By
Tim Byrne

Making a mud-brick equatorial sundial

Tim Byrne works at Scienceworks, a museum of science and technology, situated on the banks of Melbourne's Yarra River. Tim assists Scienceworks to communicate to its visitors by interpreting museum collection objects and hands-on exhibits. He also helps write and present various science stage shows, demonstrations and workshops.

Tim notes that "this is a dirt cheap project which may appeal to teachers wishing to integrate their maths, science and technology subjects. The project involves using mud bricks to produce a working sundial. The notes on the process are suggestive rather than prescriptive. Some background on equatorial sundials is included".

'Now is yesterday's tomorrow' **Shakespeare**

'With my shadow moves the world'. **A common sundial motto**

'For in and out, above, about, below, 'Tis nothing but a Magic Shadow show, Played in a box whose candle is the Sun. **Omar Khayyam**

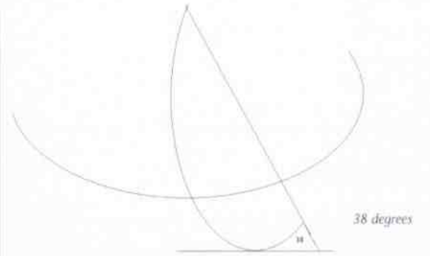
Introduction

I love sundials. I love all their various forms and their utter simplicity. I learnt a lot from making cardboard sundials before moving on to metal, wood and recently mud. Sundials are dirt simple yet can be precision instruments. I like the way they display the passage of time without any moving parts.

I like the way they express the Earth's relationship with the Sun. Sundials were invented at a time when people believed a sundial's shadow tracked the Sun's rotation across the sky. Nowadays we know they work because we understand it's the sundial, which rotates.

Figure 1

The completed sundial will be improved with a small flower garden.



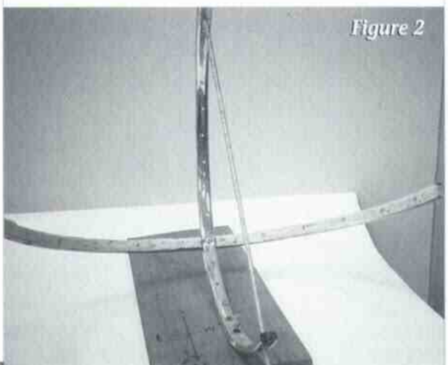


Figure 2

The sundial shown above is currently tracking the sun's apparent movement across the sky to within five minutes of clock time. Not too bad for a pile of mud and one broom stick.

This project would appeal to students and teachers looking for an integrated studies project in an outdoor setting. It would enable a diverse team of students to cooperate. It is hands on all the way. There is some debate about when the design process starts. I would suggest that it starts while making the mud bricks and preparing the site. Dealing with mud means that the results are always plastic and the design process can be quite dynamic.

The project combines some interesting yet basic maths. Students need to be able to mark off 15 degrees along a curve for the hour lines. The practical astronomy includes understanding the need to tilt the whole structure at 38 degrees to the horizontal so the gnomon lines up parallel with the Earth's axis. The Earth's axis and an effective gnomon point to the part of the sky which never seems to move, the South Celestial Pole. There is a tangible appreciation of materials technology. Students can learn the structural limits of mud. They see how straight bricks can form a curve. They can become connoisseurs of fine weather and the rare chance to do maths and science outside in the real world.

The prototype equatorial sundial shown in Figures 2 was put together with the two halves of a bicycle wheel. The hour lines are 15 degrees apart. By contrast, in a horizontal sundial the hour lines vary considerably and need to be applied using a trigonometric formula. The tilt of the gnomon or the shadow-stick needs to be set to the angle of the latitude. At Melbourne, the gnomon is set to 38 degrees.

Students easily appreciate that the sky looks like an inverted bowl and the Sun seems to move in a circular path around us (see Figure 3). These two observations are the main theoretical underpinnings of equatorial sundials.

