

MICRO Shadows



for smartphones

How to make a simple horizontal
sun dial
COOK BOOK FORMAT
NO THEORY

condensed from the full version of this book

Simon Wheaton-Smith
October 2012

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FREE

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A QUICK HANDS ON PROJECT BUILD IT FIRST – FIX IT NEXT

The next two pages offer a simple "go ahead and build it" horizontal sundial, then see what needs to be done to make it accurate. The rest of the book is the other way around, theory to understand what is going on, then build it. These two pages help you build a horizontal dial and for all readers, this is a good prelude to the rest of the book. And now, some questions...

1. What is your latitude (how far north or south are you from the equator). Many maps show this, and so does a GPS. In the appendices, Table A2.5 may help.

my latitude is:	
-----------------	--

2. **EITHER** download the spreadsheet at:

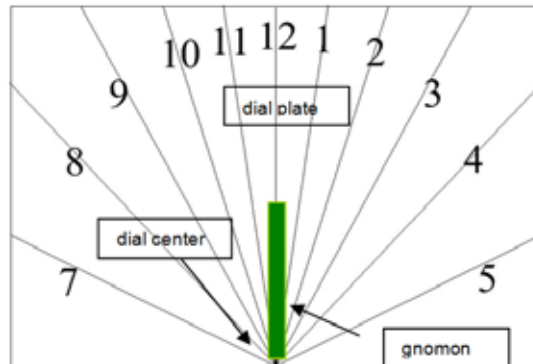
www.illustratingshadows.com/microShadows.xls

then enter the latitude. **OR** go to tables A3.1a, A3.1b, or A3.1c in the appendices, look at the latitude at the top of the columns, then find the angles for the hours you wish marked.

6am	6pm	hour line angle	
7am	5pm	hour line angle	
8am	4pm	hour line angle	
9am	3pm	hour line angle	
10am	2pm	hour line angle	
11am	1pm	hour line angle	
noon		hour line angle	

3. Mark the lines on the template "A DRAFTING SHEET FOR HORIZONTAL DIALS" from the appendices. The end result should look roughly like the fan of lines below.

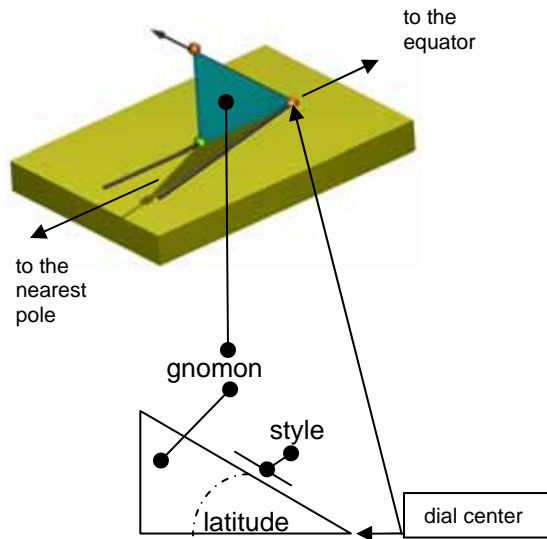
Noon is going to be on the north south line and the 6am and 6pm lines will be at 90 degrees to that, The other lines will fan out, and their angles depend on your latitude.



Transpose the hour lines to wood, PVC, copper, glass, concrete, or any other medium. This is called the dial plate.

Build a shadow casting device, called a gnomon, it is a triangle whose angle from the dial plate is equal to the latitude. The angle is important, the length is not, unless you want to add other information related to the time of year, discussed in the main part of the book. **NOTE:** the gnomon should be thin. If it is thick as shown above, then the am and

Affix the gnomon to the dial plate, the latitude angle end rests on top of where the hour lines converge (dial center), and it lies on the north south line, or the noon line.



