Armillary Sphere

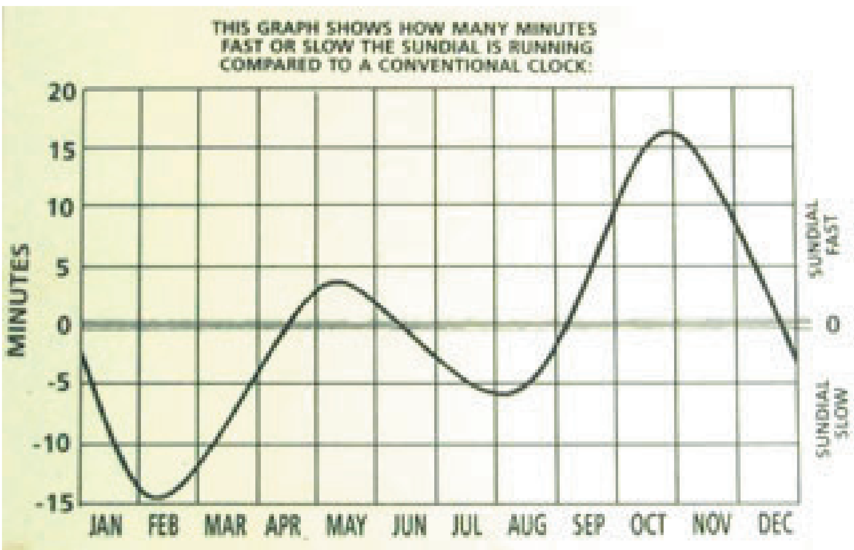
Instructions - Kim Devenish

This is a type of sundial - if the sun is out, it tells the time.
The science of sundials is called gnomonics. A Gnomon is the part of the sundial that casts the shadow. In this case the gnomon is the arrow which casts its shadow onto a band which is mounted in the equat
orial ring.
It is a garden ornament and a scientific instrument combined. As well as telling the time, it acts as a visual aid in some basic astronomy and geography.

For it to work, the base needs to be level, and the arrow needs to point south
It is already set for the local latitude. (Melbourne's latitude is 38' south)
If it is to be set up at a different latitude, adjusting it just involves tilting the sphere to the angle that corresponds with that latitude and securing it there. The tilt is only to do with the latitude of your location, not the earth's tilt, which is something else again. Telling the time is a matter of seeing where the shadow from the shaft of the arrow falls on the hour ring. The ring is marked in 15 minute intervals and the numbers go from right to left.

Different types of time:

We are conditioned to think that if it agrees with our watches, then it is "right". Its not that simple. Our clocks are all set to Standard Time, which is something devised to make things more convenient, and on top of that, we also layer on another adjustment for Daylight Savings.
Before all that, we used to use Local time. This sundial works on local time. Noon is when the sun reaches the north-south meridian - its daily half-way mark (and at the same time reaches its zenith). With local time, noon is at 12 o clock, but with Standard time and Daylight Savings, noon can occur at some other time. The amount of variation that Standard time causes depends on your Longitude. In our part of the world, for example, our time is standardised to the 150 degree East latitude line. If you are at 150 degrees East, there is no difference between local time and standardised time. If you are at 145 degrees East, like Melbourne, there is 20 minutes difference. A degree translates to about 4 minutes. Noon in Melbourne is at 12.20 PM Standard time. Add daylight savings to that and noon then occurs at 1.20 PM. Some sundials are made to be adjustable to cope



with daylight savings, or with the compensations needed for standardised time for a specific longitude built in. This dial does none of that, and we are left with good old Local Time where at noon it says that its
12 o clock.

There is one more factor which makes clock time differ from sundial time. Clocks go at the same speed all year round, but the earth goes through an annual cycle of speeding up and slowing down as it follows its elliptical (slightly egg-shaped) path around the sun and this causes a deviation between sundial time and clock time throughout the year. Most of the time they stay pretty close, but at the most extreme there is about 20 minutes difference. The graph below (known as the equation of time) plots this difference and it applies to just about all sundials everywhere.

