Pocket Sundial Project, Activities and Facts

To the Instructor: You will notice that this manual is written as if it were to be read by young learners. We have done this intentionally to provide specific language and examples that can be used in lessons taught by those unfamiliar with this topic. Feel free to use our language or simply pull out the facts and use your own.

AN INTRODUCTION TO SUNDIALS

Imagine a time before clocks… What would it be like without those two important hands of the clock telling you what time it is? What would you do if you couldn't simply look at the digital watch on your wrist? There weren't always clocks, so how did people tell time before the clock was invented? Some people would wake up in the morning when the rooster on their farm "cock-a-doodle-doo"-ed. In some societies, people would know the time of day based on the ringing of a bell or sounding of a horn. Maybe some people could tell the time of day by when they got hungry (don't you get hungry right around lunch in the middle of the day or dinner at the end of the day?). Eventually, some people in ancient civilizations realized that they could tell what time of day it was by looking at the sun's position in the sky.

Who were these people? The first sundial was believed to have been made by the Egyptians around 1500 B.C. (That's about 3,500 years ago!) Scientists have found evidence of sundials in many ancient civilizations including those of the Babylonians, Egyptians, Greeks, and Romans. In ancient times, sundials were a symbol of status-rich members of society would build big sundials in public with their names on them, in order to show their prestige.

Though sundials have been constructed in many forms, they all do the same thing; they tell time by casting a shadow. Some sundials cast a shadow onto a flat circle called a "dial," while others cast a shadow on a vertical ("up-and-down") surface. The raised part of the sundial that casts the shadow is called the *gnomon* (pronounced NO-mon). The gnomon projects a shadow that indicates the time based on lines or curves marked on the surface. These lines are labeled to correspond to hours. Sundials are not precise, but people in many civilizations used them to tell time until the invention of the first mechanical clock (called the "weight-driven clock," first made in the 13th century in England).

Today, because modern clocks are almost always accurate, easy to use and work even when the sun isn't shining, sundials are mostly used for decoration. With this activity kit, you will make your own portable sundials and be able to tell time without a clock!

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HOW SUNDIALS WORK

Have you ever heard the saying that "the sun rises in the east and sets in the west"? As the earth rotates on its axis each day, the sun appears to move across the sky. Remember that in relative terms, the sun is actually standing still, but the earth is spinning and makes one full rotation every 24 hours. During the day, as we spin, shadows created by the sun move across the ground. They move in the same direction everyday and at the same speed. This is why we can make a sundial that can help tell us the time. (On a side note, the hands of a clock rotate in the direction that they do because they mimic the movement of the shadows cast by the sun throughout the day…hence the term "clockwise".)

Sundials get a little tricky because of the tilt of the earth and the 365 day revolution that it makes around the sun. To best explain how a sundial works, for the moment let's assume that the earth is not titled. Were this the case, at any location on earth, the sun would rise and set at the same time each day. Now, if you had a fixed object (say a flag pole) it would cast the same shadow at the same time everyday. If you marked on the ground where the shadow ended one hour after sunrise and then each hour after that until sundown, you would create a sundial. You could then make a chart to indicate what happens during the day when the shadow reaches each mark. Examples might be that breakfast is eaten when the shadow reaches the 2nd mark, lunch when it reaches the 6th mark and dinner when it reaches the 11th mark. In this way, the shadows would be providing the time. The same concept would apply with a sundial of the type that you will make with this activity.