4. Transpose the hour lines to wood, PVC, copper, glass, concrete, or any other medium. This is called the dial plate.
5. Build a shadow casting device, called a gnomon, it is a triangle whose angle from the dial plate is equal to the latitude. The angle is important, the length is not, unless you want to add other information related to the time of year, discussed in the main part of the book. **NOTE:** the gnomon should be thin. If it is thick as shown above, then the am and pm hours should be separated at noon to account for it.
6. Affix the gnomon to the dial plate, the latitude angle end rests on top of where the hour lines converge (dial center), and it lies on the north south line, or the noon line.
7. Take the dial plate, it's affixed gnomon on the noon line and place it in the sun.
8. Align the noon line with north/south, and the gnomon's end placed on dial center (where it meets the hour lines), should point to the equator, south in the northern hemisphere or north in the southern hemisphere.

By north, true north is meant, not the north where a compass points. To find true north, first find magnetic north by using a compass but keep away from metal.

Then find your location's magnetic variation, or declination as sun dial people call it. If it is an easterly declination you must back away from north to the west. If it is a westerly declination, you must back away from north to the east. Magnetic declinations are often found on maps, and a table and a map in the appendix has declination information.

my magnetic declination:		E
		W

Table A2.5 and the maps in appendix 2 may help, and many websites also, you may try:

<http://www.magnetic-declination.com/>

9. With the dial plate level, the angled part of the gnomon pointing north south, the dial will now read sun-time, or local-apparent-time or LAT for short. It is still not clock accurate. There are **two corrections** to make. One is to correct for your distance from your time zone's reference **longitude**, the other is for the fact the sun is predictably slow or fast (compared to man made watches) as the year progresses, this correction is called the **equation of time** or **EOT for short**.
10. Find your **longitude**, it is on your GPS unit, or on a map of your area. Aviation and geological survey maps work, but road maps may not. Once you know your longitude, and your time zone, find your time zone's reference longitude.

my longitude is:	
Table A2.5 in the appendices may help.	
my time zone reference is:	
Table A2.6 in the appendices may help.	
difference between the two is:	
↓	
times 4 is:	_____ minutes

If your longitude is larger than the reference longitude, then ADD the difference times 4, this is the minutes to add to correct for your location.

If your longitude is smaller than the reference longitude, then SUBTRACT the difference times 4, this is the minutes to add to correct for your location.

plus [] or minus [] _ _ _ minutes to correct for location.

11. We now have a dial built for your latitude, aligned north/south, and corrected for your location's distance from the time zone's reference longitude. However it may still be off by plus or minus up to 16 minutes due to the fact the sun's orbit around the earth varies as the year progresses, and the sun similarly moves north or south of the equator. There is a table of corrections for this **equation of time or EOT**, table A2.1 is by the day.
12. That is it! You now have a working horizontal sun dial. To delve into it more, read on....

13. THE EVOLUTION OF THE DIAL

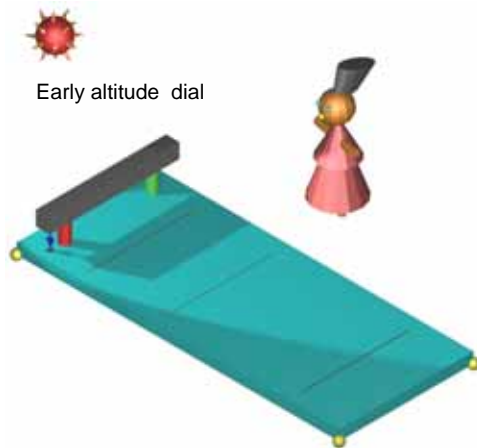
USEFUL DEFINITIONS –

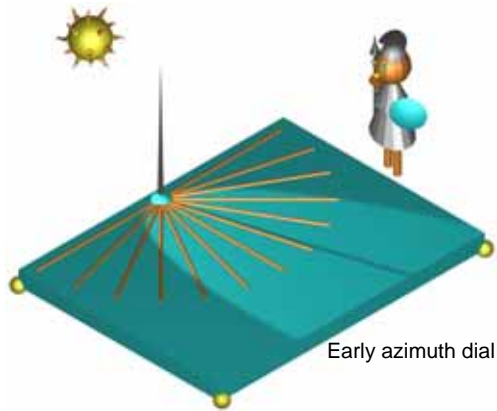
- The **EOT**, or **equation of time** is the difference between the real apparent sun and a virtual perfectly on-time sun that matches the modern "accurate" clock
- Altitude – how high above the horizon the sun is, measured in degrees.
- Azimuth ~ how far east or west of the north-south line the sun is, measured in degrees.

