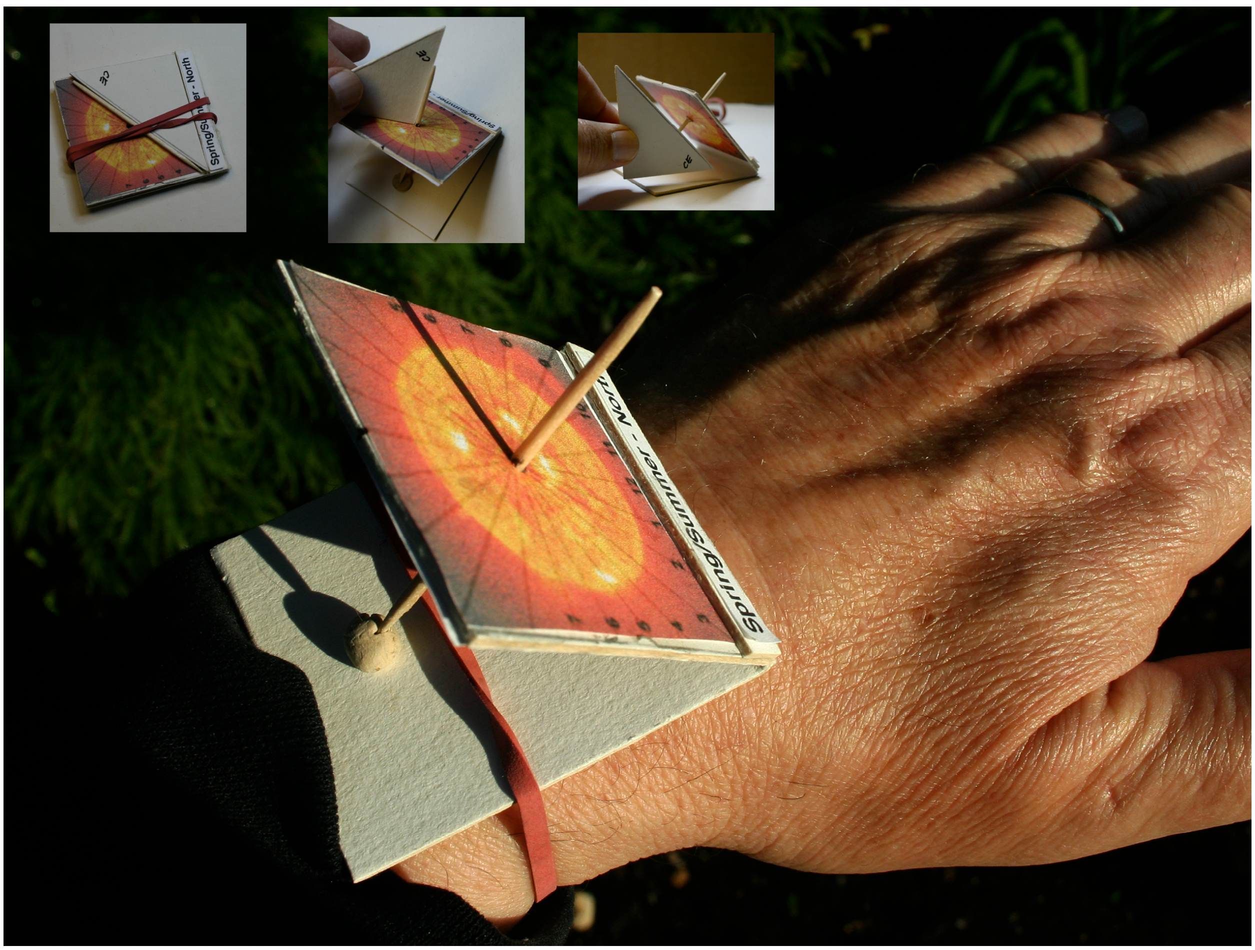
Build an inexpensive, simple, one-tooth-pick, global, equatorial, elegant and smaller than an iPod, wristdial!

Is it really all those things? Yes, and with no moving parts to break. Instead it depends on the motion of the Earth which, ponderous as it is (6.6 sextillion tons) moves like - well, like clockwork!

And simple?

Yep! Here's an image of the final product in action in the northern hemisphere early on a summer morning. (Oh, it can also find north for you, so it can double as a compass. More on this later ;-)

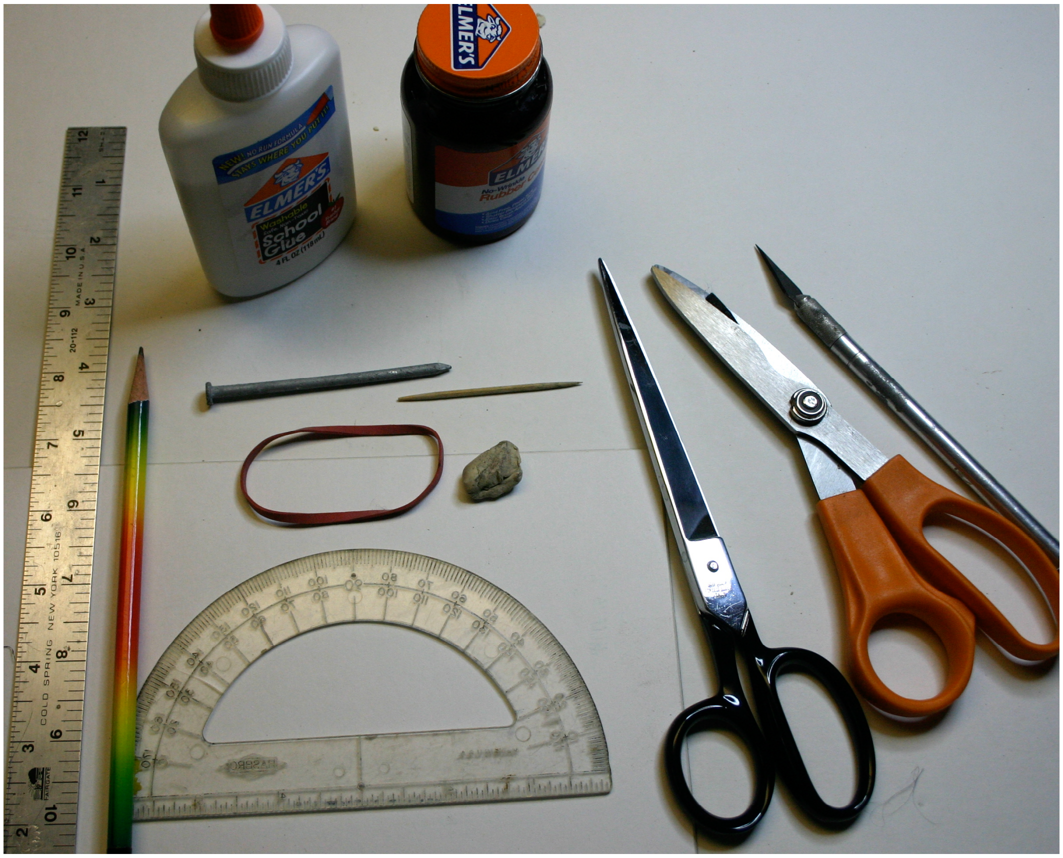


The wristdial travels in a neat, folded package (see inset at upper left). The toothpick is inserted at a right angle to the dial face, and this can be checked with the "setting triangle." The same triangle is then used to set the dial face so its plane points to the celestial equator. Get those two set correctly, and the dial works anywhere on Earth that the Sun is shining. The dial has two faces, the one shown in the preceding picture is for use in spring and summer. The **shadow falls on the underside** - shown in the picture at right - in fall and winter. The design can easily be scaled up and faces are included for a larger version, or you can use the instruction included here as a guide to designing your own.

The wristdial has now been tested in the southern hemisphere by my friend Dom in Sydney, Australia. Dom took some photos of his wristdial in action, next to a larger, traditional garden sundial. You will note three things about these photos. First, the shadow is on the underside of the dial face because when these photos were taken in mid-July it was winter in the southern hemisphere. Second, the time indicated by the dial is almost exactly the same as the time indicated by Dom's watch. That's because Sydney is not on daylight savings time in the winter. Also. Sydney's longitude is just one degree – four minutes – east of the central longitude for its time zone. Because of that the time should be four minutes fast. But, the equation of time for July is six minutes slow. When you apply the equation of time, the four minutes "fast" caused by a difference in longitude is subtracted from the six minutes "slow" of the equation of time and the dials solar time is within about two minutes of standard clock time. (This kind of calculation is described in detail for your location in the directions you can download.)