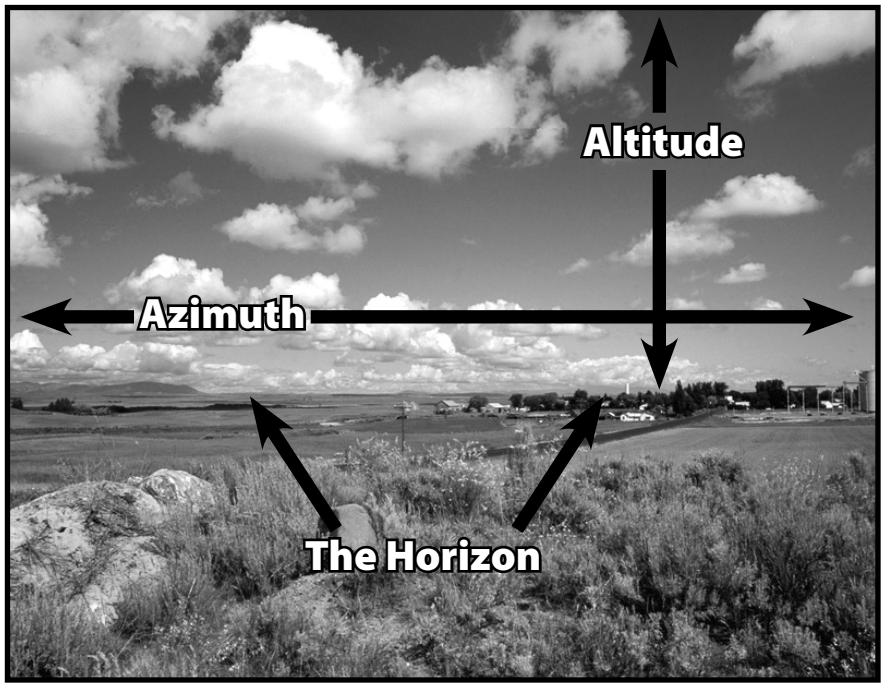
What makes this a little harder is that the earth is tipped on its axis and because of that the sun is higher or lower in the sky depending on the season and therefore the shadows it casts change with the seasons. The good news is that there is a specific pattern to this that is predictable and therefore, a sundial can be made to account for the changing seasons (even daylight savings time). Using the flagpole example, the seasonal adjustment is made by creating a "zone" or area into which the shadow will fall depending on the season. If the shadow stretches 15 feet at noon during the middle of June and 25 feet at noon during the middle of December, then this is the zone for the noon hour depending on the time of the year. The higher the sun in the sky, the shorter the shadow. The lower the sun, the longer the shadow.

On the graph that you'll be wrapping around your own Pocket Sundial, we've made sections for each month that will account for the Earth's current position and there is a zone for each time range. The other factor that affects your sundial is where you are on the Earth's surface, specifically, your *latitude* (your distance from the equator). You can't take a sundial that is calibrated for the equator and use it 2000 miles to the north without re-calibrating it for that latitude. When you begin putting together your own Pocket Sundial, you'll adjust one screw in the side to account for your latitude.

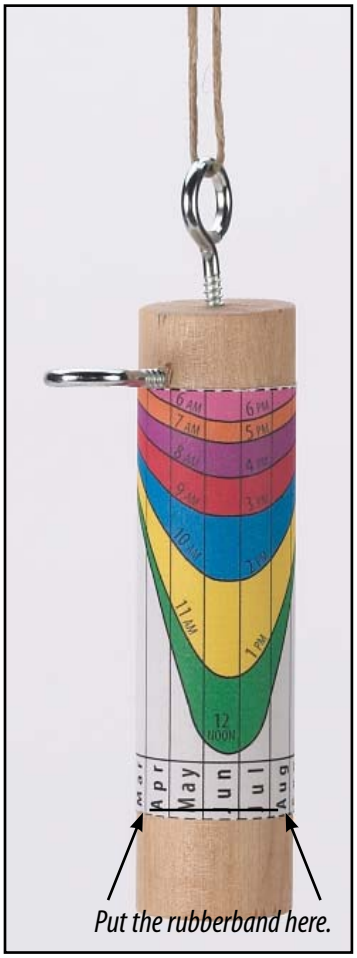
The tilt of the Earth and the fact that we are making a portable sundial make creating an accurate sundial fairly difficult, but not impossible. First, let's talk about two main kinds of sundials…

The first type of sundial is the ***Azimuth Sundial*** (pronounced AZ-uh-muth). *Azimuth* is a way of measuring horizontal position on the *horizon* (the horizon is the point where the land meets the sky, visually). Azimuth sundials use the sun's horizontal position to indicate the time. Usually these sundials need to have their gnomon pointing north.

