Sun Dial Activity

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Build a sun dial to that is easy for a classroom of students or Earth Day explorers to observe the motion of the sun in the sky, make measurements of the altitude of the sun in the sky, find local noon, and calculate where north and south are.

Materials

- 5-8 foot length of 2-4 inch diameter PVC pipe
- at least 20 feet of sturdy but flexible rope
- at least 4 stakes
- drill and bit
- hammer or mallet
- vertical level
- 4 tent stakes (2 extra to secure the base from bumps)
- 10 sturdy plastic labels/stakes, similar to those used for marking plants in the garden (each will be labeled with an hour time); consider more labels/ stakes if using a shorter time interval
- 3 or 4 spools of colored yarn
- tape measure
- level ground

Building

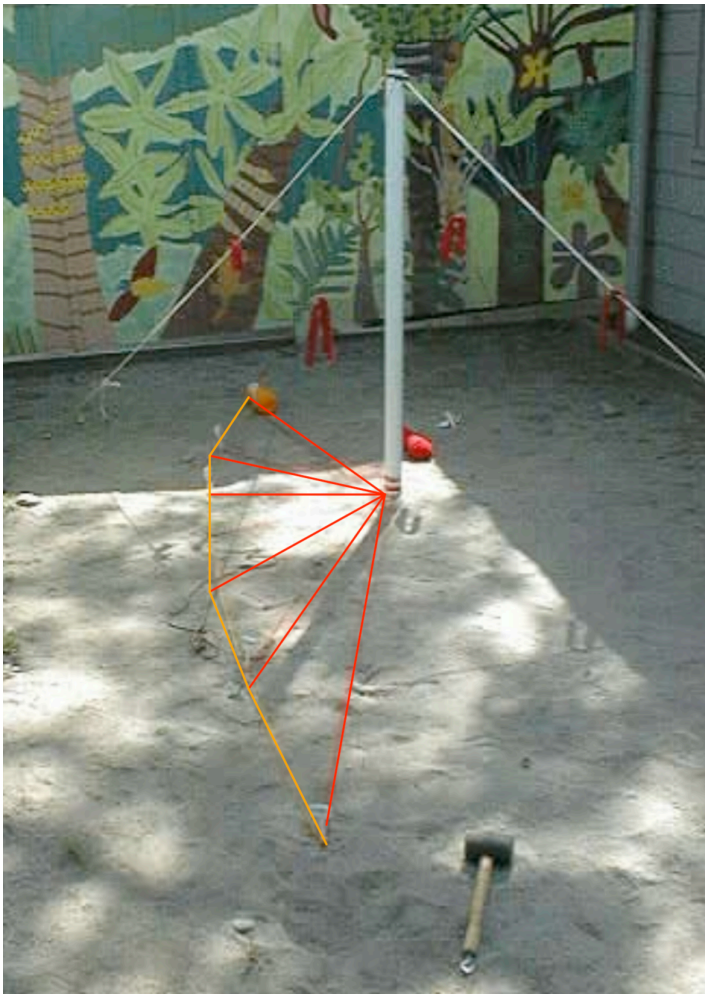
- Drill 4 equally spaced holes 1-2 feet from one end of the PVC pipe.
- Run about 10 feet of rope through two holes, and another through the remaining two holes.
- While holding the pipe vertical (helpful to have another person helping) and the holes furthest from the ground, anchor the ropes to the ground using the 4 stakes.
- Build/install the sundial as early as possible in the morning (or the day before, if an option), so measurements may start early in the morning, 10 AM at the latest.

Preparation

This activity needs to run from the morning into the afternoon in order to see the pattern of the sun's motion and use the data to measure the direction of True North and calculate when local noon occurred (clock time is different from sun time).