Sundials are simple things that point to profound truths about the motions of Earth and Sun. They'll teach you about your position on this rapidly spinning sphere and put you in direct touch with some awesome forces of nature. That's what I love about them. But right now you're probably more interested in how to make your own wristdial, so let's do it!

Getting right down to business - here’s what you’ll need



Materials:

- One small piece of cardboard - Bristol board is cool. So is mat board, or reasonably stiff cardboard like the kind used to back a pad of paper.
- One toothpick - the sturdy, round variety.
- One rubber band
- Small lump of modeling clay (optional).

Tools:

- Scissors (I used fine ones for paper, and heavy duty ones to cut cardboard.)
- Ruler, pencil, and protractor
- Sharp knife (Optional - the point of the scissors could do the job.)
- Rubber cement
- White glue (optional)
- One sharp nail a bit less in thickness than the thickest part of the toothpick.

Special knowledge (all available on the Web)

Start by finding and jotting down a few keys facts.

Latitude and longitude (http://www.getlatlon.com/) - You don't have to be super precise. All can be rounded to the nearest degree. For Westport, MA I round my latitude to 42° N, and my longitude to 71° W.

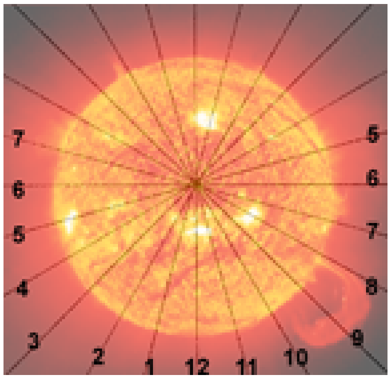
Central meridian (http://www.travel.com.hk/region/timezone.htm) - Time zones are set every 15 degrees of longitude so you'll see the central meridian for yours at the top of the map on the web page linked above. Westport, MA, is in the Eastern Standard time zone which is centered on 75 degrees longitude.

Compass deviation (http://www.geo-orbit.org/sizepgs/magmapsp.html) - I suggest you find your compass deviation only because I'm assuming you might use a magnetic compass to find north. If you have another way to determine north, you can ignore this. But a magnetic compass is not precise. In the case of Westport, MA the deviation is 16° east, which means that if my magnetic compass says it is pointing north, it is really pointing 16 degrees to the west of north, so to point true north I have to correct by pointing 16 degrees to the east of what it says is north. Of course, I might use a GPS, or call the local airport to learn the compass deviation. If nailing down true north proves difficult, you can cheat by using the finished dial itself to find north - assuming you already know the correct time - mor elater on this. ;-)

OK, let's get building! First, print out this next page, assuming you are in the northern hemisphere, or the page after it if you are in the southern hemisphere. (Look carefully at the pictures and you will see the numbering on the dial faces differs depending on your hemisphere.)

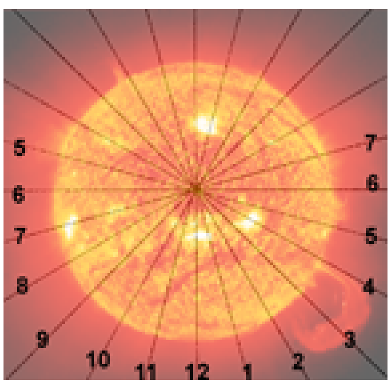
Print this page for dial faces for northern hemisphere use

top



Spring/Summer - North

top

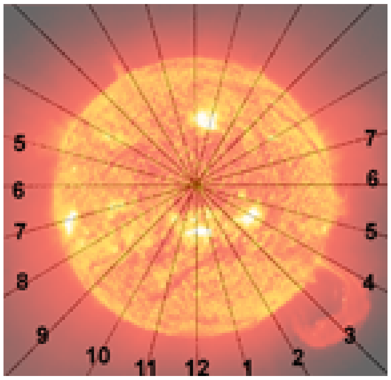


Fall/Winter

Cut along the edges of the images - except at the bottom of each. At the bottom you should cut just below the words “Spring/Summer” on one and “Fall/Winter” on the other. That way you won’t get them confused. When you are ready to glue each in place, trim the words from the bottom edge as well. (You might want to keep these strips of words and glue them on to the dial as shown.)

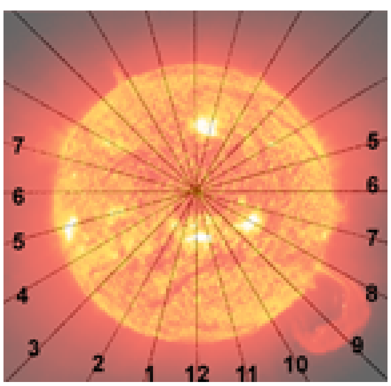
Print this page for dial faces for southern hemisphere use