Since the earliest days of the human race, it was important to know when to plant, when to hunt, and a calendar was needed and developed. The sun's angle in the sky compared to the horizon, is its altitude, and early Egyptians employed such dials.

The sun woke up and climbed, ran out of energy in mid day, and becoming tired, descended into the arms of Morpheus. The early Egyptians built a simple dial that could be turned toward the sun, and its angle at mid day cast a shadow of decreasing length as the climate became warmer. Alignment with true north or south was not needed for these altitude measuring dials, since the reference was the sun, and the horizon.

For all altitude dials, north south alignment is not used but the date must be known if the one is to tell the time.





As time became more important than the calendar, early Greeks, Arabs, and Romans had business to conduct. And so developed a sundial that measured the azimuth of the sun, its angle compared with true north or south. Such early dials often divided daylight into pieces, yet those pieces were not always of equal duration, sometimes they were just arbitrary divisions. Azimuth dials do not required a gnomon of a calculated height. The line of the shadow aligns with hour lines, or points to hour points.

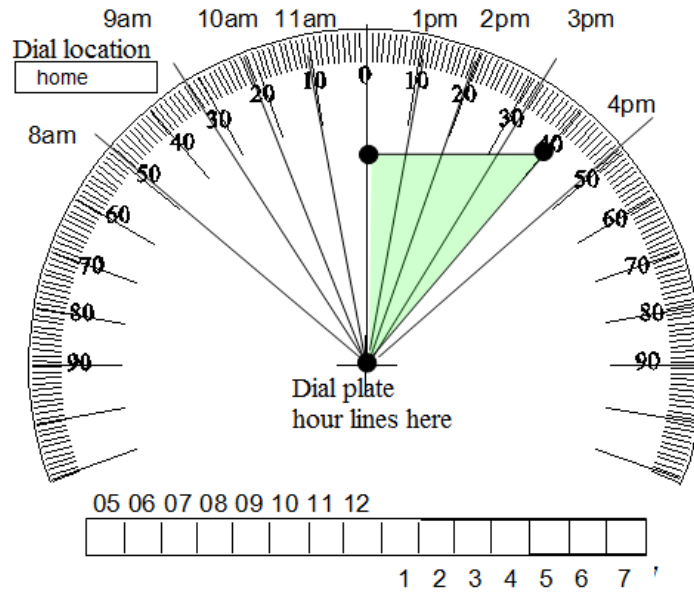
Of course time, altitude, and azimuth are all somewhat related. And a definitive study of dial history may not show such a sequenced development because different areas of the world evolved differently. As the horse and carriage produced rapid transportation, people needed common time keeping, and equal hours. So was ushered in the perfected sundial. That perfected dial used the angle the sun makes as it appears to orbit around the earth's north-south polar axis.

The reader may have noticed that the sun runs slow or fast depending on the day of the year.

Sun dials use the solar position as the basis for date and for time. The earth orbits the sun, however not by an exact number of days, and even those days vary in an annual cycle. So even city slicker watches are not synchronized as well as we might think. Is the synchronization with the daily rotation of the earth, the annual rotation around the sun, or with the fixed stars?

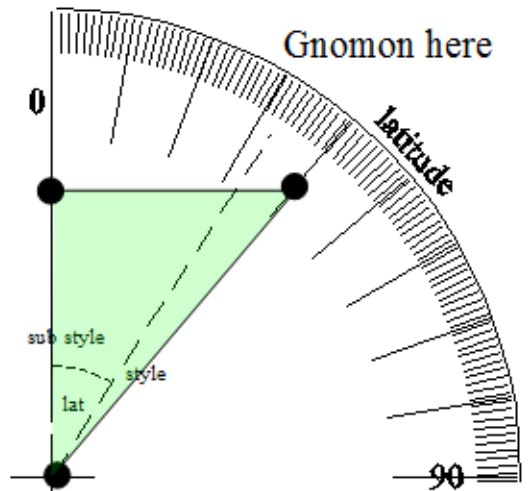
HORIZONTAL DIAL: Method: Using Tables and protractor

Protractor for the hour lines...