Equatorial sundials are readily distinguishable from other sundials because of the graceful curves along the dial plate showing the hour markings. The reason the dial plate takes a semi-circular shape is to complement the apparent path of the Sun across the sky. A useful way of imagining the Sun's apparent path around us is to think of a large circle. Daytime is when the circle is above the horizon. In summer the majority of the circle is above the horizon, while the winter circle is predominantly below the horizon, see figure 3. The equatorial sundial accommodates the Sun's passage around the large circle by marking off the hours in exact proportion to the time it takes the Sun to travel the circle. For this reason the equatorial sundial is easier for students to understand as the Sun travels 360 degrees in a day or15 degrees an hour. Although the horizontal sundial is more familiar as a common garden ornament, it requires some trigonometry and a calculator to establish the variable hour lines. There is one trick in calculating the hour lines for the equatorial sundial's and this

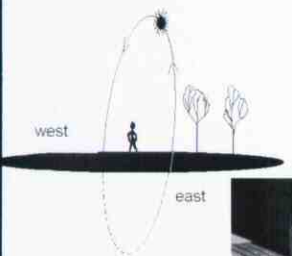


Figure 3

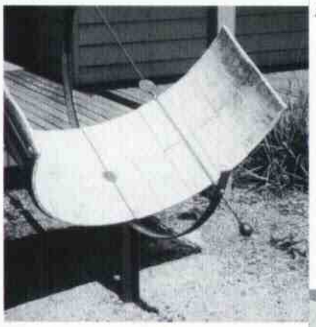


Figure 4

involves offsetting the 12 o'clock mark.

The Sun's apparent path across the sky traces a semi circular path (Figure 3), which is reflected in the shape of the equatorial sundial in Figure 4. The dial plate of this equatorial sundial is wide enough to include an analemma which is interpreted by the circular shadow.

One more aspect of theory students need to be aware of for making an equatorial sundial is the small offset required for your location within your particular time zone. The offset is due to 'local noon' being different for every place within a time zone. In Melbourne (145 degrees East), the midway point or 'noon' is about 20 minutes later than Mallacoota's 'noon' in eastern Victoria (150 degrees East) but 20 minutes before Portland in Victoria's west. Since the Sun appears to be travelling 15 degrees an hour, due to the Earth's rotation, each degree of longitude to the west of the time zone takes the Sun another four minutes. In Melbourne, another 5 degrees west of the Eastern Standard Time zone, we can make a correction to the sun clock by placing the 'noon' point at 12:20pm. It is helpful for students to realize that 'noon' is the actual mid point of the Sun's path across the sky or the time the Sun is directly over our local meridian but not always 12:00pm. The diagram below illustrates how the hour lines will look for Melbourne or any place close to 145 degrees east. If making a sundial for Sydney one would shift the noon mark one degree in the other direction. A table is included to show the corrections for various capital cities across Australia, figure 14.

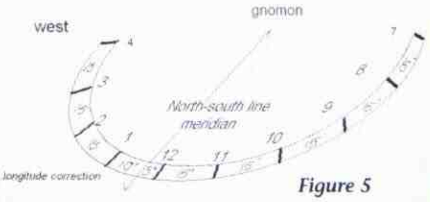


Figure 5

The diagram above shows the offset required by the longitude correction in Melbourne.

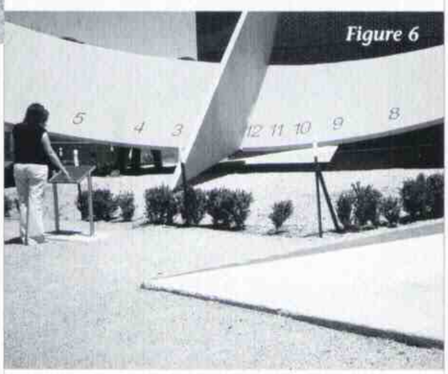


Figure 6

Figure 6, a photograph of the large sundial outside Melbourne's planetarium, shows how the gnomon is placed on an actual sundial with a longitude correction of 5 degrees viz 12:20 pm.

This project began with the careful selection of a site. I needed a site that would receive sun for most of the day and most of the year. It needed to be well drained to avoid rising damp. I drew up a rough plan based on the bicycle wheel model pictured above. A sturdy footing was poured with 'bessa' bricks and a damp course ensuring the mud bricks remain high, wide and dry. To create a form for the large rectangular sun dried mud bricks, I used an old cartwheel to form both the hour plate (east/west) and set the gnomon (north/south). In figure 9, the cartwheel was lined up with the meridian. I used both a compass and a GPS to determine the precise north/ south line but found it difficult to get within two degrees of true north because of the way a GPS jumps around as you walk with it. The alternative is to use a good quality compass and factor in the magnetic declination for your location.