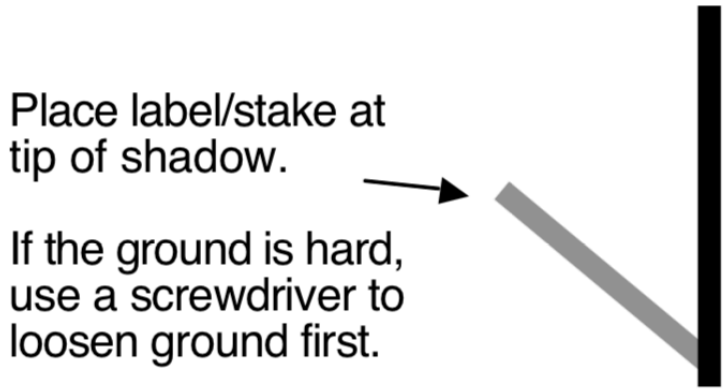
Set up the sun dial and begin taking measurements and marking with the colored yarn by 10 AM at the latest.

The sun dial activity can be run in some pretty small locations – the key is to consider the availability of open sky above and around the post.



Procedures

Every 10-15 minutes, mark the position of end of the shadow with a marker. Secure the marker in the ground. To help visualize past shadows, run a length of colored yarn between the marker and the bottom of the PVC pipe.



Local noon is the time of day when the sun is highest in the sky and the shadow will be the shortest. Local noon occurs when the sun is due south of the observer if you are north of 23.5ºN latitude, so the shadow at local noon is point to true north.

If you are south of 23.5ºS, then the sun's position at local noon will always be due north of you. Between the Tropic of Cancer (23.5ºN) and Capricorn (23.5ºS), the sun will either be directly overhead, due north or due south of you depending on the time of year.

Clock Time versus Sun Time: Being in Boston, with a longitude of 72ºW, we are very close to the eastern edge of the Eastern Time zone, and our local noon will be about half an hour before noon compared to that experienced by someone close to the western edge of the Eastern Time zone. The eastern edge of a time zone experiences sunrise, local noon, and sunset an hour earlier than the western edge of that time zone. Remember, we use standard time during the winterish months, and daylight savings time during the summerish months, so local noon may be after 1 PM depending on your location and day of year.

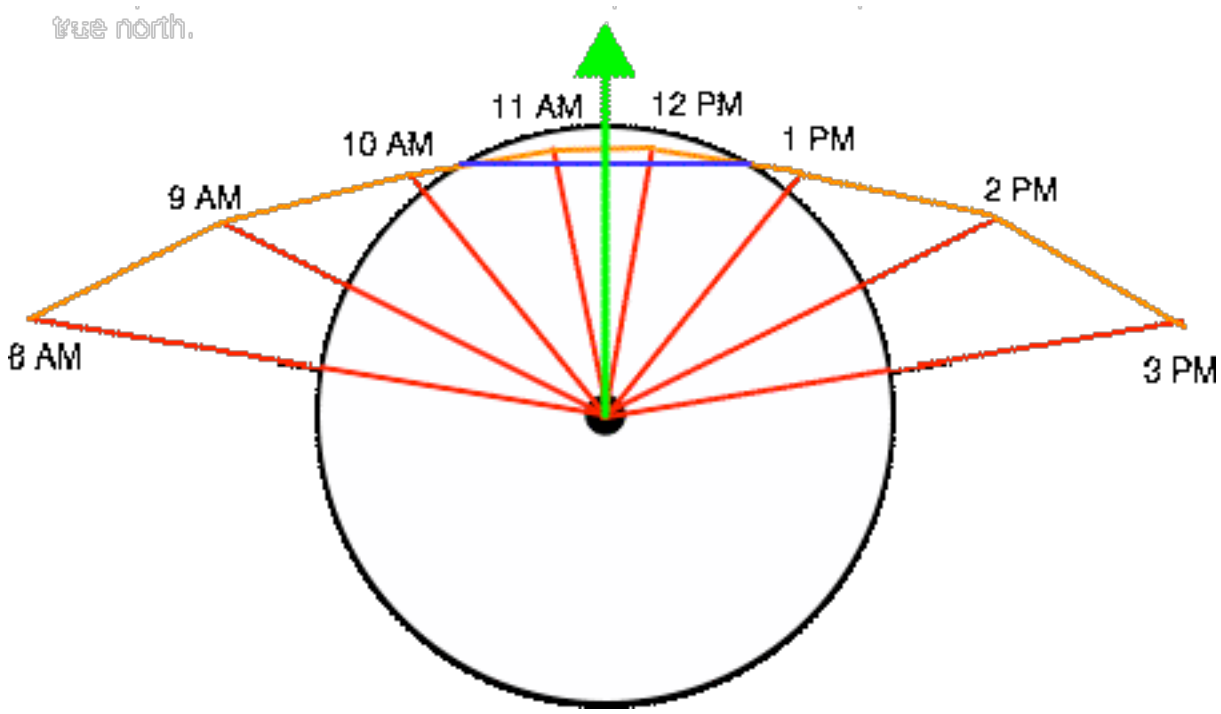
By marking shadow positions every 10-15 minutes, you will be able to calculate the time of local noon and where true north is oriented. Look at the trace of the shadows and notice that they were long in the morning, became shortest around noon, and then got long in the afternoon. The key is that the shadows' lengths are symmetric about the shortest shadow.