For those wanting to convert sundial time to clock time, there are 3 steps:

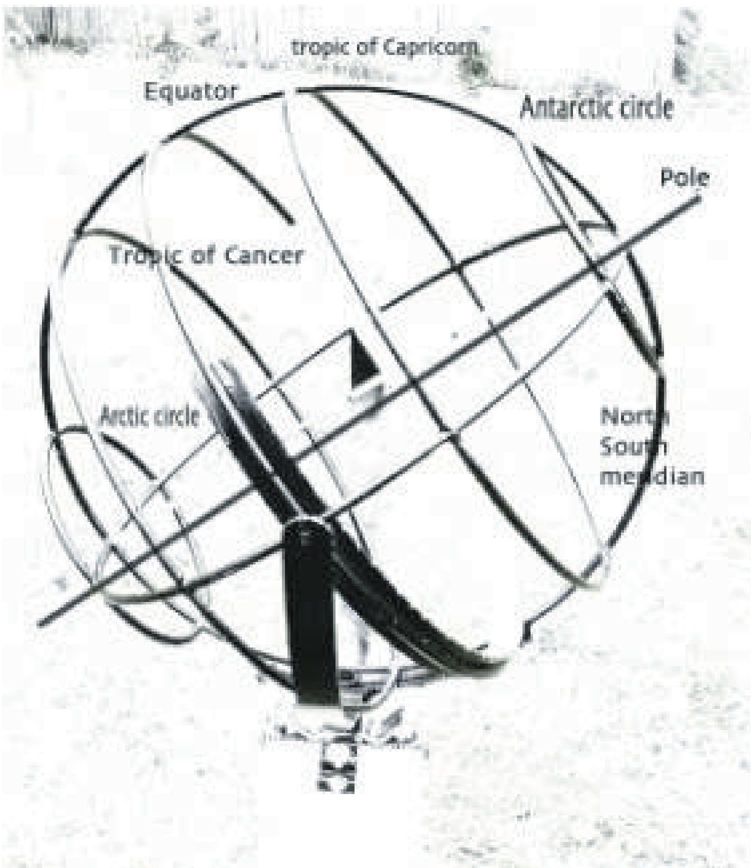
1. allow for Daylight Savings when necessary. This is the biggest factor.

2. know how different your standardised time is from local time at your locality. Like the Melbourne / Sydney example, its all about how many degrees your longitude is from the longitude of the line that we standardise time to. A sundial located a degree to the west of that line translates to the sundial appearing to run 4 minutes slow, while if its one degree to the east then it appears to run 4 minutes fast, compared to the clock. You can find the answer by looking in an atlas, or if not, the sundial itself will give you a rough idea. Anyway, once you know, then it stays the same and always applies at any time of day or year. eg: Melbournites (145 degrees east) need to always add 20 minutes. Sydneyites (151 degrees east) subtract 5 minutes. Brisbanites (153 degrees east) subtract about 15 minutes.

3. Getting finer still, look at the equation of time graph to make the last compensations according to the time of year. Most of the time its only a minor adjustment and barely necessary but, say its early November: - the dial is running 15 minutes faster than the clock.

So, for a Melbournite in early November its: add one hour for daylight savings; add 20 minutes for standardised time; subtract 15 minutes because of the equation of time; and the answer is to add one hour and 5 minutes. 12 o clock on the sundial translates to 5 past one daylight savings time on the clock.

With a sundial like this, accuracy relies on the arrow going right through the centre of the hour ring at a 90 degree angle and the whole thing being angled right and pointing the right way and the marks being put in the right place. Any further accuracy depends on the size of the sundial, the thickness of the gnomon and the fineness of the time markings. With this sundial I've kept the hour ring uncluttered and easy to view, allowing someone to quickly work out what the time was to within about five or ten minutes.



