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Constructing a Portable Sundial

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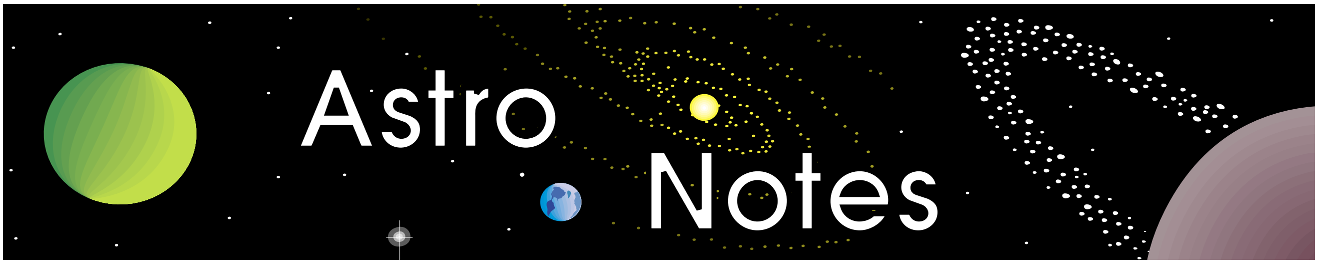

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Throughout history people have used shadows and sundials to measure the passage of time. This article describes how to construct a personal sundial that can be worn as a necklace or carried as a key chain. The activity is easily adaptable for grade levels elementary through high school. The instructions can be scaled for a schoolyard project. We've found sundial construction to be a terrific project that not only encourages students to investigate movement of the Sun in the sky, but also allows them to practice their math skills.

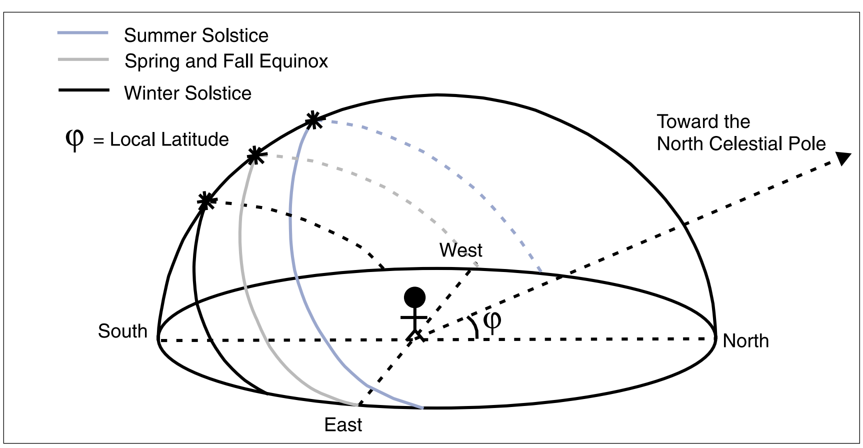

Fig. 1. Sun's seasonal path through the sky.

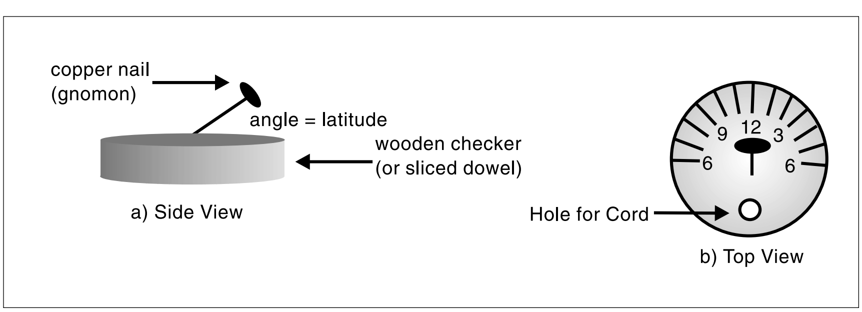

Fig. 2. Two views of finished sundial.

To understand how the sundial is constructed, we must first understand the motion of the Sun in the sky. During the different seasons, the Sun travels on slightly different paths in the southern sky, as seen by an observer in the northern hemisphere (see Fig. 1). (Instructions are also available for the southern hemisphere.[1]) Although its seasonal path varies, the Sun always travels around an axis that points close to the North Celestial Pole (NCP). On a sundial, the shadow of the northward-pointing piece that is aligned with the axis of the NCP indicates time; the outstretched arm is called the gnomon.

The NCP is remarkably easy to locate. At night, Polaris (the North Star), happens to be located at the NCP. During the day, when we want to use our sundial, we cannot see Polaris because of the Sun's light, but we know that Polaris is located due north, above the horizon the same angular degree as our latitude. Therefore, direct the gnomon of your sundial due north at an angle equal to your latitude and it will be aligned with the NCP.

