Directions: Create a document to answer the Questions. That will be your report. Optional: Include a picture of yourself using the sundial that we can put on the Physics 90 public web page.

The Equatorial Sundial

Telling Time with the Sun

Overview

There are various kinds of sundials. The easiest kind to understand is the equatorial sundial. All sundials have to be adjusted for your latitude, longitude, and daylight savings time, but the adjustments for the equatorial sundial are the simplest, so that is what we'll build.

1. Acknowledgements

Usually acknowledgements go at the end of a document, but this document relies so much on the Sky & Telescope article, "How to Make a Sundial the Simple Way," https://skyandtelescope.org/observing/how-to-make-a-sundial/, by Tony Flanders that the acknowledgement deserves to be at the beginning. In the United States, Sky & Telescope has long been the leading magazine for amateur astronomers, including some pretty serious ones. Consider subscribing for a year if you want to keep up with new discoveries in astronomy. It is not expensive.

2. Types of Sundials

The most common kind of sundial is often found in gardens. In the most common kind, the face of the "clock" is level or horizontal, and so this kind is called a "horizontal" sundial. The reason we are not making the most common kind is that a level surface receives the shadow of the Sun in a distorted way, and the amount of the distortion depends on latitude.

Question 1. There is also a kind called a "vertical" sundial, that can be mounted on a wall. It has a different design depending on which wall you mount it on (East, West, or South). In the northern hemisphere, what is the problem with mounting a sundial on the north wall of a house?

In addition to the face, the sundial needs something to cast the shadow of the Sun. This is called the "gnomon."

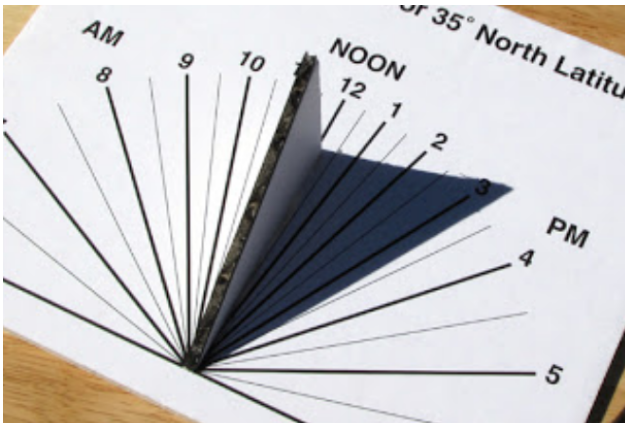


Figure 1. Horizontal Sundial.

In the horizontal sundial above, notice the distortion. The hours near noon are closer together. Essentially, this is because the shadows get longer quickly at the beginning and end of the day.

We are going to build an "equatorial" sundial. Its face is at a tilt. In fact, its face is parallel with the equator, hence the name. The rod that casts the shadow on the face will be parallel with the axis going from the North Pole to South Pole.

3. Supplies to Gather

Before going much further, let's make sure you have the supplies on hand. We hope these are all obtainable in your household:

1) This lab write-up, printed out. Actually, the only page that needs to be printed is the template. That is the last page of this PDF.
2) IF YOU DON'T HAVE A HOME PRINTER, go to the appendix for a suggestion for the template.
3) Scissors for cutting the template.
4) Tape. Preferably transparent tape ("Scotch" tape).
5) A piece of cardboard about as big as a regular piece of paper.
6) A sharpened wood pencil (one that hasn't been sharpened down to something short) to use as the gnomon.
7) A good stick and some way to keep it standing up and still for an hour or so. See the next section for more description of this and the last item in this list.
8) A couple of pebbles or anything else that can mark the position of the shadow of the top of the stick.

4. Making a True East-West Line

Now it is time to make an accurate east-west line using ancient methods. Follow the directions in the first 90 seconds of this video:

https://tinyurl.com/stick-shadow

The hardest part of this is going to be finding a nice stick. A broom? And also, some way to stand the stick up. It doesn't even have to stand straight up! You could prop the broom between two chairs. As long as the tip of the broom handle or whatever you used does not move, you'll be able to determine a good East-West line.

You need to mark the surface as the shadow of the top of the stick moves. Two pebbles? Two pieces of masking tape? Whatever you use to mark the two shadow positions establishes your east-west line. Once you have gotten the stick firmly positioned, mark the shadow position of the tip of the stick.

Now that you have marked the first shadow position, you can go on to the remaining steps. When you are done with those steps, the shadow will have moved enough to mark the second shadow position.

5. Your Latitude and Longitude

Early on in the course, we studied latitude, longitude, declination, and right ascension. For this project, you need your latitude and longitude. As an example, Moraga: 38 N latitude, 122 W longitude.

Question 2. What is your latitude and longitude? Are any of you south of the equator during shelter-in-place? Email for additional directions if you are.