Magnetic declination: _____ Horizontal dial

Protractor for the gnomon...



Latitude: _____

Longitude: _____

Legal meridian: _____

long. corr: _____

Equation of time:

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
+9 +14 +9 =0 -3 0 +6 +4 -5 -14 -15 -5

--	--	--	--	--	--	--	--	--	--	--	--

Appendix 3 table A3.1b for latitude 40 provides the following hour line angles assuming no longitude correction.

8am and 4pm 48.07 degrees
 9am and 3pm 32.73 degrees
 10am and 2pm 20.36 degrees
 11am and 1pm 9.77 degrees etc

The hour lines before and after noon are drawn. The gnomon is drawn and moved to dial center. The longitude correction of 4 degrees (at 4 minutes per degree) is 16 minutes, and is west of longitude 105 thus we must add the time. The longitude correction of 16 minutes is added to the equation of time, producing:-

Jan	Feb	Mar	Apr	May	Jun	Jly	Aug
	Sep	Oct	Nov	Dec			
+25	+30	+25	+16	+13	+16	+22	+20
	+11	+2	+1	+11			

The dial plate is aligned to true north, and the shadow is mentally corrected with the revised equation of time (EOT).

Alternatively the hour lines could be adjusted individually for longitude, however the dial would no longer be portable. If the hour lines were longitude adjusted, they would simple be rotated, but by an angle calculated for a time corrected by the 16 minutes, one hour line at a time. The equinox line is derived by extending the gnomon from the nodus to the sub-style line extended, and perpendicular to the style. Longitude corrections of 4 or more degrees cause the resulting combined EOT table to always have the same sign. That is because 4 degrees is 16 minutes, the maximum EOT deviation. This paper dial can be tested in the sun before the final dial is built as is shown in the inset.

APPENDIX 2 - Tables independent of location

EQUATION OF TIME ~ EOT

If "+" then add to solar time to get mean time as the sun is slow. If "-" then subtract from solar time to get mean time as the sun is fast. Some tables have a plus for our minus and vice versa. If in doubt look at the figure of eight equation of time. **Formulae involving dates** use approximations thus these tables may disagree with other sources using other formulae. This and other publications have figures that are well within drafting tolerances.

A2.1

	5th	15th	25th	EOT ₌₀
JAN	5.1	9.0	12.0	
FEB	13.9	14.2	13.4	
MAR	11.9	9.3	6.3	
APR	2.8	0.0	-2.3	4/15
MAY	-3.6	-4.0	-3.5	
JUN	-2.0	-0.1	2.0	6/15
JLY	3.9	5.3	5.9	
AUG	5.4	3.8	1.4	
SEP	-2.2	-5.8	-9.4	9/1
OCT	-12.7	-15.1	-16.5	
NOV	-16.5	-15.1	-12.5	
DEC	-8.8	-4.5	0.2	12/25

A2.3

LONGITUDE TO TIME

Degree (°) to Hours (h) and Minutes (m)