top



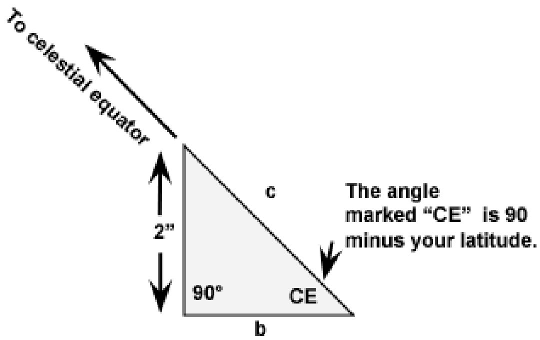
Spring/Summer - South

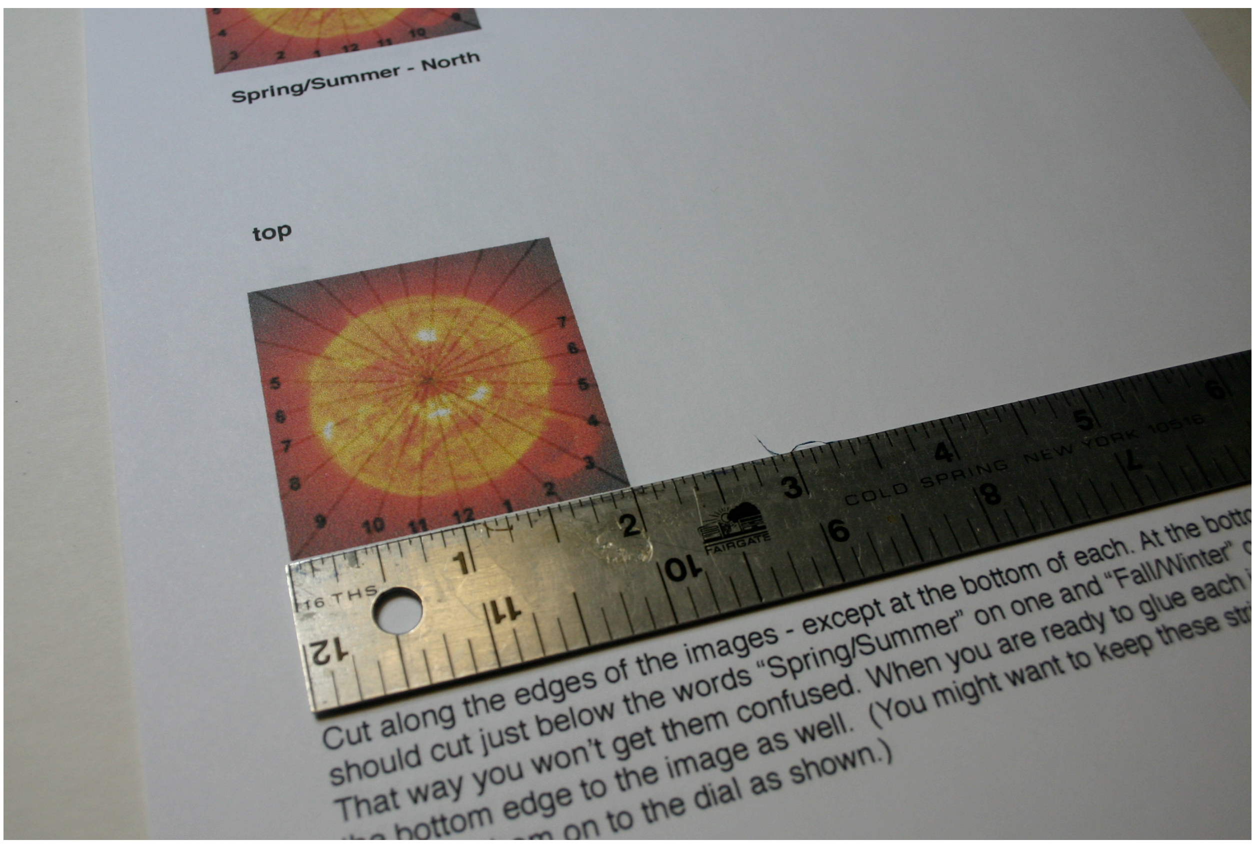
top



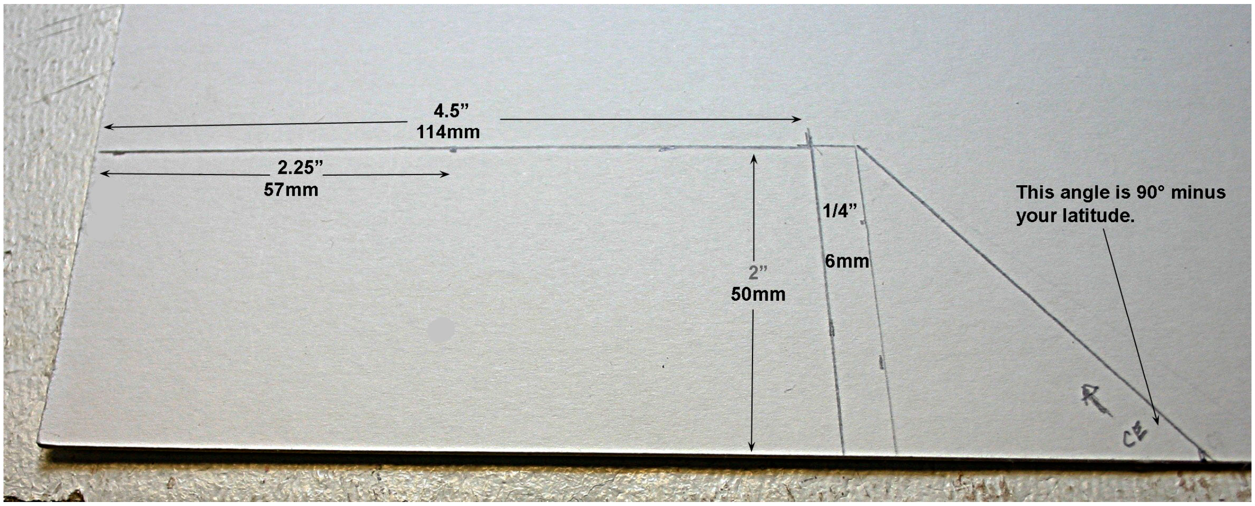
Fall/Winter

Cut along the edges of the images - except at the bottom of each. At the bottom you should cut just below the words “Spring/Summer” on one and “Fall/Winter” on the other. That way you won’t get them confused. When you are ready to glue each in place, trim the words from the bottom edge as well. (You might want to keep these strips of words and glue them on to the dial as shown.)


To celestial equator
c
The angle
marked "CE" is 90
minus your latitude.
2"
90°
CE
b

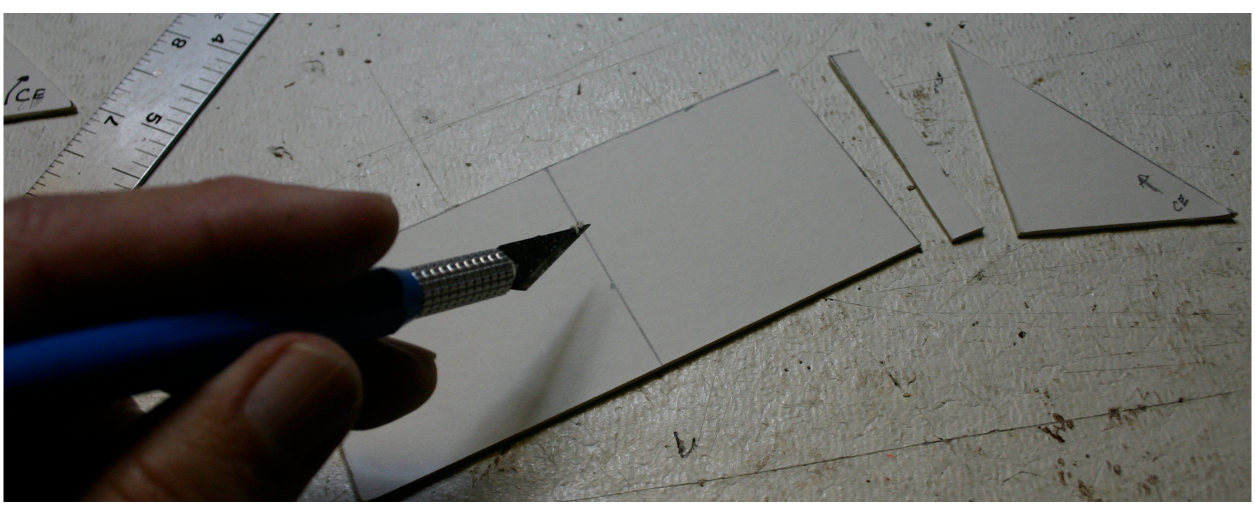

Spring/Summer - North
top
Cut along the edges of the images - except at the bottom of each. At the botto
should cut just below the words "Spring/Summer" on one and "Fall/Winter"
That way you won't get them confused. When you are ready to glue each
the bottom edge to the image as well. (You might want to keep these str
on to the dial as shown.)

Check the width on the printed sundial images. They should be two inches (50mm). But perhaps your computer and printer made them a little different. If so, you want the cardboard base to be the same width. In these directions I assume it is two inches (50mm).



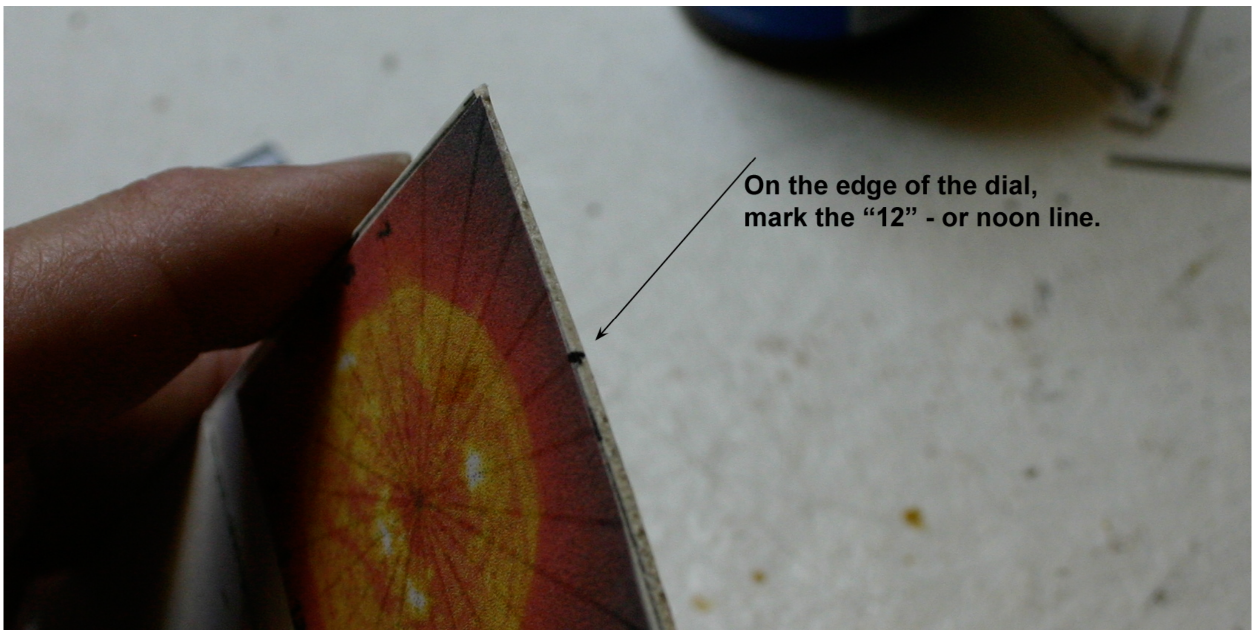
1. On your cardboard draw a rectangle that is two inches - 50mm - wide and four and a half inches - 114mm - long. Exactly halfway along this length (two and a quarter inches - 57mm) draw a line across marking the center. Add a 1/4-inch wide strip to the right end as shown. You can also add your setting triangle at this point. It looks something like this, but the length of the sides "b" and "c" will depend on the angle "CE" derived by subtracting your latitude from 90. Its use is explained later.

