Feb 2, 2006

A LUNAR DIAL DESIGNED JUST FOR THE MOON

There are several techniques that allow the time to be read from the moon. This also brings into light the definition of being a purist; is a purist someone who in this context seeks the most accurate timepiece, or is a purist one who uses just the moon, albeit empirically, and excludes references to the sun. Three techniques spring to mind, they are:-

- A lunar dial using a sundial and a correction table
- A lunar dial using the moon but with solar associations in it's mathematics
- A lunar dial using just the moon

A lunar dial using a sundial and a correction table – some old dials may have this table

A sundial itself can be used, however some adjustments are required. First, an earthling's hour is marked by about 14.5° of lunar orbit around the earth's polar axis, compared to 15° for the sun. Thus solar hours would be larger by half a degree, in other words 2 minutes. In 24 hours, that accounts for 12 degrees, or in earthling terms, 48 minutes. Thus a table can be drafted such that the moon's phase indicates the time to be added to or subtracted from the sundial's 12 o'clock midnight baseline time. Of course those 2 minutes per hour must also be considered for the hours on either side of 12 o'clock.

In the mid 1700's such a table was used that assumed a 30 day lunar cycle, however there are other variables that make this method somewhat impractical. At 15 days after the new moon, i.e. a full moon, 12 hours is added to the dial, thus 12 noon means 12 midnight. Again, this was an approximation.

Before and after full moon one must remember to subtract or add as appropriate. This system works with a little effort, and requires the date of the new or full moon to be known. Of course, it still needs some fine tuning since full moon happens at a specific date, time, and place and that may not be over your dial. Lunar dials are not known for their accuracy.

		30 day
Days before full moon	Days after full moon	Hours to adjust dial LAT
7	7	6.4
6	6	7.2
5	5	8.0
4	4	8.8
3	3	9.6
2	2	10.4
1	1	11.2
0	0	12.0

A lunar dial using the moon but with solar associations in it's mathematics

The most accurate method is to use the moon's orbital information in conjunction with that of the sun's apparent earthly orbit, and from thence, derive an accurate system.

Here is a method of determining new moon, first quarter, full moon, and last quarter for any date. The following formulae are approximations of approximations, and are drawn from chapter 32 p159 of Astronomical Formulae for Calculators, Jean Meeus. Some of the formulae in that book have been simplified elsewhere in this book. The formulae use an epoch base of 1900 which is somewhat academic, however it emphasizes the need for formulae not to be mixed from author to author, or article to article. Many books use the year 2000 as the epoch base.

Additionally, these figures are for the **mean lunar cycle**. That is 29 days, 12 hours, 44 minutes, 3 seconds, however interaction with the sun can vary this by about 6 hours on either side.

Intermediate figures

M23	=	mm/12
N23	=	(dd/30)/12
O23	=	(mm+N23)/12
P23	=	O23+yyyy
k	=	(P23-1900)*12.3685
int~of~k	=	INT(k)
T	=	k/1236.85

Julian date for new moon, first quarter, full moon, third quarter, nearest to the specified date.

```
=2415020.75933 + 29.53058868 * (int~of~k + 0.00) + 0.0001178*T*T - 0.000000155*T*T*T
=2415020.75933 + 29.53058868 * (int~of~k + 0.25) + 0.0001178*T*T - 0.000000155*T*T*T
=2415020.75933 + 29.53058868 * (int~of~k + 0.50) + 0.0001178*T*T - 0.000000155*T*T*T
=2415020.75933 + 29.53058868 * (int~of~k + 0.75) + 0.0001178*T*T - 0.000000155*T*T*T
```

Julian date you can use as a base for the above dates

```
=INT(365.25 * (4716 + (IF((IF(mm>2,1,0))=0, yyyy-1, yyyy))) +
        INT(30.6001*((IF((IF(mm>2,1,0))=0, mm+12, mm))+1))) + dd-1524.5 +
        (2-INT((IF((IF(mm>2,1,0))=0, yyyy-1, yyyy))/100) +
        INT(INT((IF((IF(mm>2,1,0))=0, yyyy-1, yyyy))/100)/4))
```

It is emphasized that these formulae are approximations, and should be treated in that light. These formulae are in the generalized spreadsheet on the web site:-

www.illustratingshadows.com/reference-spreadsheets.xls

The same spreadsheet also has the formulae to convert mean lunar phase data to true lunar phase data.

