July 17, 2006

CASE STUDY analemmatic dial for a garden

The local recreational center, where children on school breaks of vacations spend their time doing constructive things, is an ideal place the what is called the analemmatic dial. In essence it is an azimuth dial where there are no hour lines, only point on an ellipse, and there is no fixed gnomon, it moves north or south based on the month.

Constructing such a dial on the order of 20 feet across takes about an hour and in this example uses eleven 2x12x12 pavers and 8 bricks.

The method is simple. A north south line is constructed with a compass after considering magnetic variation or declination.

Then the spreadsheet: reference-spreadsheets.xls from the main Illustrating Shadows web site or on the CD that comes with the book is opened, and the latitude entered along with the east to west dimension of the ellipse.

The result is a set of calendar points for the gnomon positioning which will have the winter solstice closest to the equator, and the winter solstice closest to the pole, on a north to south line.

Additional results are the horizontal and vertical distances for the hour points.

ENTER	latitude	32
major ellipse east to west distance		16.00

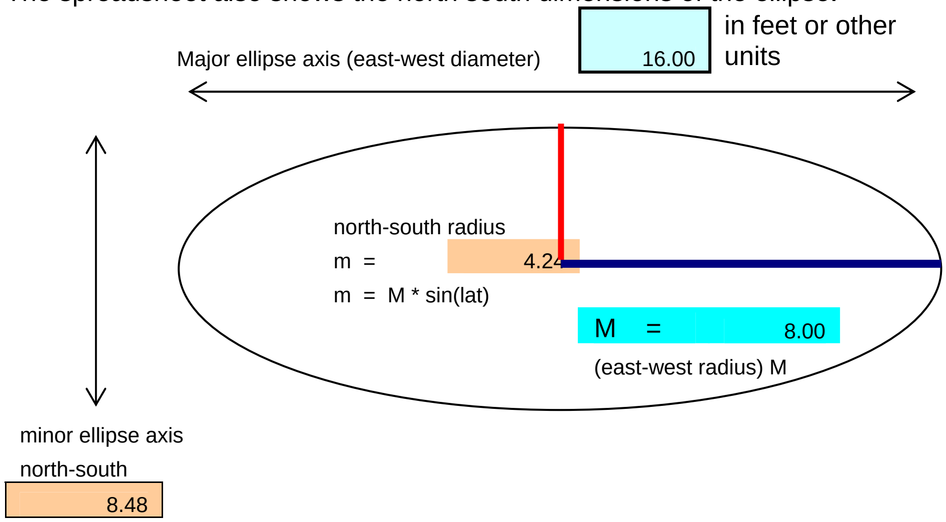
gnomon distance up/down north/south based on ellipse center = $z = M * \cos(lat) * \tan(dec)$

Date	Avg decl	Latitude 32	
Jan	-20.3	-2.51	-2.95
Feb	-12.5	-1.50	total
Mar	-1.6	-0.19	north to
Apr	9.6	1.15	south
May	18.4	2.26	distance is
Jun	22.5	2.81	5.90
Jly	20.9	2.59	assuming
Aug	14.1	1.70	plus and
Sep	3.8	0.45	minus
Oct	-7.4	-0.88	23.50
Nov	-17	-2.07	extremes
Dec	-22.1	-2.75	2.95

With the latitude and east west dimension entered, the spreadsheet provided the north and south distances for the base of the gnomon.

In this example of latitude 32 and a 16 foot wide ellipse, the January to June distances of the gnomon base range from minus 2.51 to plus 2.81, and for June to December the range is 2.81 to minus 2.75.

The spreadsheet also shows the north south dimensions of the ellipse.

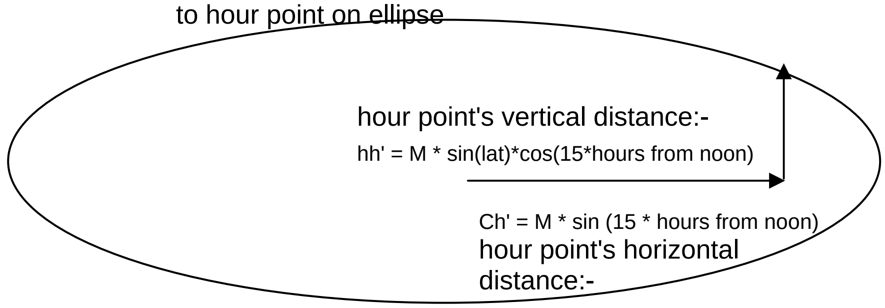


The ellipse is not drawn to scale, the pictorial is simply to help orient the diallist. At this point an ellipse can be drawn and the angles from the ellipse center used to identify the hour points. Alternatively the east west and the north south coordinates of the points can be used to locate the hour points.