Armilla means skeleton, so it's a skeletal sphere. It serves to hold the gnomon and the hour ring in position, but the rings of the sphere all represent something too. If we imagine this to be a model of the earth, then the rings represent the arctic circles, the tropics, the equator, which are all Latitude lines and all five rings are parallel. Holding them all together is the north-south meridian ring and another ring which is mostly just there for structural and reasons. The arrow represents the earth's pole. The Arctic circles and the tropics have everything to do with the earth's tilt.
That's probably more than you needed or wanted to know. If you don't care for any more of the astronomy and geography stuff, read no further!

More Armillary Sphere Information

This armillary sphere is made of 7 rings. Some have less. Some armillary spheres have more rings representing various other things: the horizon, the ecliptic, the east-west meridian, etc.. As a sundial, the only really essential elements are the pole and the equator. Designs vary widely from ultra minimal to extremely complicated, some are highly ornate while others are strong on scientific information.

The sphere represents the earth, and to set it up it needs to be aligned the same way as the earth. This varies according to where you are. The angle at which the Arrow tilts compared to the horizon needs to be the same as the angle of latitude for the location. Our latitude is the angle we are from the equator. Melbourne's latitude is 38 degrees south. In the southern hemisphere, the arrow needs to point south. In fact it points to the South Celestial Pole, which is the point in the sky which the stars appear to rotate around. If you were on the South Pole, this would be directly overhead, and the arrow would need to point straight upwards. If you were on the Equator, the South Celestial Pole would be right on the southern horizon and the arrow would need to lie horizontally. For it to work in the northern hemisphere, the numbers need to go in the opposite direction - left to right instead of right to left (the 12 and the 6's would stay where they are)

When set up, the top of the sphere represents your location on the globe.
When you live on a sphere, you're idea of "up" and "down" changes according to where you are on the globe. The centre of the world is the direction of "down", and the opposite direction is "up". When we look at a map on the wall, we get another idea again, with North being "up" and South being "down". There is no universal "up" or "down", only a local one. Wherever you are, you are on the "top" of the world and you are always right-way-up. If you can, get hold of a globe and turn it around so that you're location is at the top. As far as you are concerned, this is the right way up. This is the very same as the way the armillary sphere needs to be set up.

The idea of time can also be viewed and measured in different ways. None are wrong. Our earth time is based on two basic mechanisms: the earth's rotation (one day) and the earth's orbit around the sun (one year) We are used to Standard Time, which is something devised to make things more convenient, and on top of that, we also layer another adjustment for Daylight Savings. Before that, we used Local time. There has also been various types of Local time. For a time, some people and places (monasteries, etc) used the idea that all days were 12 hours long and all nights were 12 hours long as well.. To compensate for the days getting longer and shorter throughout the year, they just made the length of an hour longer and shorter to suit, so a summer hour could be nearly twice as long as a winter hour. As long as the people around you are using the same system, then anything goes.

The time of year can be roughly judged from the sundial also. On the central section of the arrow there are three black rings. The black rings at each end lie in line with the plane of the tropics. Only the section of the arrow between these two black lines ever casts a shadow on the hour ring. The central black ring is in line with the plane of the equator and represents the centre of the earth. In high summer, the part of the arrow that casts its shadow onto the hour ring is around the upper black ring. In mid winter, when the sun is at its lowest, the shadow is cast from the lower black ring area. At equinox time, the shadow is cast from the area around the central black ring.

Using the armillary sphere as a celestial visual aid

In our modern heads we accept that the Earth isn't the centre of the universe and the heavens don't revolve around us, but in many ways we still see things the old geo-centric way. We still talk of the sun rising and setting, and why not? Whether it be the sky turning, or us turning, it all amounts to the same thing, and many basic astronomical truths remain unaltered. As far as we are concerned, the stars are "fixed" and all turning together. The constellations don't change shape in any great hurry. The only things that we can see wandering about in amongst the stars are the planets and comets, moon and sun of our own solar system. So, unless planning some interplanetary travel, our geo-centric thinking is no impediment to understanding the basics of astronomy. In some ways it makes it easier to grasp.
The Armillary sphere serves as a basic aid to a geo-centric understanding of the universe. It helps figure out how the sky directly affects you. Where will the sun set at this time of year? How long will the day be? How high will the sun get?