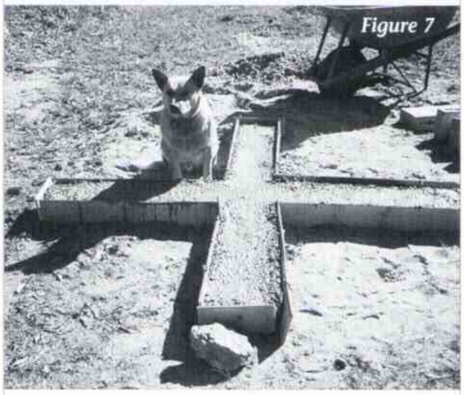


Figure 7

Figure 7 shows the concrete foundation that was poured in the shape of a cross. The north/ south meridian is used to support the gnomon. The east/west axis provides a base for the hour lines. I realised later that I needed to extend the east/ west axis to accommodate the curve. Finally, the concrete footing ended up looking like a Maltese cross. See figure 8 below.

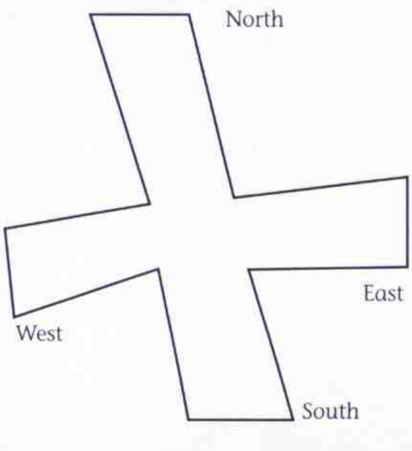
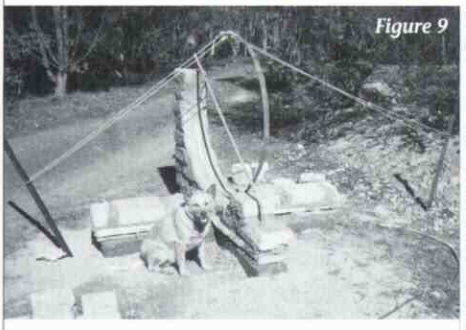


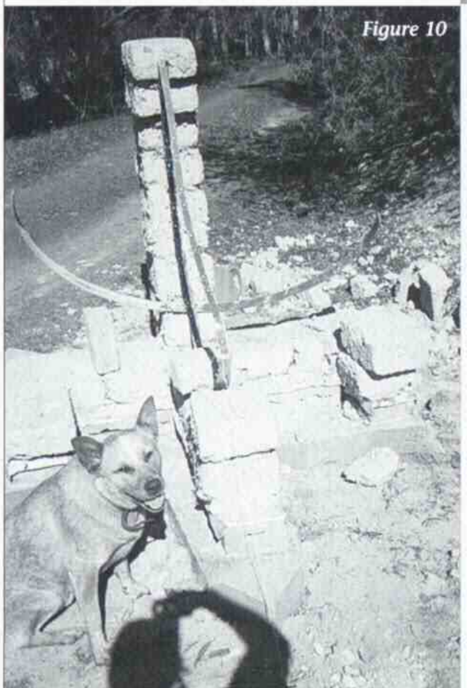
Figure 8



A cartwheel, shown in Figure 9, is used to set the correct shape for the two curving surfaces housing the gnomon. After this photograph was taken, the wheel was cut in half to provide the curve for the hour lines running east/west. In this photograph the dog is facing north and the shadow from the cart wheel reveals it is just before local noon.

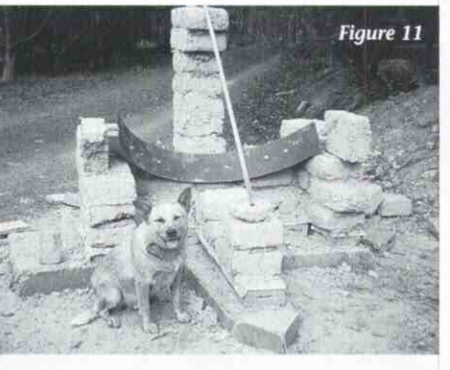
The mud bricks were staggered to build the curve on the meridian.The bricks were smoothed down some more later. The meridian curve (north/south) is not as difficult to create as first imagined because the bricks can be easily staggered. The difficult bit is getting the east/ west axis to curve while remaining perpendicular to the meridian curve. Firmly bolting together the two halves of the cartwheel ensures the east/ west curve is set 90 degrees to the other curve.

