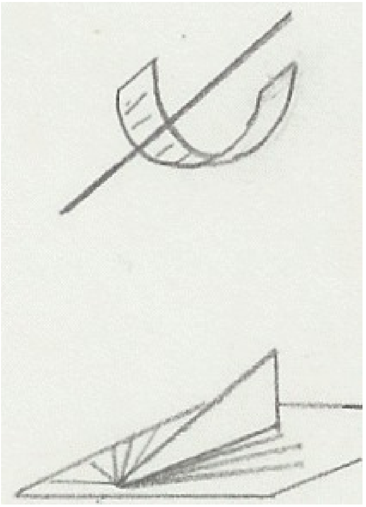
Designing an Accurate Sundial for Clock Time

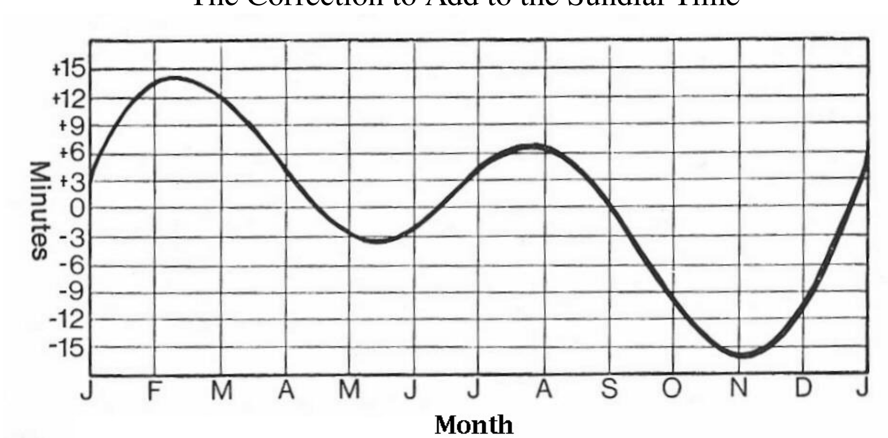


Sundials are based on a simple fact: the Earth rotates once every 24 hours, exactly. The earth being 360 degrees around, like any circle, it rotates at 15 degrees per hour, exactly, or 1 degree every four minutes. So the Sun appears to move across the sky at 15 degrees per hour, and a shadow cast by the sun moves at the same rate. An axis aligned parallel with the Earth's pole of rotation will cast a moving shadow on a band around it. Marks on the band can show the time according to the Sun.

The most common sundial has a pointer, also called the gnomon or style, parallel to the Earth's rotation axis, and a horizontal base marked with time lines. This article tells how to determine the angle of the time lines from the base of the pointer so that they show a time which, with a small correction, is the same as your local clock time. The angle of the pointer above the base is the same angle as the latitude where the sundial will be used. The angle of the time lines depend depend on both the latitude and longitude of the location.

The correction comes in since the Sun's path across the sky is not perfectly regular because the Earth's orbit around the Sun is not circular but slightly elliptical. Also, the Earth's equatorial plane is tilted from its orbital plane around the Sun. The combined effect causes the speed of the sun across the sky to vary a little during a year, so time shown by a sundial will differ from clock time. The time shown by the sundial can be ahead (fast) by as much as 16 minutes (in early November), or behind (slow) by as much as 14 minutes (in mid-February). This chart shows the correction to sundial time to get clock time (called the equation of time) during the year. Add the correction from the chart for your date to the sundial time to get the clock time. For example, on January first you add 3 minutes and on November first you subtract 16 minutes.

The Equation of Time:
The Correction to Add to the Sundial Time



A sundial corrected with the equation of time gives the “mean solar time,” the time as if the motion of the sun were unvarying. Nearby locations may have different mean solar times; a town 5 degrees of longitude west of another town (about 250 miles in the lower 48 states) has a mean solar time 20 minutes earlier. Before railroads, many places set their own local time, and not always to mean solar time. At the noon bell you would see men in the street setting their watches to the local time. Some places even fired a small cannon once a day at the same time. But everyone having different times made railroad operations very difficult to manage: you could arrive at a time before you departed. To simplify things time zones were invented. Now with jet planes you can arrive before you depart, so the flight attendant tells you the local time so you can set your watch, just like with the noon gun. But now there are fewer different times to keep track of.

Time zones set all clocks over large areas to the same time, regardless of where the sun is in the sky. Clocks from eastern Maine to western Michigan all show the same time, although solar time in those two locations differ by nearly two hours. Time zones shift clock time from sundial time much more than the Sun's equation of time correction. The sundial design sheet here includes a shift in the position of the time lines on the sundial so its time conforms to its time zone. A sundial with this feature can be used to find your time zone's clock time without you making any correction other than the correction from the chart above. Is is possible to build sundials which also correct for the equation of time, so you can read clock time directly off the sundial, but those are complicated.

Most sundials you see in gardens and on monuments show the wrong time. A few were designed for their location and are accurate. Most sundials for sale are made for a latitude which naturally will not happen to be your latitude. In the US you can even find English sundials for sale which would work only in Juneau Alaska. No sundials for sale include the correction for the time zone. A sundial whose gnomon is at the wrong angle for your latitude, whose time lines are at the wrong angles, and with no adjustment built in for time zone, will of course show the wrong time, sometimes by as much as half an hour and it cannot be corrected in any simple way.