Locate the black ring at the half-way point on the arrow. Imagine that this point is where earth is and you in there in the centre looking out to the sky which is a great sphere turning around us. The armillary sphere becomes a grid that divides up the sky. The rings of the Armillary sphere take on different representations. The sky rolls around in the direction of the Latitude rings. In our winter, the sun is low, the days are short. At mid winter, the sun's path is described by the Tropic of Cancer ring - the lower ring. In mid-summer, its the Tropic of Capricorn's ring's turn to plot out the sun's path. At equinox time, the equatorial ring plots the sun's path. At that time the days will start at six and also end at six. The sun will peek over the horizon due east and set due west .

Only within the Arctic and Antarctic circles can you have 24 hours of darkness, or 24 hours of daylight. To see daylight every day, you need to be outside of the arctic circle. Only between the two tropics can the sun be directly overhead. All of this is because of the tilt of the earth in relation to its orbit around the sun. It is the cause of the cycle of seasons. This tilt of 23.5 degrees is the same angle as the angle of latitude at the tropics. Likewise, the arctic circles are 23.5 degrees away from the poles.

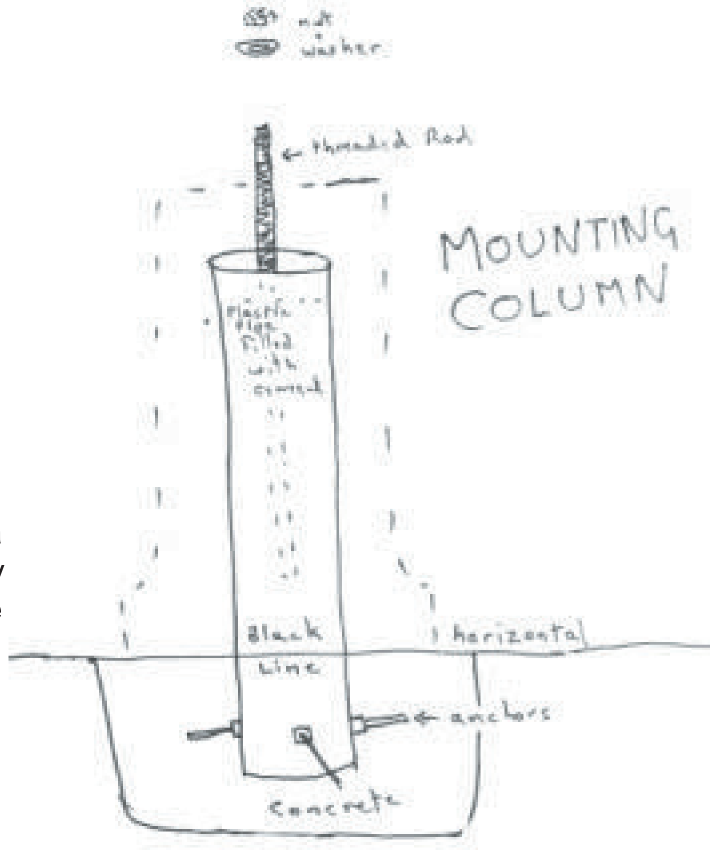
The Armillary Sphere sort of hints at the answers to lots of basic astronomical and geographical questions and if you get into it, leaves you wanting to find out more.

Mounting the Armillary sphere

The Armillary sphere is made up of separate parts, which join together:
The Sphere, the Steel Base and the Cement Pedestal

For temporary mounting, like on a shop floor, a Steel Square goes up inside the Cement Ped-

estal. A bolt then goes between the Steel Base and the steel square, sandwiching the top of the Cement Pedestal in between.
The Sphere then attaches to the Steel base with two nuts, which are attached behind the 6 o clock marks and one bolt, which sets it at the correct tilt. Everything holds together, but it is not anchored to the ground.