True North points to the axis of the Earth's rotation and is in the direction of the shortest shadow of day since the Sun is due south and highest in the sky at that time.

To find the direction of the shortest shadow,
1) Using a string tied to the base of the sundial, create a circle (black) from center post

2) Mark where the trace of the shadows (orange line) crosses the circle (blue line).

3) Find the midpoint of the blue line (place a string along the blue line and fold it in half) and extend the green line from the center post through this point. The green line is pointing true north.



Finding **Local Noon**, which is the time of day the Sun is highest in the sky.

Use the circle, shadow trace, and intersections described above to calculate the time of Local Noon:

1) Estimate the time the trace of the shadow first crosses the circle. In this example, it appears to be near 10:15 AM.

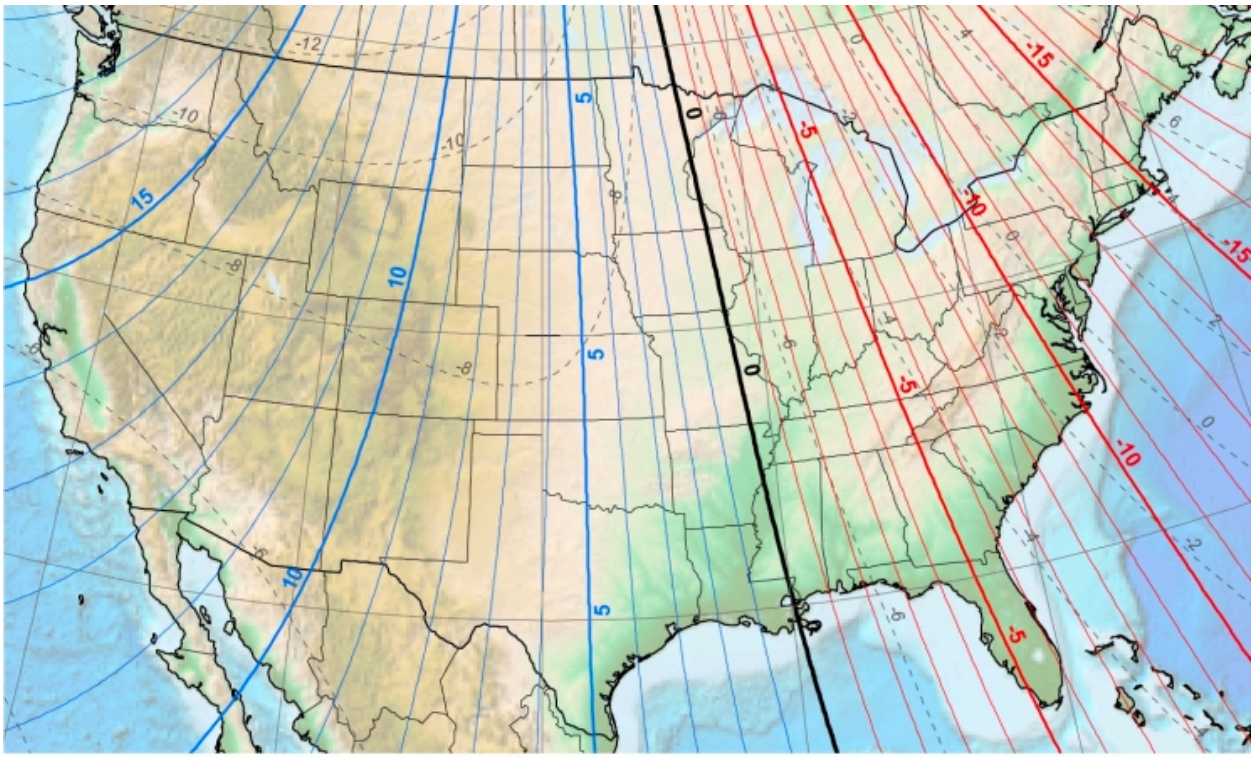
2) Estimate the time the shadow moved outside the circle. For this example, it appears to be near 12:45 PM.