horizontal and vertical distances from ellipse center to the hour point
for a semi major radius of 8.00

Latitude	0	Latitude	32
HOUR	HOUR	**horizontal**	**vertical**
am	pm	**Ch'**	**hh'**
12	12	0.00	4.24
11	13	2.07	4.09
10	14	4.00	3.67
9	15	5.66	3.00
8	16	6.93	2.12
7	17	7.73	1.10
6	18	8.00	0.00
5	19	7.73	-1.10
4	20	6.93	-2.12
am	pm		

x and y distance from center
to hour point on ellipse



First, select a suitable location, and ensure ants and other wildlife will not be a factor. These ants, about six feet from the winter end of the gnomon track are normally friendly. However for some reason the day the dial was built they became more than inquisitive. These ants are about 1/2 inch long.

Then the gnomon track was laid out, and this used a Brunton compass for alignment. The magnetic declination was 10.8 degrees easterly, thus a reading of 349 was required for correct alignment. Additionally, the east west axis of the eclipse was also measured both from the east and the west to minimize nearby magnetic disturbances from rebar or automobiles.

At about 9 pm the alignment was cross checked against the north star Polaris. This was done with a 6 foot wooden bar, used for the calendar information on the gnomon track. It was held vertical using its own weight and then sighted with the array track. Looking up at latitude, Polaris was sighted within close limits, remember, Polaris is not perfectly where the extended polar axis or the celestial polar axis, it is off, and precesses every 25,800 years.

Then for added measure, the astrocompass was used to check the other methods. Using the instructions in the book Illustrating Shadows, a time of 1033 daylight savings, or 0933 mountain standard time was used. The longitude correction for a sundial is 12 minutes 48 seconds. The equation of time on July 2, 2006 when this was double checked was to add 4 minutes 12 seconds to a dial. The total correction to mst being thus exactly plus 17 minutes. Of course, the azimuth method used for declining dials can also be used for aligning a horizontal object.

So, exactly 17 minutes is subtracted from the clock time to get the time used to calculate the hour angle. 0933 minus 17 minutes is 0916, which is 4 degrees (16 minutes of time) short of 45 degrees (3 hours) from noon. Or, 41 degrees from the noon line. The astrocompass was aligned and leveled, set to the latitude and approximate solar declination, and the local hour angle set to 41 minutes from noon. At the appointed time the shadow was found to well aligned.

Armed with this information the dial was laid out. An excellent project for the youth of the country.

There is a 6 foot wooden rod with dates marked on it, and a gnomon is placed on the north south line where the date indicates.

The gnomon casts a shadow and in this case the date rod is used to project the shadow to the hour point, it shows about ten minutes past 1 in the afternoon.

The equation of time must be factored in, 3 minutes to be added in this case, making it 1:13 pm.

And summer time must be added in making it 2:13 pm.

Longitude was not considered in this dial, although the spreadsheet can easily accommodate times on either side of the hour. In this case the dial was at longitude 108.2 and the legal time zone meridian was 105, making about 12 minutes to be added. Making the final correct time about 2:25 in the afternoon, which was quite close.

The dial columns have been mortared and the dial ready for a more permanent life.

The formulae are straightforward:-

lat	=	latitude
M	=	major axis (east to west) radius
dec	=	declination for the calendar date

gnomon distance up/down north/south based on

ellipse center = z = M * cos (lat) * tan (dec)

north-south radius

m = M * sin(lat)

angle from dial center to the hour point

x = arctan (tan(hour from noon * 15) / sin (latitude))

hour point's vertical distance from dial center north/south)

hh' = M * sin(lat)*cos(15*hours from noon)

hour point's horizontal distance:-

Ch' = M * sin (15 * hours from noon)

The sun's declination used for the calendar displacement can be found in tables or calculated. The simplest formula is possibly:

dec = (23.45*sin(radians(0.9678(jd-80)))) alternative formula agrees within half a degree

where

jd = julian day of the year.