° ° ° ° ° ° |

0	0.00	30	2.00	60	4.00	90	6.00	120	8.00	150	10.00
1	0.04	31	2.04	61	4.04	91	6.04	121	8.04	151	10.04
2	0.08	32	2.08	62	4.08	92	6.08	122	8.08	152	10.08
3	0.12	33	2.12	63	4.12	93	6.12	123	8.12	153	10.12
4	0.16	34	2.16	64	4.16	94	6.16	124	8.16	154	10.16
5	0.20	35	2.20	65	4.20	95	6.20	125	8.20	155	10.20
6	0.24	36	2.24	66	4.24	96	6.24	126	8.24	156	10.24
7	0.28	37	2.28	67	4.28	97	6.28	127	8.28	157	10.28
8	0.32	38	2.32	68	4.32	98	6.32	128	8.32	158	10.32
9	0.36	39	2.36	69	4.36	99	6.36	129	8.36	159	10.36
10	0.40	40	2.40	70	4.40	100	6.40	130	8.40	160	10.40
11	0.44	41	2.44	71	4.44	101	6.44	131	8.44	161	10.44
12	0.48	42	2.48	72	4.48	102	6.48	132	8.48	162	10.48
13	0.52	43	2.52	73	4.52	103	6.52	133	8.52	163	10.52
14	0.56	44	2.56	74	4.56	104	6.56	134	8.56	164	10.56
15	1.00	45	3.00	75	5.00	105	7.00	135	9.00	165	11.00
16	1.04	46	3.04	76	5.04	106	7.04	136	9.04	166	11.04
17	1.08	47	3.08	77	5.08	107	7.08	137	9.08	167	11.08
18	1.12	48	3.12	78	5.12	108	7.12	138	9.12	168	11.12
19	1.16	49	3.16	79	5.16	109	7.16	139	9.16	169	11.16
20	1.20	50	3.20	80	5.20	110	7.20	140	9.20	170	11.20
21	1.24	51	3.24	81	5.24	111	7.24	141	9.24	171	11.24
22	1.28	52	3.28	82	5.28	112	7.28	142	9.28	172	11.28
23	1.32	53	3.32	83	5.32	113	7.32	143	9.32	173	11.32
24	1.36	54	3.36	84	5.36	114	7.36	144	9.36	174	11.36
25	1.40	55	3.40	85	5.40	115	7.40	145	9.40	175	11.40
26	1.44	56	3.44	86	5.44	116	7.44	146	9.44	176	11.44
27	1.48	57	3.48	87	5.48	117	7.48	147	9.48	177	11.48
28	1.52	58	3.52	88	5.52	118	7.52	148	9.52	178	11.52
29	1.56	59	3.56	89	5.56	119	7.56	149	9.56	179	11.56
										180	12.00

A2.5

CITY DATA WITH LATITUDE, LONGITUDE AND ITS CORRECTION

City id				Lat	Long	Mag var	Time ref	Long
				+n -s	+w -e			corr
	UK		London	51.5	0.5	2.5w	0	2
	UK		Weymouth	50.6	2.5	3.4w	0	10
PHX	USA	AZ	Phoenix	33.5	112.0	11.8e	105	28
SDL	USA	AZ	Scottsdale	33.6	111.9	11.8e	105	27.6
LAX	USA	CA	Los Angeles	34.0	118.3	13.4e	120	-6.8
SAN	USA	CA	San Diego	32.8	117.2	13.1e	120	-11.2
SFO	USA	CA	San Fransisco	37.8	122.5	15.4e	120	10
DEN	USA	CO	Denver	39.8	105.0	10.2e	105	0
DCA	USA	DC	Washington	38.9	77.0	10.3w	75	8
CHI	USA	IL	Chicago,	41.8	87.8	2.2w	90	-8.8
SVC	USA	NM	Silver City	32.8	108.2	10.6e	105	12.8
LAS	USA	NV	Las Vegas	36.2	115.2	13.3e	120	-19.2
JFK	USA	NY	New York	40.7	73.8	13.8w	75	-4.8
ELP	USA	TX	El Paso	31.8	106.5	10.1e	105	6

A2.6

DAYLIGHT SAVING TIME AND TABLE OF TIME ZONES

Zone	Name	Meridian	GMT+
	Newfoundland	52.5	3.5
4	Atlantic	60	4
5	Eastern	75	5
6	Central	90	6
7	Mountain	105	7
8	Pacific	120	8
9	Yukon	135	9
10	Alaska-Hawaii	150	10
11	Bering	165	11
	GMT Greenwich Mean Time		0
	BST British Summer Time		-1
	IST Irish Summer Time		-1
	WET Western Europe Time		0
	WEST Western Europe Summer Time		-1
	CET Central Europe Time		-1
	CEST Central Europe Summer Time		-2
	EET Eastern Europe Time		-2
	EEST Eastern Europe Summer Time		-3
	MSK Moscow Time		-3
	MSD Moscow Summer Time		-4

SUMMER TIME RULES

USA: whatever congress has decided on the spur of the moment

EU: last Sunday in March to the last Sunday in October.
 The website: <http://webexhibits.org/daylightsaving/> has other useful information.

