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CA1 2.11: Designing an Equatorial Sundial Activity

Purpose: To design an equatorial sundial and learn about motions of the sun and earth that have a bearing on its design.

Materials: poster board, length of stiff wire or dowel rod, tape, protractor, ruler, pencil.
Background information:

1. Look up in an atlas or other reference the longitude and latitude of your location.

Longitude:

Latitude:

The style

The style of a sundial does not refer to its artistic interpretation. It refers to the stick in the center of the sundial which casts the shadow used to tell time. The style is the yellow stick in the illustration at the top of the page.

The sun rising and setting and moving through the sky each day is caused by the rotation of the earth. By coincidence, the rotation axis of the earth points to the star called Polaris. Equatorial sundials take advantage of this fact by pointing the style at Polaris.

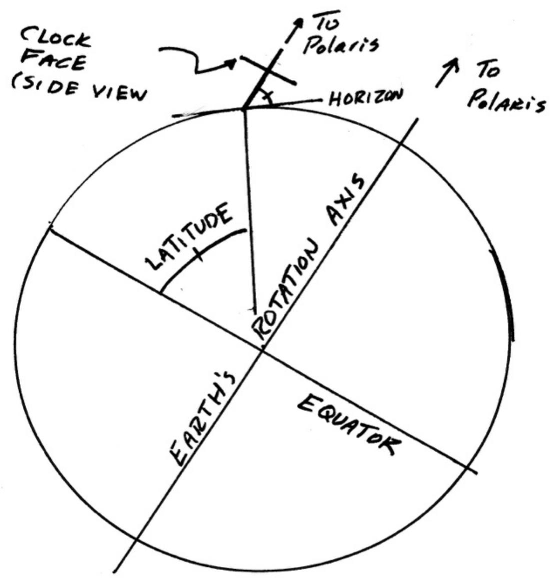

Figure 1. The style of the sundial must point to Polaris.

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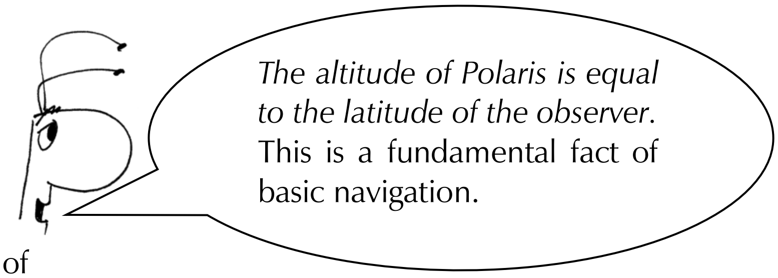
Therefore, the style will be parallel to the earth's axis. The clock face will be perpendicular to the style, and will therefore be parallel to the earth's equator. This is why the design is called an equatorial sundial. The angle from the horizon to Polaris is called the altitude of the North Celestial Pole. (Or very nearly so, because Polaris is near, but not at, the pole.) Some basic geometry can be used to prove that this angle is also equal to the observer's latitude.



Thus, as the earth rotates, the sun appears to go around the stick in exactly 24 hours.

When you design your sundial, then, you will need to find a way of supporting the style at the proper angle.

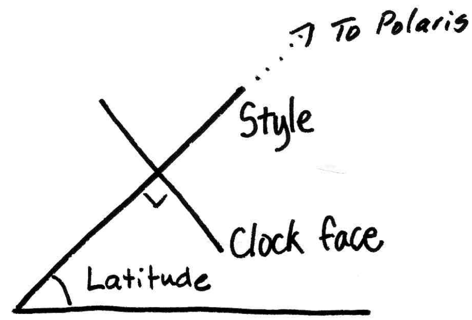


Figure 2. Equatorial Sundial (side view)

2. Use this space to sketch ideas or write down plans for your sundial.

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Part Three: The clock face

The clock face must be perpendicular to the style. Markings on the clock face will show hours like the hour hand of a clock, although the spacing and order is a little different than for an analog clock.

3. Begin by finding a piece of cardboard or other material for the face. Put a dot in the center of the cardboard (eventually the style will go through this spot) and draw a line straight down to represent 12:00 local solar time.

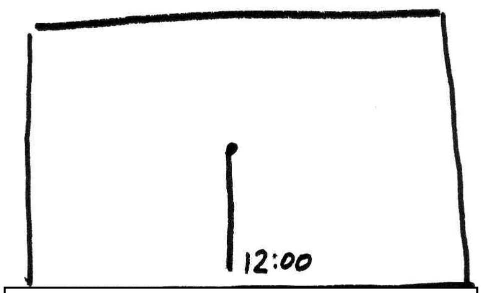

Figure 3. Noon is straight down.