6. Cutting and Folding

First, cut along the dotted lines labeled 1 on the template. Don't go past the end of the dotted lines.

Second, fold the paper along the line labeled 2. Once you've made a nice crease open it back up. The writing should face out when you make the fold.

Third, fold the paper along the lines labeled 3. Once you've made a nice crease in one of those lines, open the paper back up. Do the other line labeled 3. The writing should face out when making these creases.

Fourth, fold along the latitude line that is best for your latitude. First with the writing facing out, and then again with the writing facing in.

7. Taping it all in Place

Steps 5-7 on the template are hopefully self-explanatory. Two comments though:

1) The pencil needs to end up perpendicular to the "clock" face. Once you have the pencil in a good position, and the paper taped to the cardboard, add tape to the eraser end of the pencil to secure it to the cardboard.
2) Return to the place you are making the east-west line.

8.Pointing the Sundial to True North

The shadow that has been moving since you set it up in Section 4 needs its new position marked. The old position and the new position together make an east-west line! If you align your sundial's edge with that line, the pencil is parallel to the Earth's axis.

Question 3. It's daytime. Nonetheless, you know what star the pencil points at. What is a name for this star? What constellation is it in?

9. The Sundial in Winter

In summer in the northern hemisphere, the Sun is north of the equator. In fact, right now it is at a declination of about 17° N. Since the clock face is parallel to the equator, and the Sun is north of that, the Sun casts a shadow on the north side of the clock face, which is its front. In winter in the northern hemisphere, the Sun is south of the equator.

Question 4. Where would the shadow of the pencil hit the paper in winter?

10. Correcting for Daylight Savings Time

In most of the United States, we move our clocks ahead one hour on March 8th. Of course the Sun doesn't jump an hour ahead so all summer long, we have to add an hour to our sundial's time. This year we will go back to Standard time on November 1st.

11. Correcting for your Longitude

California is a big state in the east-west direction (and even bigger in the north-south direction). For convenience in working with other Californians, we all are on the same time zone. But you can see that as the Sun moves west across the sky, it is going to get highest over Truckee before it gets highest over Sacramento, and it gets highest over Sacramento before it gets highest over Moraga.

The Earth is marked out in 24 time zones each 15° wide. Standard time in California agrees with the Sun only for those people halfway across our time zone. the middle of the Pacific time zone is at 120°. Moraga is a full 2° west of that. Each degree is 4 minutes, so if you set up your sundial in Moraga it will run 8 minutes slow on average.

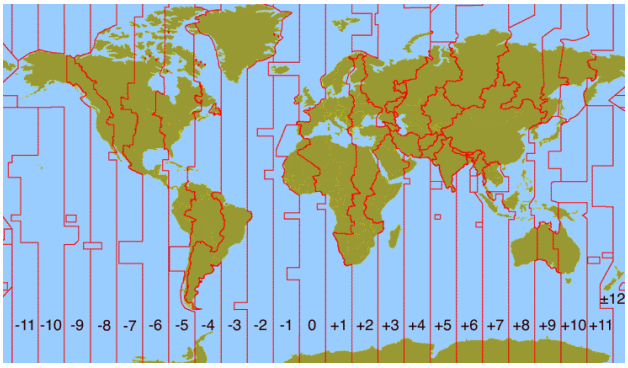


FIGURE 2. The world's time zones.gif

Before the world was broken up into time zones, people marked time from "high noon." High noon is when the Sun is most overhead.

QUESTION 5. Using your longitude and the map above, how much ahead or behind is noon in standard time from high noon at your location?

FIGURE 3. The O.K. Corral, Star Trek S3 E6.

The famous gunfight at the O.K. Corral occurred about 3pm. It does seem fun though to challenge someone to do something at "high noon" and now you know how to use your longitude to get high noon from standard time.

12. Conclusion and More Corrections

There is even a bit more complexity to the whole problem of corrections. Everything we have said so far is true if the Earth's orbit was circular. It is close to circular, but it is actually slightly elliptical. When we are closer to the Sun, the days and nights last a little longer than 24 hours. When we are farthest from the Sun, the days and nights are a little shorter than 24 hours. The time on a modern clock takes a perfect average all year round, but your sundial will run a little slow relative to this perfect average for about half the year and a little fast for the other half. If you want to see how complicated this last correction is, you can Google "The Equation of Time." Let's just be happy that we understand the daylight savings correction and the longitude correction and call it a day (nice pun, eh?).

Optional Question 6. In the email to your lab professor with the five questions above answered, you could take a picture of you or your sundial for us to post publicly on the Physics 90 web pages. It just seems like a nice way to finish a semester where we don't have in-person meetings. At least we can share some photos.