2. I cut about halfway through the cardboard with an Xacto razor knife. The basic idea is to score the cardboard base at the halfway point to make it fold nicely in two equal pieces and you may be able to do this with the scissor point depending on the thickness and strength of the cardboard you're using.



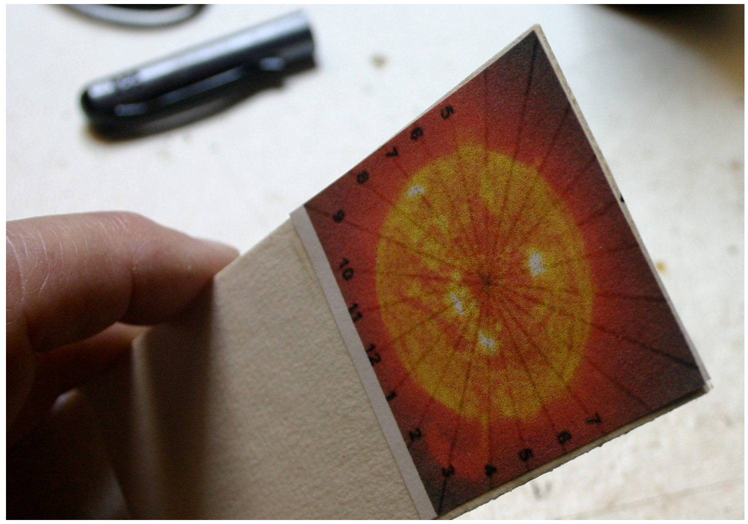
This cut (or scored) side is the "top" of your base - the side that will hold the "Spring/Summer" dial face. (The 1/4-inch (6 mm) strip of cardboard, two inches (50mm) wide, will be used to help hold the toothpick and "setting triangle" when dial is folded.)

3. Now you can cut off the words from the "Spring/Summer" sundial face and glue your sundial's face only to the cardboard. I used rubber cement, but any paper glue would do. Alignment is critical, but simple enough. Lay out the cardboard lengthwise in front of you with the side with the cut or score in it up. On the right hand side place the "Summer" dial face. Make sure the top edge - the one without the numbers along it - is flush with the right hand edge of the cardboard base.

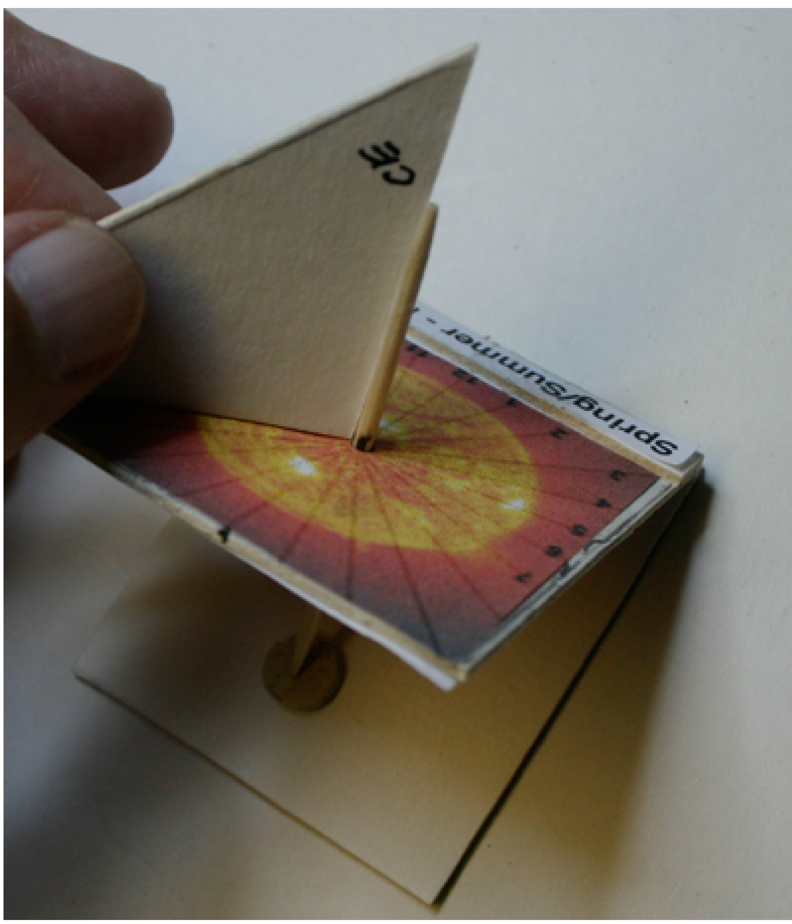


4. Now look at the line marked "12." Mark the thin, right-hand edge of the cardboard where this line meets that edge. That mark provides a guide to make sure the other dial face is perfectly aligned with this one. (This is really just an added check - if your cardboard is the same width of the dial faces this alignment should be right on.)

5. Now flip your cardboard base over and carefully glue the remaining dial face, aligning it flush with the right-hand edge as shown. You want its “12” line to line up with the dot you made from the 12 line on the other side. But make sure there are no numbers at this end - the numbers should be near the center line of the base.



With both in place and the glue dry you can glue the one-quarter-inch (6mm) strip of cardboard across the bottom of the first dial face between the numbers and the cut (score) you made to fold the dial. Then you can add the words. “Spring/Summer” to this strip.

