the Sun to seem like it is rising and thus increasing the solar altitude. At midday, this side of the planet begins to rotate away from the Sun, decreasing its exposure to the Sun, causing the Sun to seem like it is setting and thus decreasing the solar altitude.

Solar altitude changes throughout the year

The Earth has a yearly orbit around the Sun. If you create a plane of this orbit, you will notice that the Earth's axis is not perpendicular to it, it is actually titled at an angle of 23.5 degrees away from vertical. This tilt and the Earth's orbit around the Sun are the reasons why we have seasons. It is also why the solar altitude at noon (or at any other time) will change throughout the year. During the summer, the northern hemisphere will be tilted toward the Sun, whereas it is tiled away during the winter. This is what causes the solar altitude to be higher during the summer in these parts of the planet.



Ingenium – Canada's Museums of Science and Innovation has more than 110 000 artifacts in its collection, including many ones related to clinometers. You can explore other objects in the collection at: ingeniumcanada.org/ingenium/collection-research/collection.php.