A lunar dial using just the moon

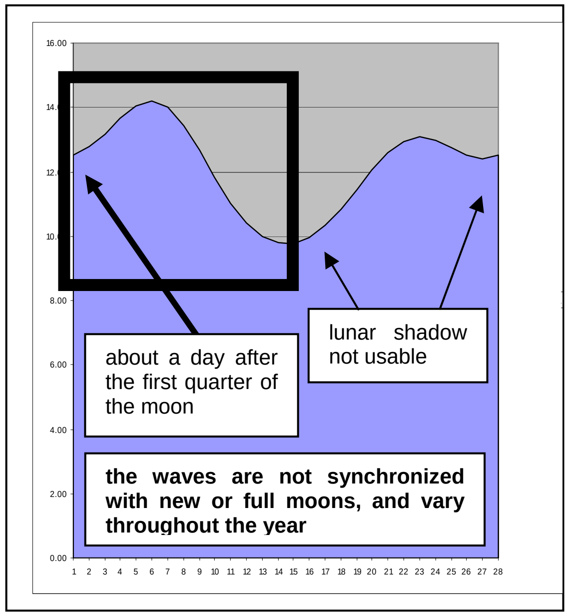
The lunar dial discussed in this section does not require the above formulae, it is simply set when the observer detects a first quarter of the moon, and rotated each day by 12.2 degrees eastward. Simpler to use and more practical than a sundial with a table of corrections, yet not as accurate as a lunar dial based on solar data, this is the lunar dial that uses just the moon itself.

A dial plate designed for 14.5 degree hour angles and an adjustment for 12.2 degrees per day can be used based on the observation of the phase of the moon. An armillary dial can also be used, as can an equatorial dial, all of these will require a daily rotational adjustment, be that mechanical or mathematical.

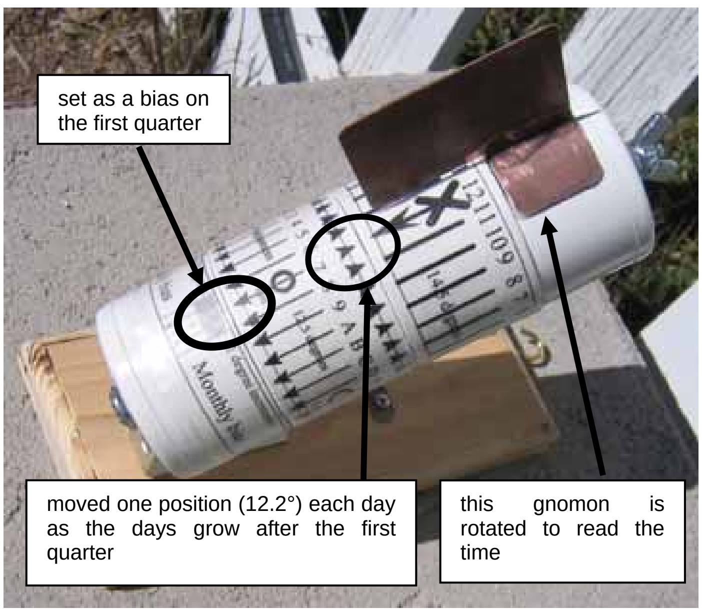
Because the moon's apparent orbit around the earth is a bit slower than the sun's, an hour uses less lunar degrees around the earth's polar axis than does the sun. Since the moon retards about 2 minutes per earth hour, that is in polar axis hour angles 1/2 a degree since 1 degree represents 4 minutes. Thus a lunar hour is indicated by about 14.5° and not 15 which is used for the sun.

Because a mean lunar month is about 29.5 days (a true lunar month may vary from the mean by 6 hours), and because this must account for 360 degrees of rotation before the moon is back in synchronization with itself, this means a daily rotation backwards of about 12.2 degrees is required. An analysis of almanacs over 40 years shows that the actual daily adjustment can be as little as 9.5 or as much as 14.6 degrees, and the day to day variation may be as much as 1 degree plus or minus. There are a couple of waves of this variation throughout the lunar month. Thus this dial needs to be set on the first usable day (first quarter) and would probably need fine tuning once or twice over the next two weeks which is the life of the usable shadow. An example of two weeks of data starting on the day after a first quarter moon of March, 2003.

				Daily shift	Daily diff
2003					
Mar	349	8	349.13		
	336	36	336.60	12.53	
	323	50	323.83	12.77	-0.23
	310	40	310.67	13.17	-0.40
	297	1	297.02	13.65	***-0.48***
	282	58	282.97	14.05	-0.40
	268	45	268.75	***14.22***	-0.17
	254	45	254.75	14.00	0.22
	241	19	241.32	13.43	0.57
	228	39	228.65	12.67	0.77
	216	50	216.83	11.82	***0.85***
	205	48	205.80	11.03	0.78
	195	23	195.38	10.42	0.62
Apr	185	24	185.40	9.98	0.43
	175	37	175.62	***9.78***	0.20



Because the sun's maximum declination is 23.5 degrees and the moon has a 5 degree orbital offset, it's declination range is 28.5 degrees, or a peak to peek range of 57 degrees.



Because of the need for a daily dial rotation, and the fact that the baseline to start the two weeks of good lunar use varies, the following dial is easy to build and to use.

To the left is a picture of the dial. The top rotating section is a moving gnomon, it is turned to get a null shadow.