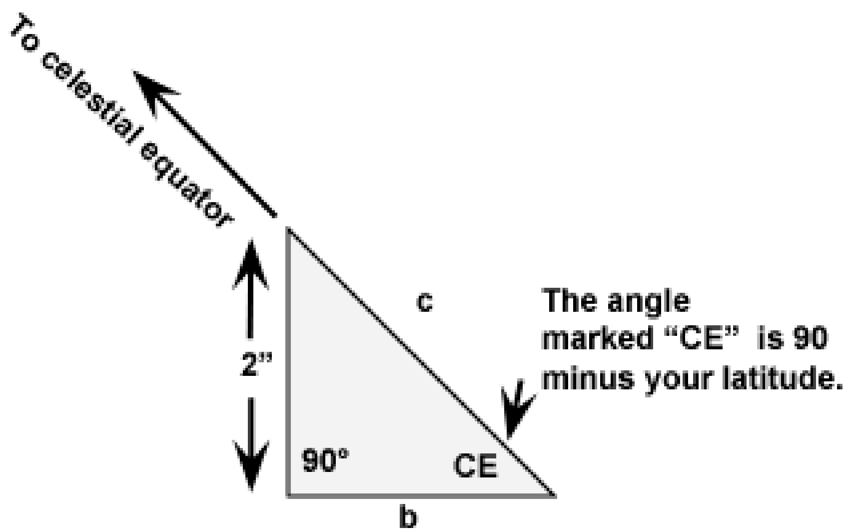


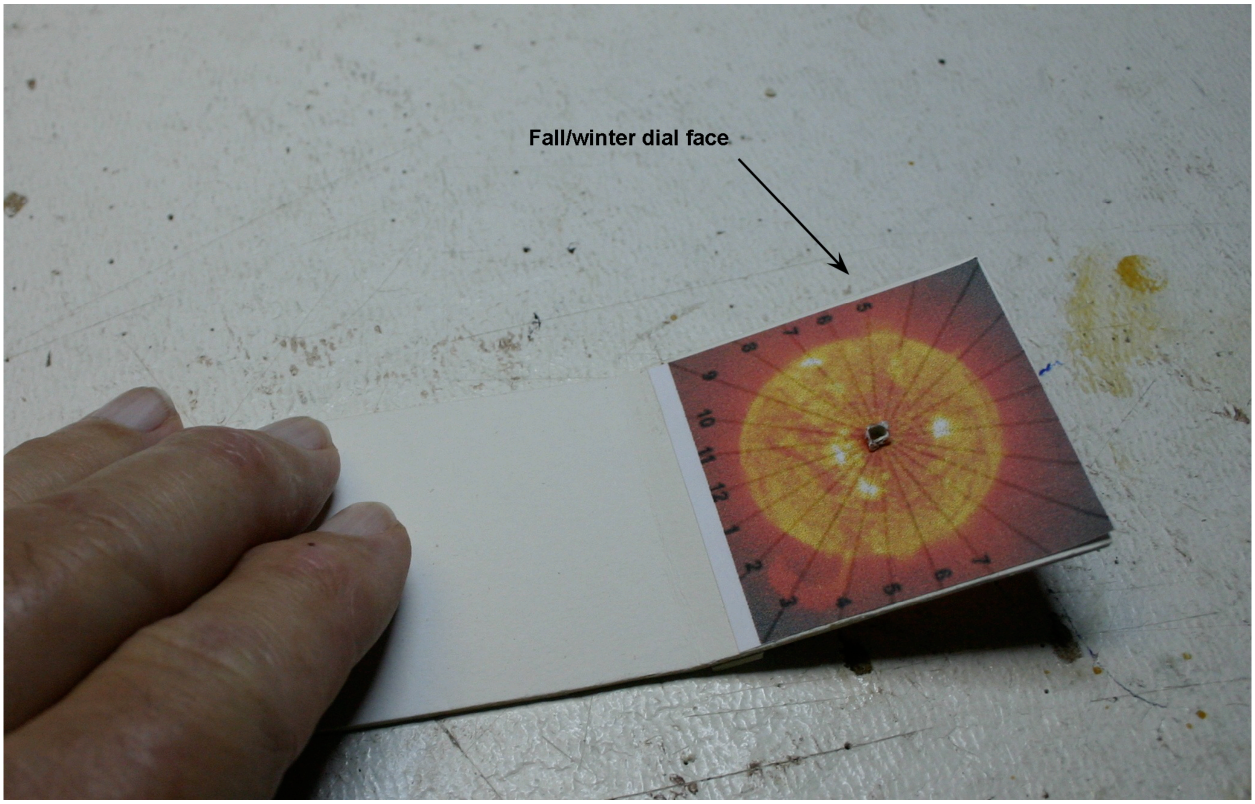
6. Using a nail that is a little smaller in diameter than the toothpick, make a hole right in the center of the dial face where the hour lines converge. Pushing the nail through one side of the center of the dial should result in its going through the center of the other dial face as well if

you aligned your dial face images correctly. be careful to keep the hole a tad smaller than the toothpick. The toothpick needs to fit tightly.

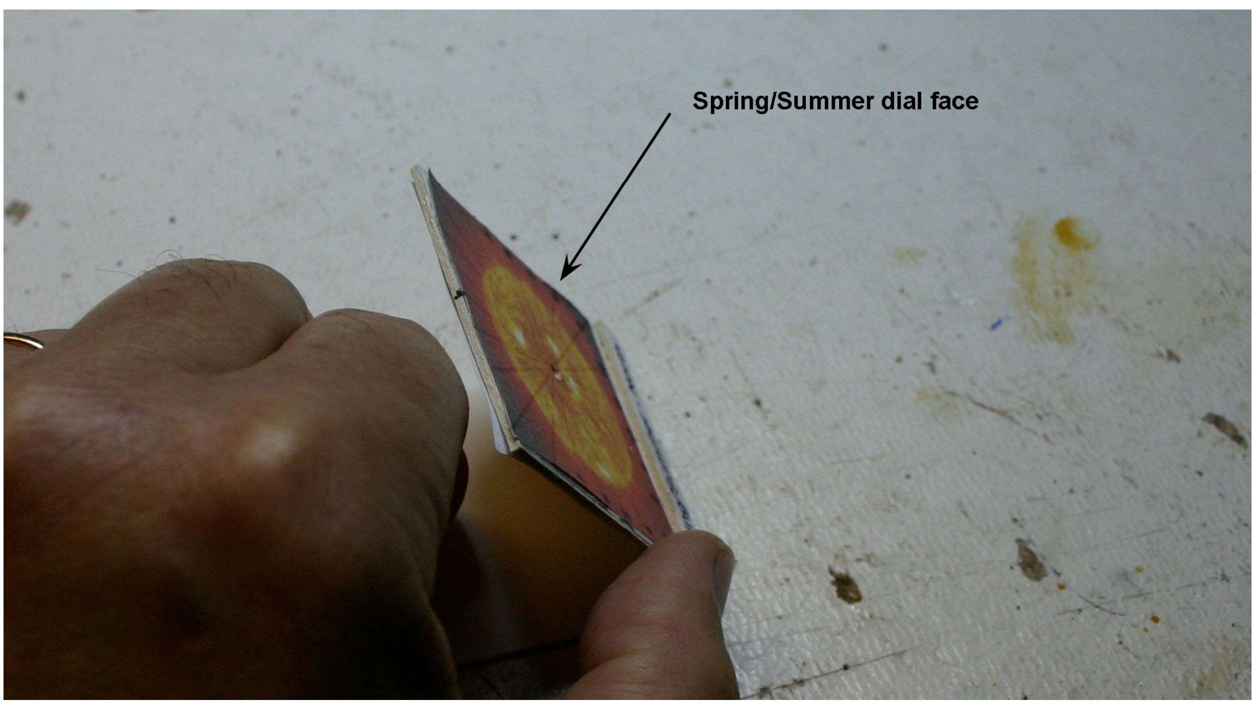
Setting the Sundial for your Latitude

The setting triangle is the critical tool you will use to set your Sundial to your latitude so the dial is accurate. You need only do this once - then you can make a mark on the toothpick where it meets the face of the dial to remember this setting.





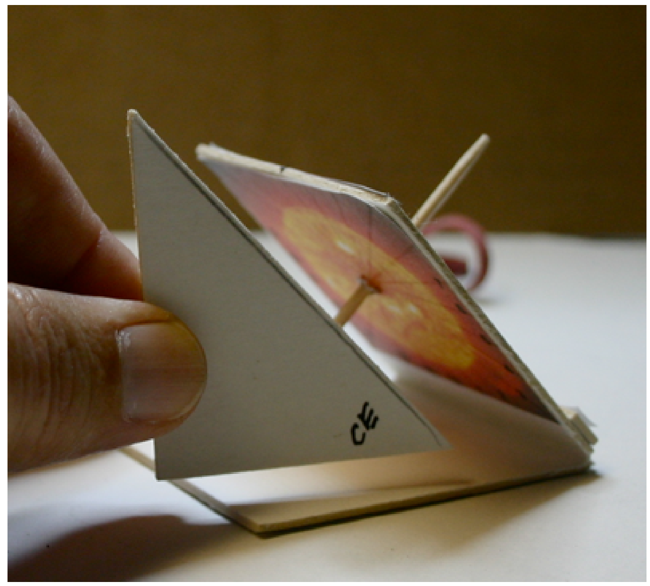
With the cut - scored - side down, fold your dial in half by grabbing the right-hand edge and bending it up and back so the “Summer” side is displayed on top. (See next picture.)



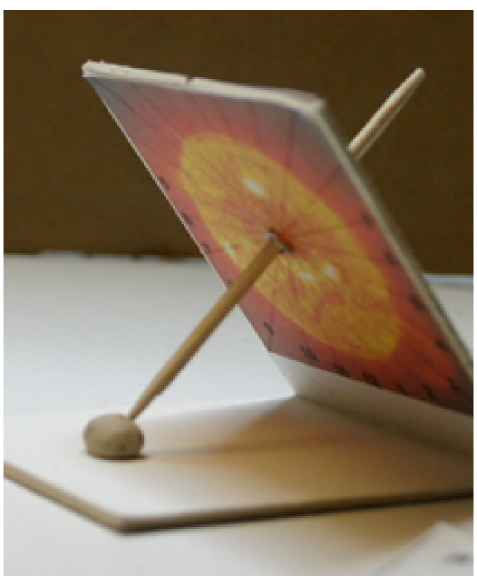
I suggest you trim the point off one end of the toothpick - the end that protrudes from the dial - simply because it's sharp. (You only need about half an inch of toothpick projecting from the dial face.)

Place the toothpick through the center hole - keep it perpendicular to the dial face. You can check this with the right angle side of your setting triangle.