4. Why is the 12:00 line straight down? On regular clocks, 12:00 is straight up.

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5.Next draw "slices" for the hours which are 15 degrees apart. The best method is to hold a protractor still and mark every 15 degrees. If you move the protractor each time you will accumulate systematic error.

6. The illustration shows that the slices do not need to go all the way around the style. Why is that?

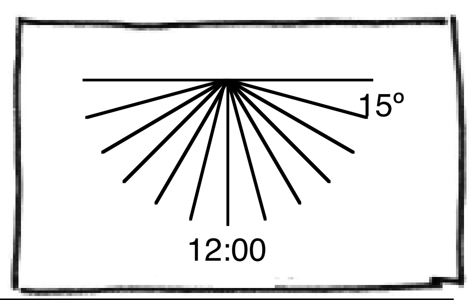

Figure 4. Hour marks are 15 degrees apart.

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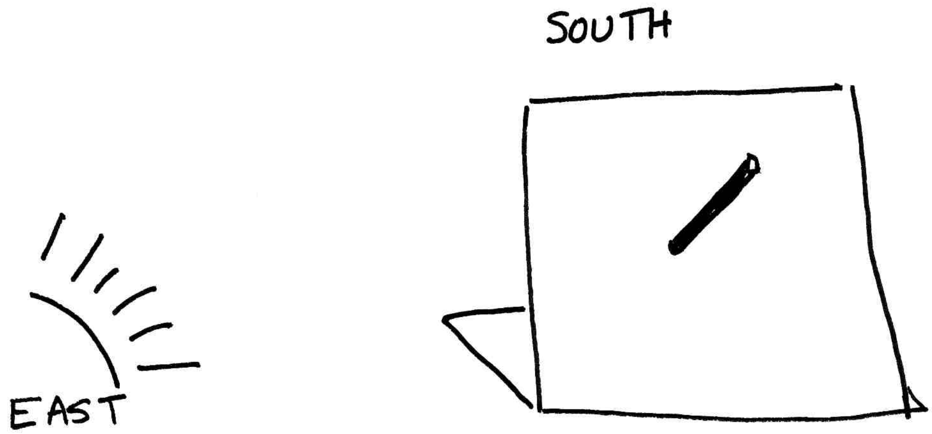

Figure 5. When the sun rises in the east, which way will the shadow point?

Figure 5 shows what the sundial will look like when assembled, with the style pointing north, at sunrise. If you face south looking at the sundial, the sun will be on your left.

7. Draw on Figure 5 to show which way the shadow of the style will fall. This must be the AM side on the clock face.

\Using this logic, the clock's face should start on the right at 6AM, increase to the bottom at 12:00 noon, then start counting from 1 to 6 PM on the left (Figure 6).

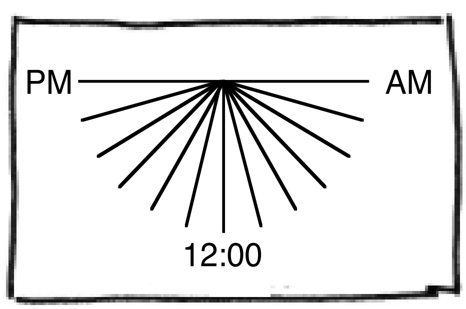

Figure 6. AM is on the right on the clock face.

You might want to put some marks between the hours to stand for half and quarter hours. On very large sundials you can even mark minutes. However, the shadow gets fuzzy when the sundial is larger, so an accuracy of ±5 minutes or so is all you can expect with a small sundial.

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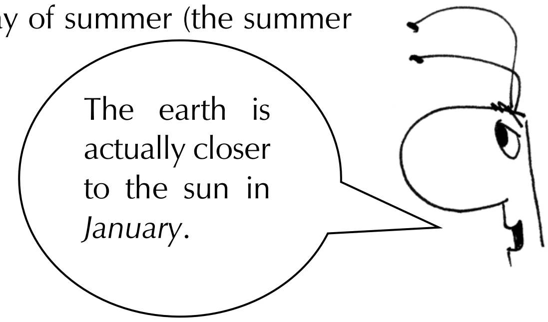
Our design so far has a flaw: it only works six months of the year. The sun is not aligned with the earth's equator. The sun appears to move above and below the earth's equator because the earth's axis is tilted. This phenomenon also causes our seasons. The northern hemisphere is hot in the summer because the earth is tilted towards the sun, not because the earth is closer to the sun.

The amount of tilt is 23.5 degrees. On the first day of summer (the summer solstice) the sun stops moving north and is above the plane of the earth's equator all day long. But on the first day of winter (the winter solstice) the sun stops moving south and is below the plane of the earth's equator—and the clock face—all day long. This means the clock face is in shadow all through the fall and winter, and can't be used to tell time.