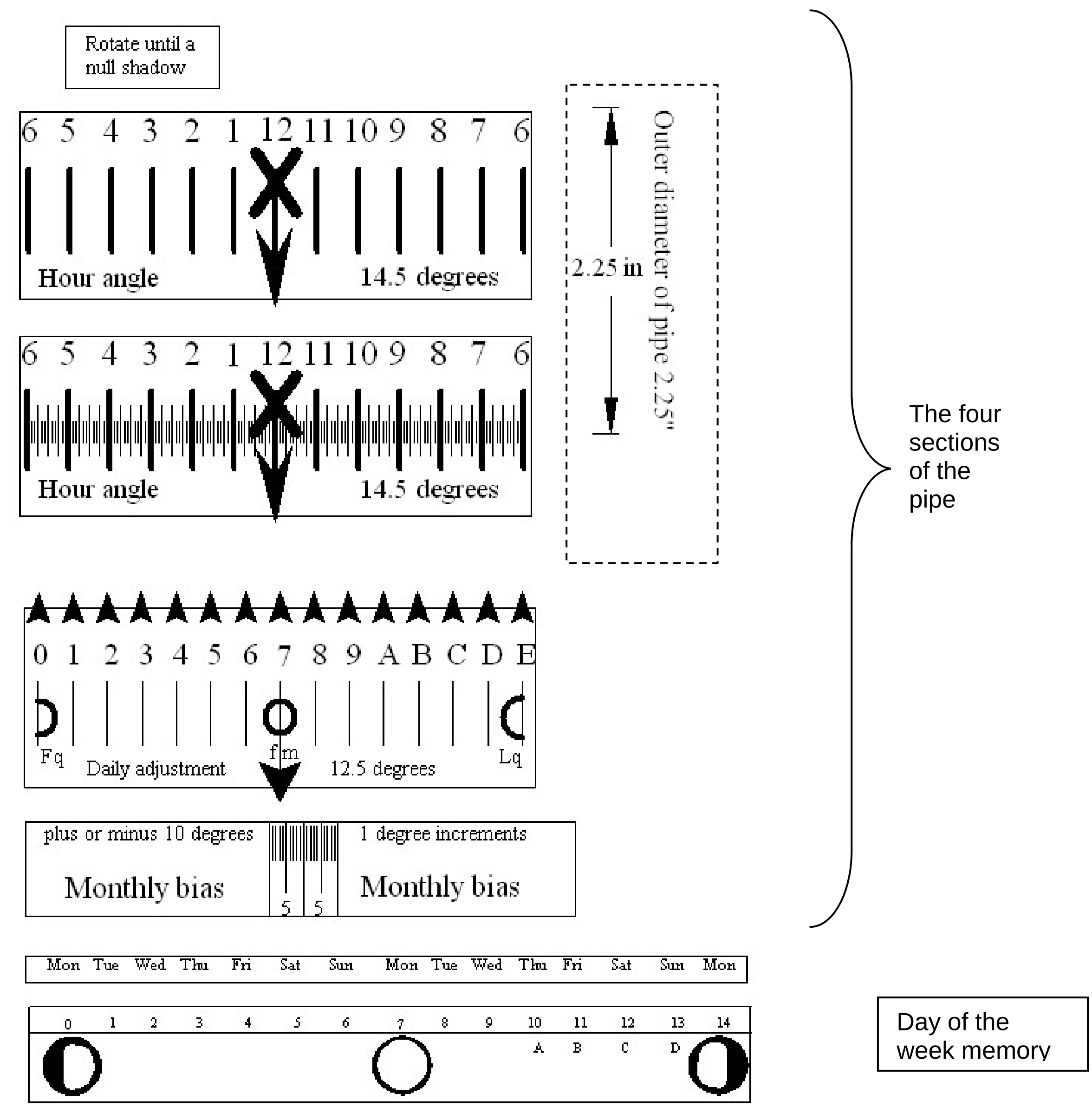
That null shadow causes the extension of the gnomon to indicate the time on the next rotating section down. In this case it is being used in the daytime with an assumption that 14.5 degree hour line angles is close to 15 degree angles. It indicated 1 pm.

The 12 o'clock hour line on the second rotating section has an arrow pointing down, which is set to the day from the first quarter, the days are numbered 0-14, or as 0-9, and A-E. For people who go to bed early, days 0 through 9 work well, for late night people, all 14 days are usable.

That two week lunar span is also rotated. On the first quarter, the second section up which holds the 14 days after the first quarter, is rotated around the lowest or first section, to calibrate the time against a standard time watch. This corrects for lunar variations up to the first quarter, as well as the dial's longitude. This way the days of usable lunar shadow don't need daily fine tuning, the hour section is simply always rotated to the next day, not to a few degrees before or after it. A recalibration at full moon is probably needed because of the moon's inconsistencies.

This lunar dial also has a fourteen day calendar, not visible in this picture, so that the sliding days can be used as a reminder as to which day in the two usable weeks it is. The sun rotates around the earth's polar axis, so does the moon except it rises and sets close to the ecliptic, it's orbit being within about 5° of the ecliptic, or the sun's apparent orbit around the earth.

Because of the many and less easily predictable variations in the lunar orbit, by the day, month, and year, these dials are not excessively accurate, and probably need recalibration every few days, maybe set once on the first quarter, and again on the full moon. The appendices have a larger version of the following template which needs scaling to the correct scale.



The above pictorial can be rescaled for any desired PVC piping, it was designed for a 2.25 outer diameter PVC pipe.

This is not an all inclusive guide to lunar dials, rather a starting point from which to work, and that starting point is a working lunar dial.