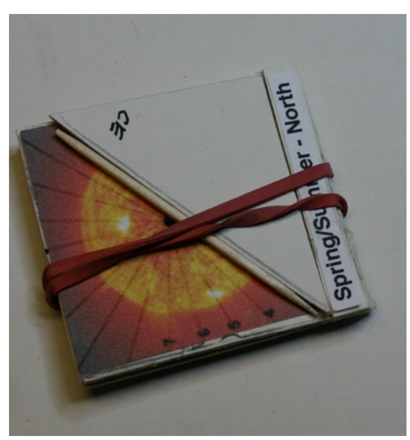
Now place your "Setting Triangle" tool so that the angle marked "CE" is right at the fold.



In mid-latitudes (in fact, most inhabited places) the toothpick can be pushed all the way through until it hits the bottom of the dial holder as shown. You can then make a mark at this point and glue a small lump of clay at this point. When you set up the dial push the pointed end of the toothpick into the clay. With toothpick marked and the clay in place you won't have to repeatedly use the setting triangle when you set up your dial for use.



Making
this setting means two things. First, **the toothpick is now at the correct angle to point at the celestial pole** - North Celestial Pole for northern hemisphere users, and the South Celestial Pole, for southern hemisphere users. Of course you have to know which way is north or south, and we'll get to that in the telling time section if you find it a problem.



But the second thing this does is set **the plane of the face of your dial so it points to the celestial equator -** a projection of the Earth's equator on the dome of the sky - and that's why this is called an **"equatorial" sundial**. The concept of the celestial equator is critical to understanding how and why it works and why there are two faces.

In spring and summer of the northern hemisphere the Sun is north of the celestial equator, so it casts a shadow on the side of the dial that faces north. In fall and winter of the northern hemisphere the Sun is south of the celestial equator, so it will cast a shadow on the underside of the dial. And yes, at the spring and fall equinoxes, the Sun strikes the dial edge on because at that time the Sun is on the celestial equator! It works in a similar fashion for the folks in the southern hemisphere, except then summer sees the Sun south - not north - of the celestial equator and the Sun's shadow is on the south facing dial.

Question - how would this work if you were at the North or South Pole? How about the equator?

Figured it out? Think a minute. When you have the answer - or are stumped, read on.

Answer: If you were standing right at the North or South Pole, the Celestial Equator would be the same as your horizon. So the toothpick would now point straight up - at the North Pole it would be pointing very close to the North Star. During the day the Sun would appear to circle you - and assuming it was spring or summer, the day would be continuous, the Sun never setting. Of course during the fall and winter the Sun would be below the Celestial Equator, and thus below your horizon. You couldn't use a Sundial to tell time because there would be no Sun - and no, a flashlight won't help ;-)

What about being at the Equator? Now the toothpick is pointing horizontal to your horizon. The Celestial Equator - a projection of the Equator on the sky - is now straight over head. Either dial will work here - you just need to be sure the side marked "north" or "south" is facing in that direction. The toothpick would be pointing towards both celestial poles.

In practical terms, If near the equator - a special case

Users near the equator will find the dial face too close to perpendicular for the toothpick to reach the base. Those users should use the setting triangle to hold the dial face at the correct angle. This is a little more awkward. **You need to put the triangle on the West side of the dial before noon and on the East side after noon so as not to block the Sun**. An alternative might be to set the dial once and put glue in the cut where you've made the fold. Or maybe hold it in place with a little of the modeling clay. But any such permanent solution would mean you can't fold the dial for transport.

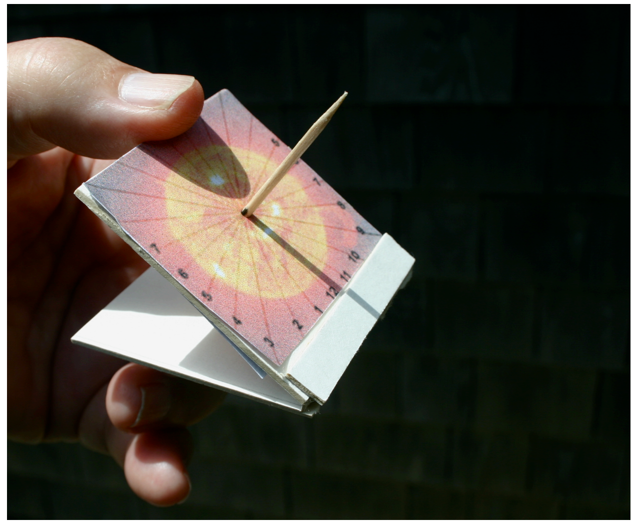
Folded for travel

One end of the toothpick can go into the edge of the cardboard strip at the bottom of the top side of the dial. A rubber band then keeps the dial, toothpick, and setting triangle together and neatly packed for travel.

And now - how to tell time ;-)

Step 1 - Point the sundial towards the nearest pole - uh, that would mean facing north if you are in the northern hemisphere, south if in the southern hemisphere.

Read the time by the trailing edge of the shadow of the toothpick - the technical name for this is gnomon - cast by the Sun on the dial face.



That's it. The picture to the right, for example, was taken at a few minutes before noon on a summer day in the northern hemisphere.

"But is this the correct time?" you ask.

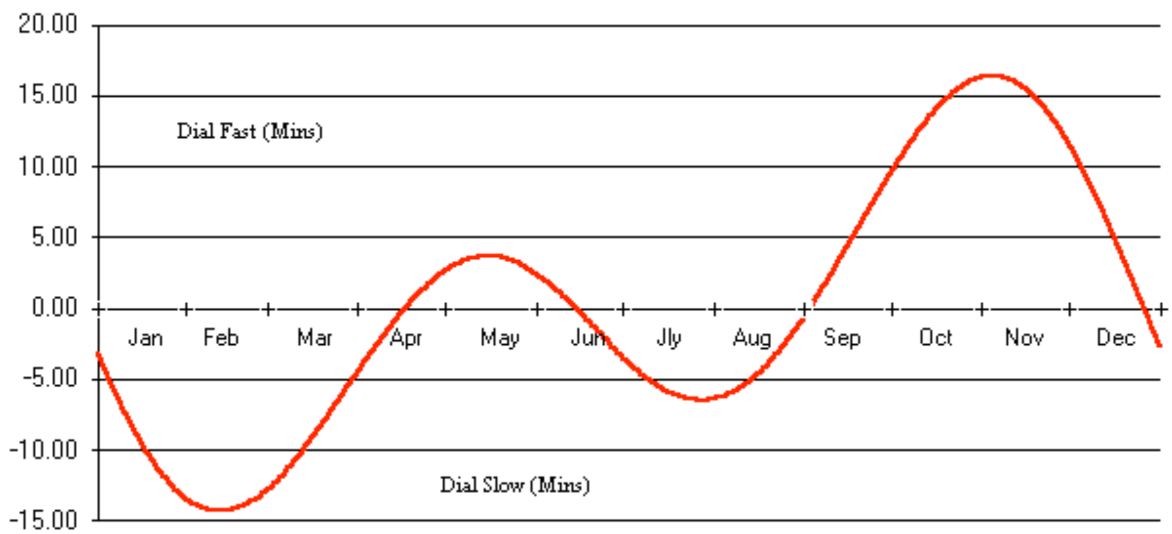
Yes - but it depends on what you mean by "correct" time. It is telling the correct Local Solar Time.

Let's get to the meat of the issue. You want to know if the Sundial time relates to the time on your watch, right? And the answer is "yes, if you're willing to do a little figuring." There are three adjustments you can make.

1. **You have to correct for Daylight Savings Time**. This is the big one. For example, the dial above showed it was about 11:55 am Local Solar Time in Westport, MA, when the picture was taken. But my watch said it was really about 12:40 pm. Why? First, because **my watch is an hour ahead of the Sun - that's what Daylight Savings Time is all about.** We "spring ahead" when we introduce daylight savings. But that obviously isn't the whole answer. If that was all there was to it, then at 11:55 am Local Solar Time in Westport it would be 12:55 pm Eastern Daylight Savings Time - and it wasn't - we were roughly 15 minutes shy. Why?