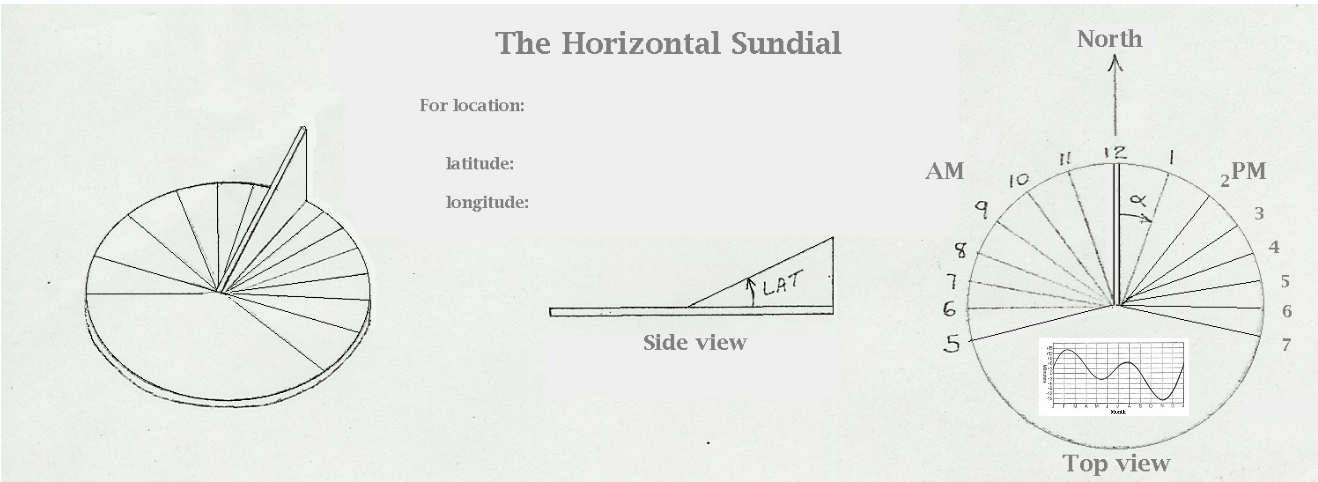
On a small sundial, or one with few time lines or broad time lines, it is hard to read the location of the shadow to within five or ten minutes, limiting how well you will be able to tell the time.

With a properly designed sundial, and one which is large enough, you can read the time on the dial to the nearest minute, so you can find clock time to within about a minute. If you make a sundial whose time lines are about 10 or 12 inches (30 cm) long or longer, the end of the shadow will move about millimeter per minute, which may allow reading the time to the nearest minute, if the dial has many accurate time lines. Since the Sun itself extends across half a degree of the sky, the width of the edge of the shadow of the pointer is equivalent to 2 minutes on a sundial. You may be able to estimate the center of the shadow better than that, perhaps to the nearest minute. There is no reason to build a simple sundial much larger than this in an attempt to increase accuracy, except that a larger sundial can have more time lines which are clearly separated. The larger you make a sundial, the wider the edge of the shadow of the pointer becomes, always about 2 minutes wide on the time scale. To get even two minutes of accuracy you will need to include time lines for every four or five minutes, or even more, and mark the sundial plate accordingly.

Next is a worksheet to design a sundial with a horizontal base plate. Most of the design involves determining the angles of the hour to time lines on the dial. Construction decisions are up to you; many choices will work fine.

Beginning the design of a sundial for your location, the angle of the gnomon or pointer above the horizon is the same as the latitude; that is key. The angles of the time lines are computed on the work sheet, including adjustments for the latitude *and* the longitude *and* the time zone. If a sundial is made correctly for its exact latitude and longitude, mounted horizontally, and pointed to true north, you will have an accurate time piece. To find the time, read the sundial, and add the correction from the chart. The chart can be mounted on the sundial.

First find the latitude and longitude of your location, in decimal degrees, such as 39.98 North and 105.22 West. The angle of the top edge of the pointer on the sundial exactly equals the latitude. The sundial is mounted so that the pointer points to true north (not magnetic north from a compass). The pointer will then be parallel to the Earth's axis of rotation. The pointer could have a single sharp 'knife' edge on top, or more practically be flat on top with two straight edges, on the east and west sides. In that case the time lines to the east are at angles measured from a north-pointing line directly below the east edge on the pointer, not from the center line of the pointer. The west time lines are at angles from a different line, below the west edge of the pointer.



Worksheet to design a horizontal sundial to give clock time

You need the latitude and longitude of your location, in decimal degrees, such as 39.07 North and 108.50 West. The angle of the top edge of the pointer on the sundial exactly equals the latitude. The sundial is mounted so that the pointer points to true north (not magnetic north from a compass). Time lines are marked on the base plate, which is exactly horizontal. The base plate can be any outline, but the times lines need to be on one surface.

You also need to know the difference in longitude from the center longitude of your time zone; called here dLong. The center longitudes in the lower 48 states are 75, 90, 105 and 120 degrees west. If you live in Grand Junction Colorado at 108.50 W, your dLong is 3.50 degrees. dLong corrects your sundial time to the time zone.

Use the table below, computing the angles of whatever time lines you want on your sundial. An example is shown for 3 PM in Grand Junction (latitude 39.07). For each time line, you first compute “HA,” which is the time (in hours from noon) multiplied by 15.0 degrees/hour (45.00 degrees for 3 PM); *then* apply the dLong adjustment, which is added for hours before noon and subtracted for hours after noon. So the HA for Grand Junction at 3 PM is 45.00 –3.50 or 41.50 degrees. Then the angle “alpha” of the time line from noon is given by

tan (alpha) = sin (latitude) * tan (HA)

time	hours*15/hour	HA	alpha	time	hours*15/hour	HA	alpha
3:00 PM	45.00	41.50	29.14				
_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____
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In software use, for example (180.0/pi) * atan(sin ((pi/180.0) * 39.07) * tan ((pi/180.0) *41.500))