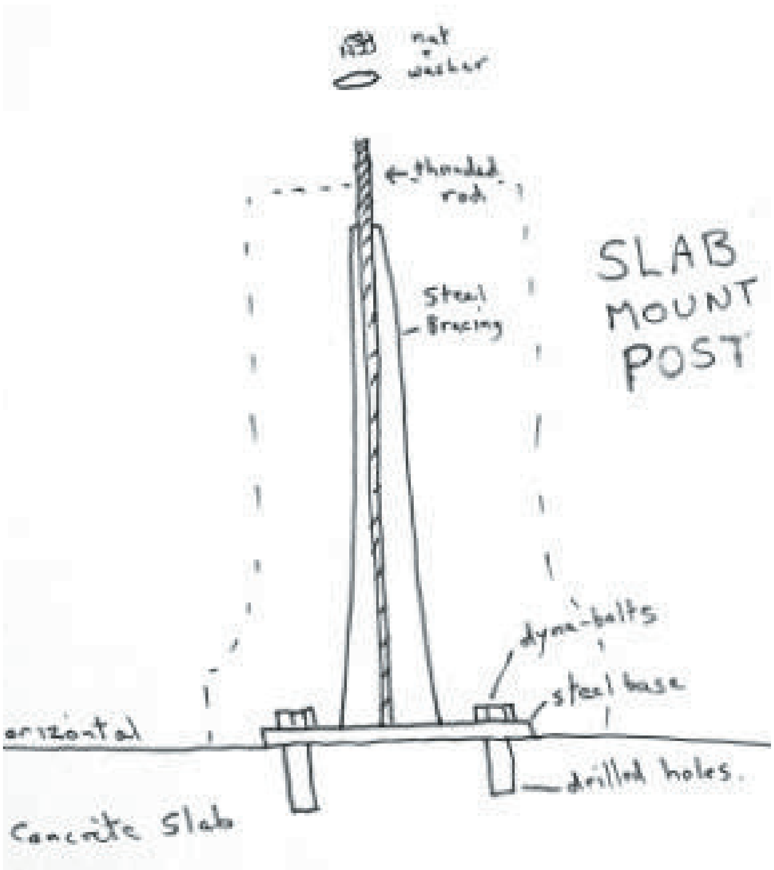
Two all- purpose, easy, mounting option suitable for home gardens.
There are many options, but with this sundial design, they all involve a nut and bolt arrangement connecting the steel base with the ground

Option 1. Mounting into the ground

The steel base of the armillary sphere connects to a Mounting Column. This consists of a long piece of threaded rod embedded vertically into a piece of poly pipe filled with cement. The pipe also has anchors around its base. The black line approx. 150 mm from the bottom is the depth to which it should be sunk. The simplest method would be to make the hole that is wider than the Mounting column and 150 mm deep, sit the mounting column directly onto the floor of the hole and pour in the concrete. Of course, the cement work can get much more elaborate than that, but as long as the Mounting Column is set into place at the right depth, it will work out. So far, none of the process involves the Cement Pedestal. Once all the cementing is done, the next step is to lower the Cement Pedestal over the Mounting Column. The Cement pedestal stands about 550 mm high. If its bottom is level with the black line, the threaded rod will be long enough to poke up through the pedestal. Depending on how elaborate your concrete foundations are, the Cement Pedestal will either be sitting directly onto the ground or onto a Cement base of your own making. Anything goes as long as its level. Use a spirit level, or a plumb line to check that the Cement pedestal is standing straight, not tilted.
Next, lower the steel base over the pedestal so that the threaded rod pokes through the central hole in the steel base. A washer and nut is put on from above and tightened using a 16 mm spark plug socket spanner. It’s fiddly, because it has been designed so that this crucial nut is

quite difficult to tamper with later on. Stick to the rule of the Black Line, or else the rod will stick through too far, or not far enough. Too short and you may not be able to do up the nut. Too long and the socket spanner may not be able to get the nut all the way down. But don't worry, there is some leeway.
Next, the sphere attaches using the three nut/bolts. To lock these nuts onto the bolts so they can't come off, use a hammer and a sharp centre punch. Aims the centre punch at the place where the nut touches the bolt, and with the hammer give it a couple of hard taps to jam the threads together. Once the sphere is on for keeps, it also prevents access to the main mounting nut at the base.