2. **Location, location, location - it's all about where you are in relation to your Standard Time Meridian.** The central meridians of our time zones are 15 degrees (one hour) apart starting at the meridian of longitude that runs through Greenwich England and moving westward for 180 degrees. These lines also count upward as they move eastward eastward for 180 degrees. In my case, Westport is in the Eastern Time Zone and the central meridian for that zone is at 75 degrees longitude. But Westport isn't at 75 degrees - in round numbers it is at 71 degrees. That puts it four degreees east of 75 degrees. **Thus the Sun rises in Westport 16 minutes before it rises at the central meridian of the Eastern Time Zone.** Why 16 minutes? Because each degree represents four minutes and we're four degrees east of the Central Meridian. (Why? If the Sun moves 15 degrees each hour and each hour is 60 minutes long, then it is going to take 60/15 - or **four minutes to move one degree**.) Because I'm East of the central meridian for my time zone, my Local Solar Time is "fast" - that is, ahead of the solar time at the central meridian for my zone. If you are west of it, you would be behind - your local solar time is "slow." So let's get back to our example. It was 11:55 am Local Solar Time. Add an hour for Daylight Savings Time and it is 12:55 pm on my watch. But then we have to subtract 16 minutes because the Sun gets to Westport before it gets to the central meridian. **So my watch should read 11:39 pm. Ooops - close, but no cigar!**

3. **OK, there's one other reason for it being off - it's called the "equation of time" and it's fairly complicated and quite frankly, really doesn't amount to much a good deal of the year.** I mean, quite honestly I can't read my little wristdial right down to the minute. But there are certain times of the year when the equation of time accounts for as much as 16 minutes difference between our watches and what the sundial shows. This picture was not taken at one of those times. It was taken when the equation of time made very little difference. So how do I know when to worry about the equation of time? Well, look at this graph, borrowed from the Web site found here: http://ourworld.compuserve.com/homepages/patrick_powers/sundials.htm



My picture in the example was take in early June. Notice that the equation of time for early June gives a difference near zero. In other words I could ignore it. In fact during the spring and summer months here I do ignore it because it seldom amounts to more than five minutes. **So I just keep in my head that the sundial on my wrist - or in my garden - is about 45 minutes behind the time on my watch and that's close enough for me.** In fact, I kind of like living by Local Solar Time - though I admit it's not practical for interaction in a global society ;-) I also know that in the fall and winter months this time difference does get serious much of the time - the sundial can be more than 16 minutes fast in early November and almost that much slower in February. (December is one of those months where it doesn't much matter.)

But why?

Another good question. Take a deep breath, sit back, and accept the fact that you live on the surface of a ball that's rotating several hundreds of miles an hour - exactly how many depends on exactly where you are sitting on that ball - and that it is whipping around the Sun at about 66,000 miles an hour - but notice I say “about.” That’s because the Earth doesn’t travel in a circle, it travels in an ellipse. That means that sometimes it is going faster than at other times. If that sounds complicated, believe me, it is, and that’s why it took centuries to figure it all out and get it “right.”

A sundial can be made so it is precise. In fact, about a century ago French railroads were run by watches and clocks which were set by just such a precise sundial! Yes, you can make a very precise sundial and make a very precise calculation between it and a watch. But clock time itself is an approximation driven by the fact that we want all our hours and days to be the same length - and the reality of the Sun-Earth system is it produces days and hours that are of slightly different length.

The spur to get a system we could all agree to was to keep the railroads running on schedule. That’s how this whole business of time zones got started. Once we started moving about at something faster than the pace of a good horse, we started covering a lot of ground and having every town keep its own Local Solar Time made for a very confusing situation. That part of the problem is easy to see. And we solved it with standard time zones agreed to at an international conference in Washington, DC, in 1884.

If you look at a map you’ll see the time zones created don’t follow nice straight lines like the meridians of longitude. They are based on a central meridian for each zone, but politics and economic issues dictated that time zones had to zig and zag some to take in people in communities that regularly interacted with one another. (Imagine waking up in one time zone and going to work in another. It happens, of course, but the zones were drawn to minimize this sort of thing.)

But Local Solar Time has other pesky problems. Of course it can’t change for Daylight Savings Time, but there’s that issue of the Earth moving faster or slower at different times of the year. That means that days are of different lengths. Also, the tilt of the Earth’s orbit in relation to the plane of the solar system not only gives us seasons, but has the Sun appearing to move across our sky at slightly different speeds at different times of the year. The detailed math of all these differences is frankly beyond me - but it’s easy to see that to come up with a standard time keeping system you have to make some arbitrary decisions - like decide that all hours must contain 60 minutes and all days are exactly 24 hours long - then compensate for the accumulating error by throwing in an extra day every four years and even an extra second every four hundred years.

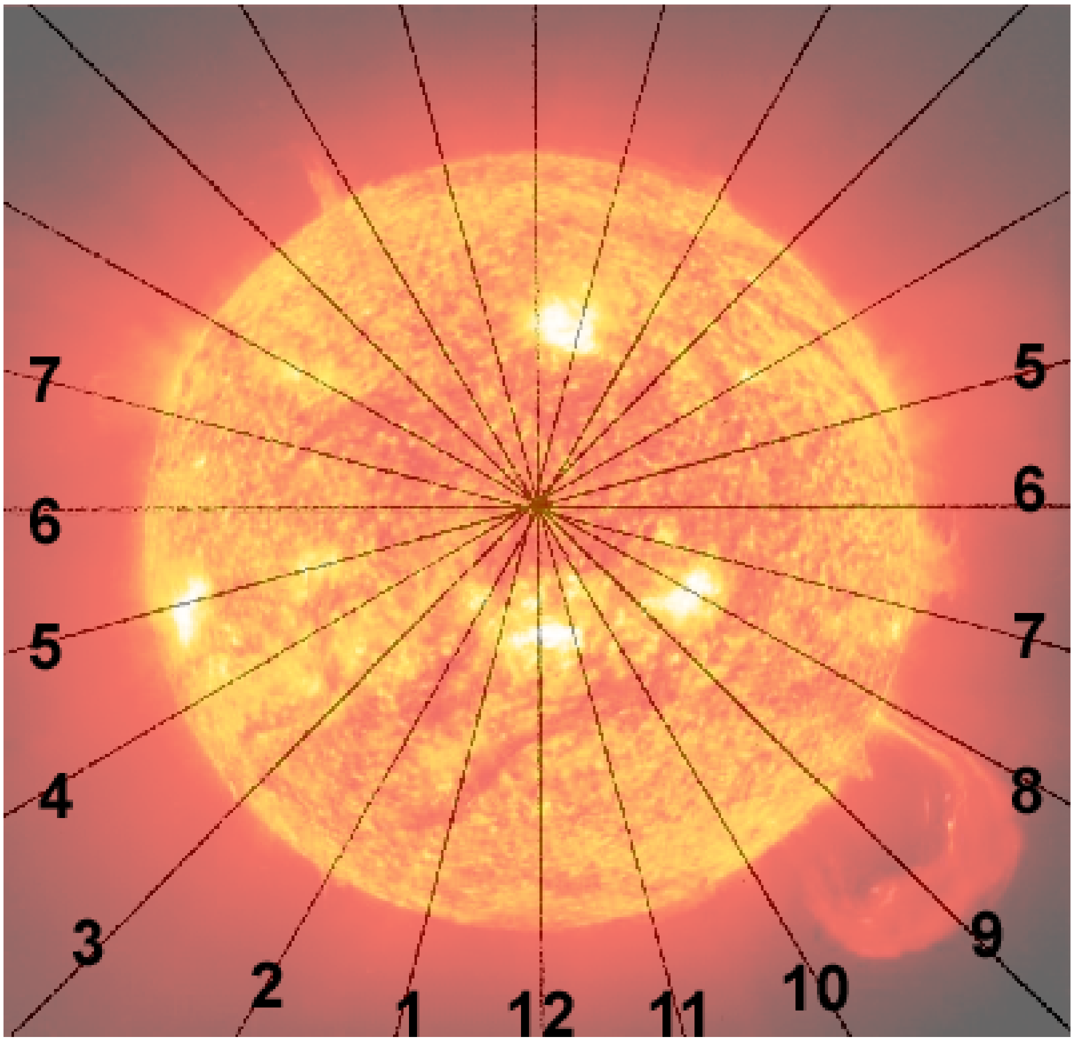
But so what? To me the larger point is that using the sundial is just one more way to put myself in close, intuitive touch on a regular basis with this incredible universe. The cleaned up time on my watch doesn’t do that. It’s convenient. But it obscures what is really going on. It allows us to forget we’re on spaceship Earth, rotating and revolving at incredible speeds with incredible precision.

Those two unimaginable motions defy common sense, for there’s little in the experience of our common senses that reveal them. Except the sundial. Yet this Sun-Earth system, huge as it is and fast as it is, does move like precision clock work - celestial clockwork where the wheels and gears are the Earth and Sun, and the power is provided by Mister Newton’s mysterious force, gravity. Can you even imagine moving an object as large as the Earth as fast as that and with the precision of a Swiss watch?