For each sundial you will need:

- 1 wooden disk (about the size of a 3-cm checker)
- 1 nail (copper is attractive) 3/4- to 1-inch size (2 to 2.5 cm)
- 1 meter of string or cording

Hours from Noon	Hour Angle (H)	Hour-Line Angle (θ)
0	0°	0°
1	15°	9.8
2	30°	20.4
3	45°	32.7
4	60°	48.1
5	75°	67.4
6	90°	90°

Fig. 3. Hour-line angles for 40° latitude.

Also have available to each student: protractor, pen and pencil, template paper, hammer, calculator, drill. (Each grade level would join the activity at different points, as will be indicated.) High-school students can complete the entire activity.

First, hammer the nail straight into the center of the wooden disk and then bend it over until it makes an angle with the disk equal to the latitude where the sundial is being used (see Fig. 2a.) The nail serves as the gnomon. Just as the position of the gnomon depends on latitude, so do the lines that indicate the time of day. These lines are called hour lines.

The Sun appears to travel 360 degrees in 24 hours, or 15 degrees each hour. So each hour angle (H) is 15 degrees multiplied by how many hours you are away from noon. For example, 2:00 and 10:00 are each two hours away from noon, so the hour angle for 2:00 and 10:00 is 30 degrees.

Students calculate the angles of the hour lines using

$$\theta = \tan^{-1} [(\sin L) (\tan H)] \qquad (1)$$

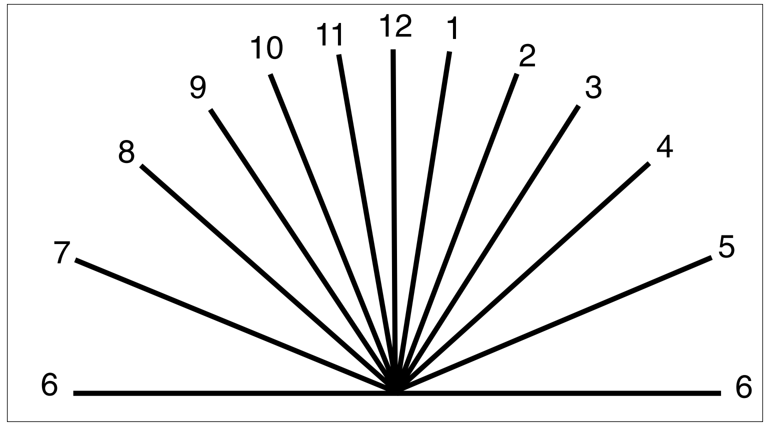

Fig. 4. Hour-line markings for 40° latitude.

where θ is the angle at which to draw each hour line. Angle θ is measured from the center line (noon), L is the latitude, in degrees, for where the sundial will be used, and H is the hour angle, which changes depending on which specific hour line you are calculating. Figure 3 shows the angles for 40 degrees latitude.

After calculating θ for each hour angle up to 90 degrees (corresponding to 6:00) students use a protractor to draw a template like the one in Fig. 4. (Middle-school students should start the activity here, beginning with the drawing of the hour-line template using a protractor.)

Once the template of hour lines is completed, place the wooden disk on top of it with the center of the disk (where the nail is) directly over the intersection of the horizontal and vertical lines. The horizontal line, marked with a 6 on each side (see Fig. 4), should run underneath the disk exactly across the center. Without shifting the disk, rotate it until the head of the nail is pointing up the 12 o'clock line. (Elementary-school students should start the activity here, placing the disk on a copy of the hour-line template drawn by the instructor.) While holding the disk very still, make 13 pencil marks on the top face of the wood, each mark in line with the appropriate hour line (see Fig. 2b).

After making all the hour marks, trace over them in ink and write in the appropriate hour numbers. Because the sundial face is small, it might be best to include only some of the hour labels, as we have in Fig. 2b. Finish the sundial by drilling a hole opposite the 12:00 line and threading the cording through to make a necklace or key chain.

Now, go outside on a sunny day, hold your sundial perfectly horizontal, and point the head of the gnomon due north. (Remember that a compass tells you magnetic north; we want geographic north. Call your local airport for the appropriate correction, or visit the website in Ref. 1 to learn how to construct and use a shadow plot to find geographic north.)

The shadow cast by the gnomon should fall on the correct hour line to indicate time of day. The portable sundial is not perfectly accurate, but it will indicate local time to within 15 minutes.

Note: During daylight saving time you will need to add one hour to the time you read off your sundial in order to agree with local "clock" time.

Reference

1. This activity, as well as several others, and more information is available at www.lmsal.com/YPOP/Classroom/