3) The midpoint between these two times is Local Noon:

(10:15 + 12:45) / 2 = 23 / 2 = 11:30 AM

Extension: Comparing True North to Magnetic North

True north is usually not aligned with magnetic north. The angle between true north and magnetic north is called magnetic declination. Use http://www.magnetic-declination.com/ to find your magnetic declination. Map, below, from https://www.westcoastweathervanes.com/installation/magnetic-declination/.



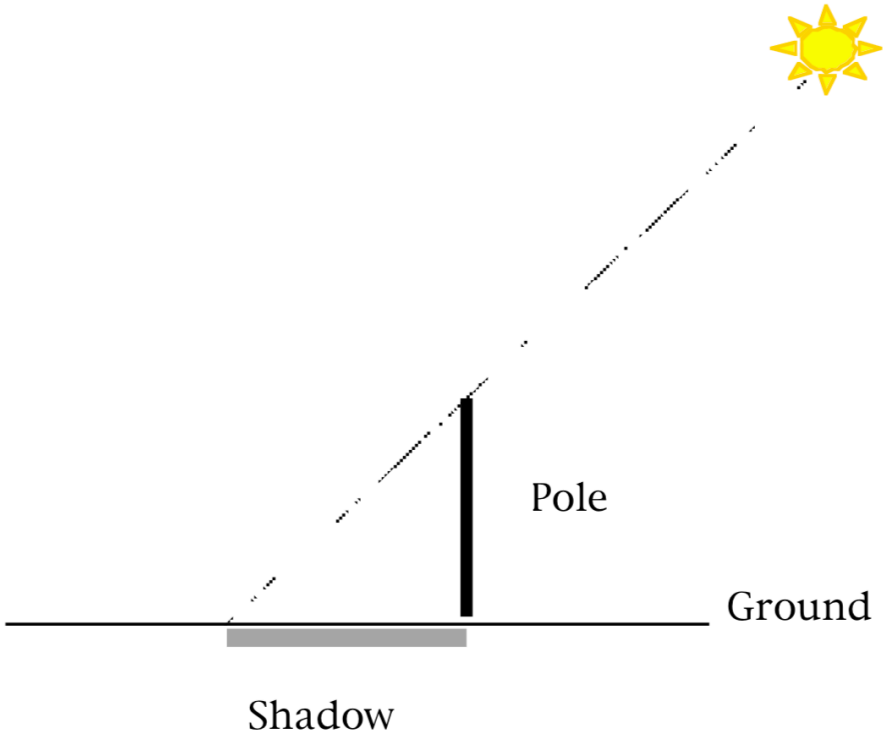
Extension: Use a sundial as a calendar

If you can save the markings, run this activity every week or two and compare the differences of the location and shape of the shadow trace (orange line above). If you are after December 21 and before June 21, the shadows get closer to sundial each day. And between June 21 and December 21, the shadows more away from the sundial. If you have saved each week's shadow trace, you have a calendar!

Extension: Calculating the Altitude of the Sun in the Sky

You need to be familiar with the tangent function, so some familiarity with geometry or trigonometry is needed.

$$\text{Angle of sun above the horizon} = \tan\left[\frac{\text{Height of Pole}}{\text{Length of Shadow}}\right]$$



If you measure the angle of the sun at local noon during an equinox (March 21 or September 21), you may calculate your latitude.

Latitude = 90º - local noon sun angle

For other days of the year, if you are north of 23.5ºN:

Latitude = 90º - local noon sun angle + sun declination

See Sun-Earth Connection at sciencepickle.com to explore declination.