The second main type of sundial—the kind you will be building today—is the ***Altitude Sundial*** (also called the Elevation Sundial). *Altitude* is the vertical position of the sun over the observer's horizon. In other words, altitude measures how high or low the sun is in the sky. Altitude sundials use the height of the sun to tell time, and usually do not have to have their gnomon pointed north (our flagpole is a good example). In your sundial, the wooden dowel that makes up the main portion will be vertical (perpendicular to the ground), so the gnomon "screw eye" will be horizontal (parallel to the ground). As the sun strikes the gnomon, the sun will cast a long shadow when it's high in the sky (around noon each day) and a short shadow when it's low (in the morning and evening). (See the picture below for an illustration of altitude, azimuth, and the horizon.)



HOW TO MAKE YOUR OWN POCKET SUNDIAL



Materials:

- 4" long wooden dowel
- 2 screw eyes
- Sundial Graph card
- String
- Rubberband
- Scissors, markers, clear tape (you provide)

Directions:

1. To begin this project, you must know whether you are currently observing daylight savings time (most states observe daylight savings time from the second Sunday in March through the first Sunday in November). Color in the hour lines on the correct side (ST or DST) of the Sundial Graph card. Color lightly so that the times are still visible. Then, cut out the sundial graph along the dotted lines on the side that you colored.
2. Screw one screw eye into the pre-drilled hole at the top of the dowel so it is about ¼" – ½" deep. (Just far enough so it won't pull out.) This is the "hanging" screw eye.
3. The second screw eye is your sundial's gnomon. Screw this screw eye into the pre-drilled hole along the side of the dowel. (You will learn how far to turn it to adjust for your latitude in the "How To Use Your Pocket Sundial" section on the next page.)
4. Wrap the sundial graph around the dowel and tape one end over the other where it says "Tape edge over here." Ensure that the colored side is facing out and the month names are at the bottom (away from the screws). Don't tape the graph onto the dowel. The graph should be just loose enough to be able to move and rotate around the dowel.
5. Slide the graph up so its top edge touches the screw eye on the side.
6. Wrap a rubber band around the bottom of the dowel (just below the graph card) so the sundial graph cannot slip off the bottom. Don't put the rubber band on the paper.
7. Tie a piece of string through the "hanging" screw eye so you can hang the sundial or wear it around your neck.

ADDITIONAL ACTIVITIES

1. **Review and Extended Learning Questions.** We know that because the earth's axis is tiled and because the earth rotates around the sun, the sun appears in the sky for different amounts of time each day in the year. During what part of the year is the sun in the sky for the most time each day? When is there the least sun each day? Do you think this has anything to do with the seasons? (Do additional research to find out why.) There are four time zones in the (continental) United States. Can you name them all? Which one are you in? Talk about the sun's altitude and azimuth on a sunny day. Start with the altitude—does the sun have a high altitude? (This would mean it's high in the sky, far away from the horizon, like in the middle of the day.) Or does it have a low altitude? (This would mean it's close to the horizon, like in the morning or evening.) Now, the sun's azimuth… Is it close to the east (in the morning) or close to the west (in the late afternoon)? (You can figure this out by using a compass or through the "Get oriented!" activity below.)
2. **Get oriented!** Stand outside during the day and figure out where north, south, east and west are. It's pretty easy (you just have to know where in the sky the sun rose). Stand facing the direction in the sky where the sun rose—that's east. Directly behind you is west. Now, while still standing facing the east, point to your left—that's north. And to your right is south. This works anywhere. You just have to know where the sun came up.
3. **Time Trivia.** Do additional research on the internet or in the library on what other tools were used to tell time before the clock came about. There were some pretty neat ones!
4. **Time to Practice Math.** We learned in the "Time Terms" section about the many different units involved in measuring time (days, hours, minutes, etc.). Try out some math problems using this information. They can be simple ("If there are 24 hours in one day, how many hours are in two days?") or a bit more complicated ("How many seconds are there in a week?).
5. **Design your own sundial.** As you've seen, sundials can come in many different shapes and sizes. They can stand up and have a horizontal gnomon, or they can be flat with a vertical gnomon. Design a sundial yourself. What shape would it be? Would you paint or color it? How and where would the shadow be cast? When you're done, compare it with your friends!