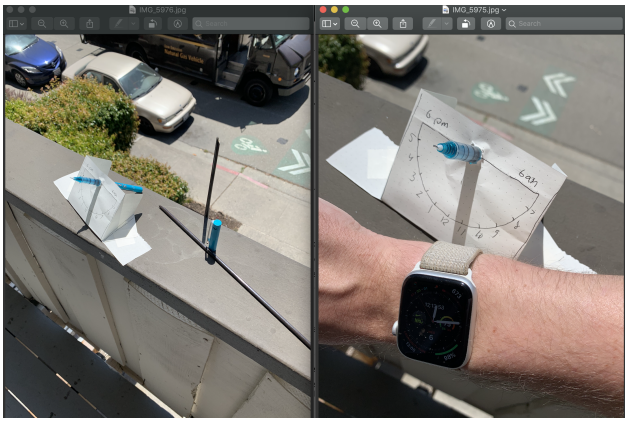
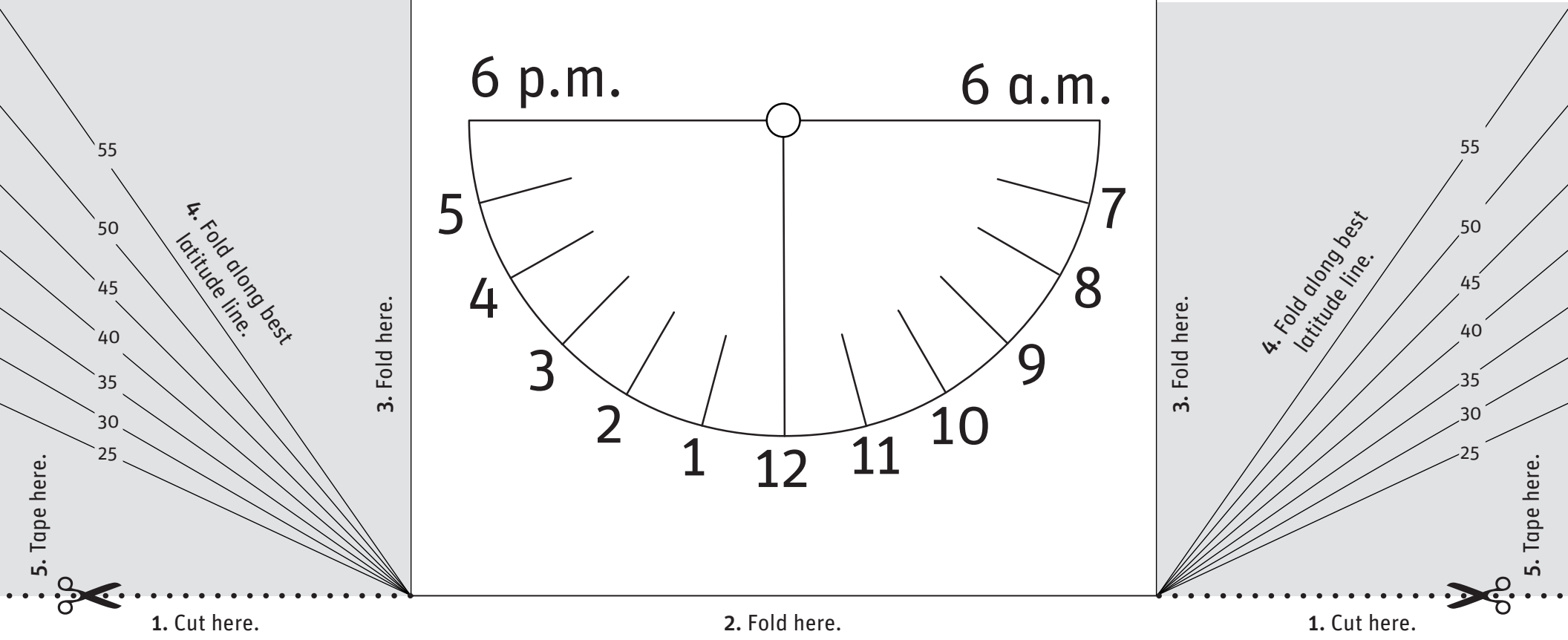


Figure 4. Prof. Lee's Sundial

Appendix. No Printer?!?

As you can see in the photo in the last section, Prof. Lee didn't print his sundial. He drew it because he didn't have a printer handy. Please be creative if you are stuck in the same position. You can measure the sundial template off of your computer screen and make as accurate a model as you can. It should still come out pretty well as you can see from his photo.



Northern Hemisphere Sundial

1. Cut in from edge of paper along dotted lines. Stop at solid lines.

2. Fold along solid horizontal line with line on outside. Crease, then open flat again.

3. Fold along solid vertical lines with lines on outside. Crease, then open flat again.

4. Select the latitude line closest to your latitude. Fold with line outside, crease, and fold again with line on *inside*.

5. Tape the paper together as shown at right.

6. Insert a sharp pencil point-first through the small circle at top center. Remove pencil and reinsert it with the eraser first.

7. If needed for stability or durability, tape the whole thing to a sheet of cardboard.