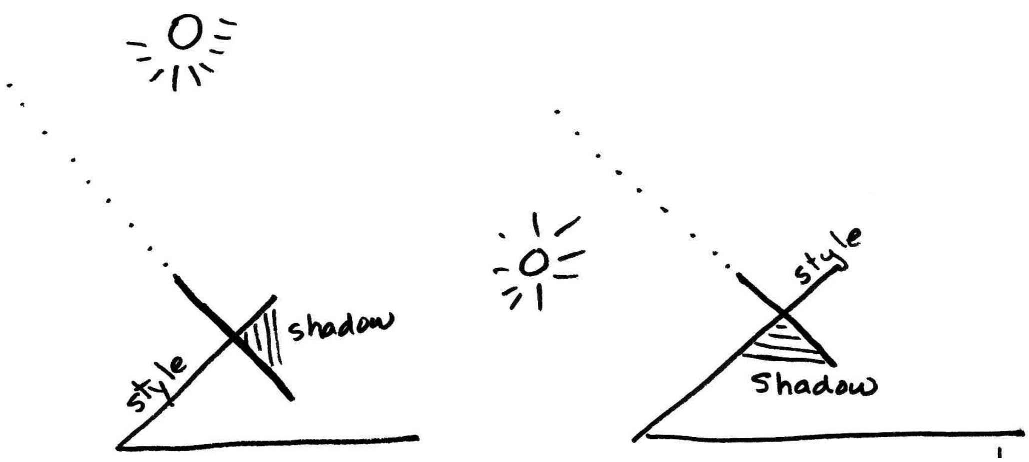
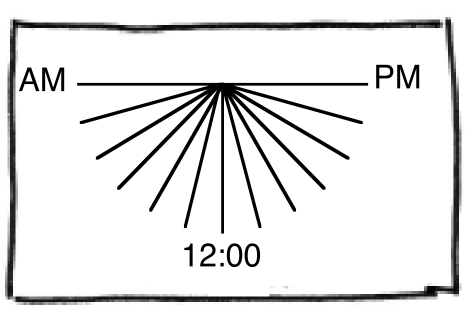


Figure 7. Why the sundial needs two faces.

In Spring and Summer, the sun is above the plane of the earth's equator (and the sundial face) all day long (seen on the left here). In Autumn and Winter, the sun is below the plane of the equator all day long (seen on the right here.)

8. Thus, we need a clock face on the bottom of the dial too. When reading it, we'll be facing *north*, so the dial will have to be reversed because we're facing the other way.



If you've completed all of these steps, you should have a functional sundial. Take it out in bright sunlight and point the dial north. The sundial only reads local solar time, and will not match your watch. There is a handout elsewhere in this book (CA1 2.12) which explains how to convert local solar time to standard time.

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Questions:

1. What would an equatorial sundial look like if it was designed for use at the North Pole?

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2. What would an equatorial sundial look like if it was designed for use at the earth's equator?

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3. A photograph shows a person standing next to a sundial. Tell how to determine what latitude they were visiting when the picture was taken.

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4. How would your sundial be different in the southern hemisphere?

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5. If an equatorial sundial is designed so its clock face is parallel to the earth's equator, what do you think a horizontal sundial would look like?

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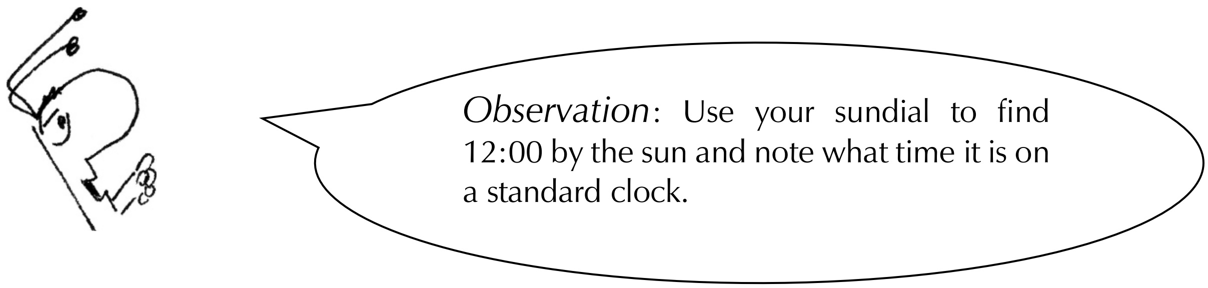

Challenges:
1. Redesign the clock face so only one clock face is needed.
2. Rebuild the sundial for a different latitude.
3. Adjust the sundial faces to account for the errors explained in the CA1 2.12 on converting sundial time to standard time.
4. Decorate the sundial with a sun or time related quotation.
5. Make the sundial a permanent structure with weatherproof materials.