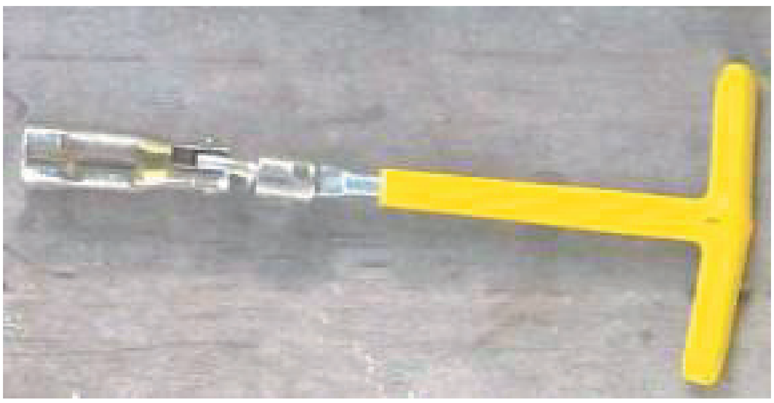
Option 2. Mounting onto a concrete slab



Similar in many ways to Option 1., with an internal vertical threaded rod attaching to the steel base in the same way except instead of setting a Mounting Column into the ground, a slab mount post is used. It is a long threaded rod attached to a steel plate, which bolts to the slab using dyna-bolts. Some bracing has also been added to eliminate flexyness. Drill holes into the slab, insert the DynaBolts through the steel plate into the slab and tighten, then following the same course of action to Option 1.

The beauty of these method is that the sundial can be firmly mounted into place, but because the Cement Pedestal is not embedded into anything on the ground, the whole structure can still be turned until it is facing the right way, so there's no pressure to have it perfectly aligned before you start pouring cement. Once it is aligned, a bit of extra cement or earth, or even stakes around the base of the Cement Pedestal will prevent it from being turned any more.

Mounting device and tool



The Armillary Sphere can be assembled for Temporary mounting with a steel plate and bolt. For those who wish it, either a Mounting column or a Slab Mount Post with dyna-bolts will also be supplied, along with the socket spanner which is crucial for reaching into the steel base and doing up the main mounting nut (It's also very difficult to take apart without it, which is a good thing). The only additional thing you will need to organize is the digging, the cement, or the means of drilling some holes into a slab. For added tamper-proofing, you also need to find a hammer and a center punch for jamming the nuts onto the bolts.

Aligning it to point to true south

All that is left is to point the thing the right way. In the Southern Hemisphere, it's just a matter of finding true south. There are many ways to do this, but here are a few:

Using a compass: find magnetic south, then allow for the deviation between magnetic south and true south for your part of the world. Mark it out on the ground with tape or a stick pointing towards the center of the pedestal, then using your eye, turn the Armillary sphere until the arrow lines up with your marker.

Using your watch: The sun has to be out. Work out the difference between clock time and Sundial time as set out on page 2. Using the Melbourne in early November example, then turn the sundial until it shows the time to be 1 hour and 5 minutes slower than your watch. If your watch says 3.15, then set sundial for 2.10. Don't be too alarmed. Most of the discrepancy is because of Daylight Savings. If all this is done correctly, the arrow will be pointing south.

Using a stick: The sun has to be out. Hammer a stick vertically into the ground. For an hour or so in the middle part of the day, every 5 minutes or so, mark out where the tip of the stick's shadow touches the ground. Figure out which mark is the one closest to the stick and make a line between the stick and the mark. That will be your north- south line. This is because at noon, the sun is due north and also at it's highest.

To view a range of my sundials on the web, visit
kimdevenish.bollywaffle.com

To get in touch, write to
PO Box 213 Foster, Victoria, Australia 3960

-Kim Devenish