That’s why just a glance at your little wristdial should leave you rapt in awe! It should open your eyes to the mysterious of which Einstein spoke - the emotion that is the “source of all art and science.”

Spring/Summer Dial for northern hemisphere or Fall/Winter dial for southern hemisphere

Top

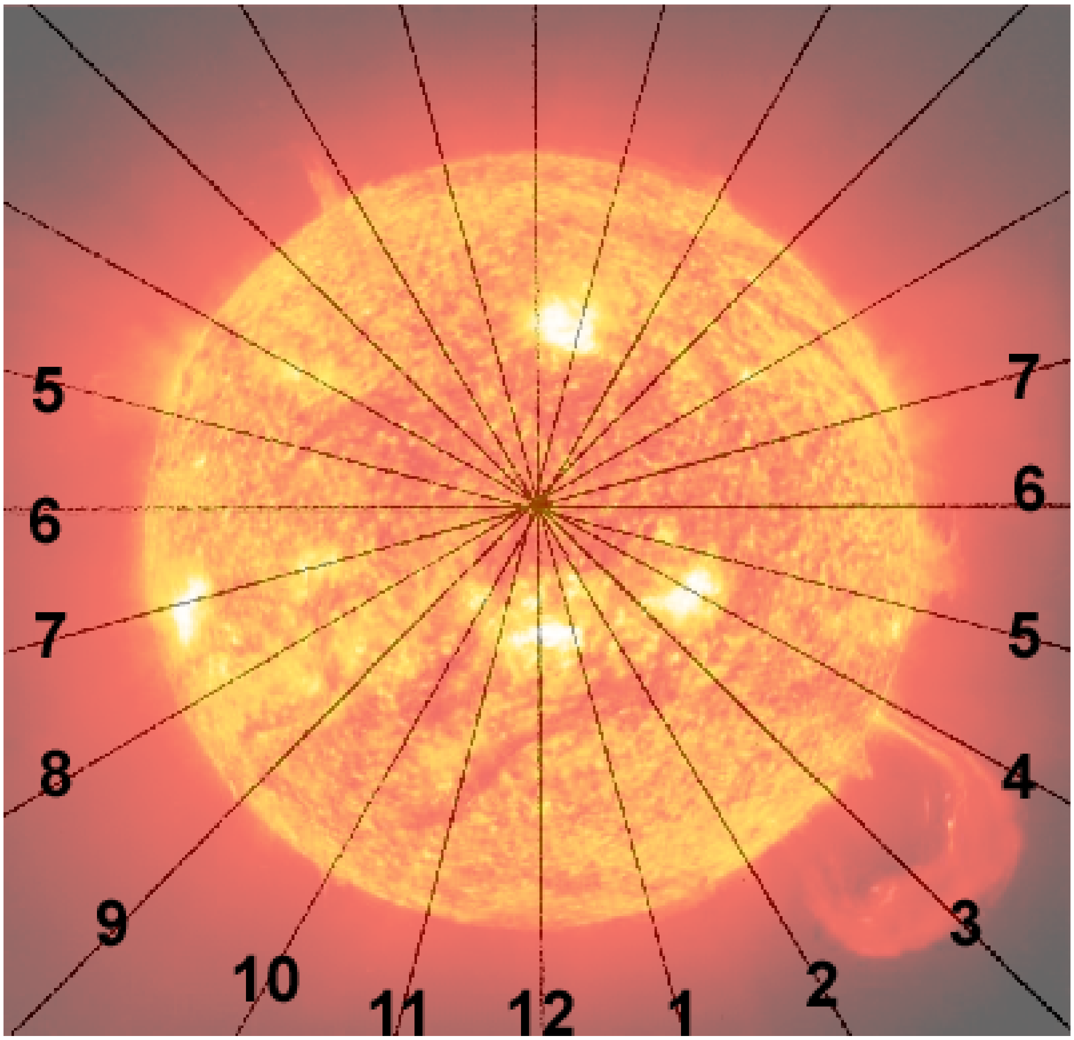


Bottom East

Cut out exactly and paste to underside of board.

Fall/Winter dial for northern hemisphere or Spring/Summer dial for southern hemisphere

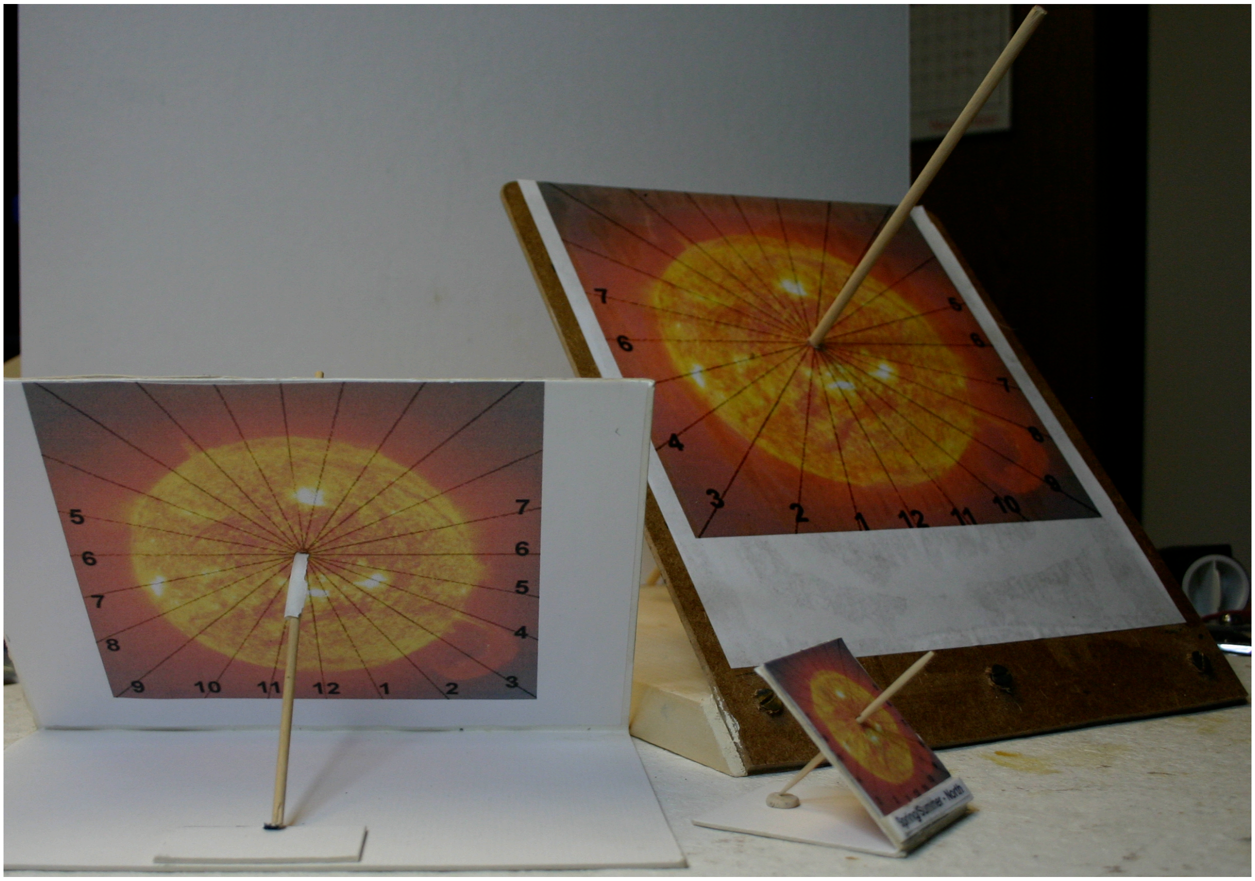
Top



East

Bottom

Cut out exactly and paste to underside of board.



Dials of various size and weather proofing are easy to make. Since the hours are simply 15-degrees apart, I'm sure you can come up with your own version of a permanent dial for the garden or other area. There are many, many sundial designs and different approaches to making them. I like the equatorial dial best because of its simplicity and because it teaches us about the celestial equator and the seasonal movement of the Sun to one side of it, or the other. In a way it is a miniature version of the Universe as we view it, driving home the Earth's headlong rush around the Sun and how that gives us a constantly changing perspective.