The two halves of the cartwheel provide a datum point for all the



bricks and the future formwork as shown in Figure 10. The bolted semi-circles of the cart wheels ensured both faces are perpendicular. The wheel halves also need to be tilted to the angle of latitude.

After building up the east/ west bricks until they approximate the curve of the cartwheel, a form is built to create a more accurate surface or smoother finish. For this purpose, I first traced the cartwheel curve on to some MDF or any similar timber board and cut the curve out with a jigsaw. A rectangular strip of Masonite was then fixed to the MDF curve. This wooden form enabled two things to happen. Firstly, it provided me with the right curve and secondly, a place to pack fresh mud on to the base bricks. The mud took a few days to dry sufficiently to enable me to remove the masonite/MDF form. This mud curvature would then become the dial face for the all important hour lines.



The Masonite and MDF form is set into the square bricks by cutting a groove for the MDF curve as shown in Figure 11. Wet mud is slapped against and behind the form ensuring the hour line surface is both accurate and smooth.

When the form is removed the sundial is almost complete. All that remains to do now is the smoothing down operation and inscribing of the hours. The gnomon tilt is best checked for accuracy using both a triangle and an angle-measuring tool. The meridian is used to set the centre point for the hour lines. Since Melbourne is five degrees west of the time zone, it is best if the '12 o'clock' mark on the curve is offset by 20 minutes.

After the form is removed, the hour line curve is fairly prominent (see

Figure 12). The fun part of the project involves lots of rubbing and smoothing of the mud. By eliminating all the joins, the mud can produce an integrated surface. There are benefits for having a harder and smoother surface, water runs off and the mud lasts longer. Waterproofing of the mud can be done with a mix of mineral turpentine and linseed oil, at an approximate ratio of about 4:1.

The hour lines on the east west axis are all set 15 degrees apart, with the '12 o'clock' mark being the pivot point for all the others. A dressmaker's tape was used to find the distance between successive hours. I used 100mm galvanised nails to mark the eight hours on either side of the 12 o'clock datum point. I drilled some plastic numbers to hang on the nails. Around daylight savings time I can bump all the hours along.

So there it is a clock made of mud, which never needs to be wound up but still needs an occasional light oil. The first surviving equatorial sundial dates back to 340BCE when Berosus is credited with carving a hemispherium from a stone block. Maybe before Berosus carved his original from stone, he used mud to clarify his ideas.

Because it's all mud, there are any numbers of ways to finish off the curves (see Figure 13). On the east / west axis, I chose to gently merge the curve with its support base. I could not come up with anything very elegant other than the block and wedge look for the gnomon curve. From the side, the tall part of the structure leans over and could easily have ended up as a head of an animal or zodiac figure. The option of a suitable flower bed around the base is recommended after all the finishing touches have been made.

References:

Margaret Folkard & John Ward, Sundials Australia 2nd edition is the best reference for southern hemisphere sundial making. They explain all the reasons behind the necessary steps. The book contains all the essential algorithms to make nearly any kind of sundial. It has an extensive list of references and images from sundials all over the world.

Internet sites

Good general site and 'Equation of Time' graph

http://www.sundials.co.uk/home3.htm

Interesting background on the giant sundial at Jaipur

http://www.atco-fr.com/cadrans/jaipur/jaip_uk.php3

General site on equatorial sundials

http://www.wsanford.com/~wsanford/exo/sundials/equatorial_sundials.html

Example	Melbourne	Sydney	Brisbane	Adelaide	Perth
Approximate Longitude	145 ° East	151°	153°	139°	116°
Longitude of Time Zone	150° E	150°E	150 ° E	142°30' E	120° E
Approx. Longitude difference	-5°	+1°	+3°	-4°	-4°
Time Correction due to Longitude	+20 minutes	-4 minutes	-12 minutes	+16 minutes	+16 minutes
Local noon	12:20 pm	11:56 am	11:48 am	12:16 pm	12:16 pm

Figure 14
Table expressing the longitude correction for various capital cities.