Name: _____

How to Use Your Pocket Sundial

Use these directions to "set up" your sundial the first time you use it and to tell the time with it. You can fold this page up and keep it in your pocket. Also, be sure to familiarize yourself with the "Time Terms" at the bottom of the page!

1. The sun must be shining for your sundial to work. Before you use your pocket sundial for the first time, you will need to adjust for your location on earth. Follow these steps:
    - Stand with your back squarely to the sun.
    - Hold the dial (by the string) out in front of you with the side screw facing directly towards you. (Don't let your arm block the sun.)
    - At this point, sun should be striking the top of the side screw (your gnomon) and creating a shadow that is being cast down onto the colored piece of paper.
    - Turn the graph so that the correct month is directly below the "gnomon,"
    - Read the time on your graph. Check the time on a clock or watch that you know is accurate. Unless you got very lucky, these won't match yet.
    - Now, turn the "gnomon" screw until the tip of it's shadow falls at the current time. If the shadow does not extend far enough down the graph, turn the screw to the counterclockwise. If the shadow extends too far, turn the screw to the clockwise. Continue adjusting until the shadow end is in the correct location for the current time. Note that the "gnomon" screw eye's head should end up being horizontal (as shown in the picture), so you may have to rotate it slightly once you've found its exact place.
2. To tell the time with your pocket sundial…
    - As months pass, turn the graph on the dowel until the current month is directly below the "gnomon" screw eye.
    - Stand with your back to the sun. Hold your sundial by the string and slowly turn your sundial until the shadow from the "gnomon" is pointing directly downward.
    - The shadow of the edge of the "gnomon" screw eye will indicate the time. As you can see by looking at the lines on the graph, each line (except the lowest one) corresponds to two times. You must decide whether it is morning or afternoon.
3. If you initially put together your sundial for daylight savings time and you have switched back to standard time, simply subtract one hour from every reading. (The DST graph will be one hour "fast" during standard time.)
4. You may have to "re-calibrate" your sundial if your location changes significantly from your initial location. To do so, follow the steps in section #1.

Time Terms

Horology (ho-ROL-u-gee) is the science of timekeeping. There are many different terms that are used to describe different measurements of time—we use some every day like "minutes," "hours", or "days," but there are others that you probably use but don't think of as part of telling time. They include:

- ***Year:*** a period of 365 days that it takes for Earth to make one complete trip around the sun; the year begins on January 1st
- ***Month:*** one of the 12 divisions of the year; probably based approximately on the length of one moon cycle (from new moon to new moon)
- ***Week:*** seven days in a row; a week begins on Sunday and ends at midnight on the following Saturday
- ***Day:*** the time the Earth takes to make one complete turn on its axis; a period of 24 hours beginning at midnight
- ***Hour:*** one of the 24 divisions of a day
- ***Minute:*** one of the 60 divisions of an hour
- ***Second:*** one of the 60 divisions of a minute
- ***Leap Year:*** a year that contains 366 days, one extra day (February 29)
- ***Time Zone:*** a geographical region within which the same standard time is used; time zones divide the earth into 24 "slices" so that the sun will be at its highest point in the sky at noon every day in each zone. (The exact time at which the sun hits its highest point each day changes slightly depending on one's position within their time zone)
- ***A.M. and P.M.:*** A.M. means "ante meridiem" (mu-RID-ee-um), before midday, and P.M. means "post meridiem," after midday; these words were created by the Romans

What is Daylight Savings Time? Have you ever heard the saying "spring forward, fall back"? In order to have daylight hours coincide with the time when most people are awake, the United States Congress decided that daylight savings time would "jump forward" an hour on the second Sunday in March and "jump backward" one hour on the first Sunday in November. During daylight savings time, the sun rises and sets one hour later than it would under Standard Time. During Daylight Savings Time, we basically "shift" each day's sunlight one hour later. (If we didn't, it would get sunny very early because the sun spends so much time in the sky during the long summer months during daylight savings.)