APPENDIX 3

TABLES THAT CONSIDER LOCATION

HORIZONTAL (AND VERTICAL DIAL) HOUR LINE ANGLES

hour angle	Horizontal dial
hour angle	DEGREES(ATAN(TAN(RADIANS(15*time))*SIN(RADIANS(lat))))
hour angle	H = atan (sin(lat) * tan (ha))

TIME	33	34	35	36	37	38	39	
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	noon
0.25	2.04	2.10	2.15	2.21	2.26	2.31	2.36	11.75
0.50	4.10	4.21	4.32	4.42	4.53	4.63	4.74	11.50
0.75	6.18	6.35	6.51	6.67	6.83	6.98	7.14	11.25
1	8.30	8.52	8.74	8.95	9.16	9.37	9.57	11
1.25	10.47	10.75	11.02	11.28	11.55	11.80	12.06	10.75
1.50	12.71	13.04	13.36	13.68	14.00	14.31	14.61	10.50
1.75	15.03	15.42	15.79	16.16	16.53	16.89	17.24	10.25
2	17.46	17.89	18.32	18.75	19.16	19.57	19.97	10
2.25	20.00	20.49	20.97	21.44	21.91	22.36	22.81	9.75
2.50	22.68	23.22	23.76	24.28	24.79	25.29	25.78	9.50
2.75	25.53	26.12	26.70	27.27	27.82	28.37	28.89	9.25
3	28.57	29.21	29.84	30.45	31.04	31.62	32.18	9
3.25	31.84	32.52	33.19	33.83	34.46	35.07	35.66	8.75
3.50	35.37	36.08	36.78	37.45	38.11	38.74	39.36	8.50
3.75	39.18	39.93	40.64	41.34	42.01	42.66	43.28	8.25
4	43.33	44.08	44.81	45.51	46.19	46.84	47.47	8
4.25	47.84	48.59	49.31	50.00	50.67	51.31	51.92	7.75
4.50	52.75	53.47	54.16	54.83	55.46	56.07	56.65	7.50
4.75	58.07	58.74	59.38	59.99	60.57	61.13	61.66	7.25
5	63.80	64.40	64.96	65.49	66.00	66.48	66.94	7
5.25	69.94	70.42	70.87	71.30	71.71	72.10	72.46	6.75
5.50	76.41	76.75	77.07	77.38	77.66	77.93	78.18	6.50
5.75	83.14	83.31	83.48	83.64	83.78	83.92	84.05	6.25
6	90.00	90.00	90.00	90.00	90.00	90.00	90.00	6

NOTE: Values are degrees and tenths and hundredths of a degree. Thus latitude 39 at 1pm or 11am shows 9.57 degrees, not 9 degrees, 57 minutes. And 9.57 degrees converts to 9 degrees 34.2 minutes of arc, which is consistent with other publications.

TIME	40	42	44	45	46	48	49	
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	noon
0.25	2.41	2.51	2.61	2.65	2.70	2.79	2.83	11.75
0.50	4.84	5.03	5.23	5.32	5.41	5.59	5.67	11.50
0.75	7.29	7.58	7.87	8.01	8.14	8.41	8.54	11.25
1	9.77	10.16	10.54	10.73	10.91	11.26	11.43	11
1.25	12.31	12.80	13.27	13.50	13.72	14.16	14.37	10.75
1.50	14.91	15.49	16.05	16.32	16.59	17.11	17.36	10.50
1.75	17.59	18.26	18.91	19.22	19.53	20.13	20.41	10.25
2	20.36	21.12	21.85	22.21	22.55	23.22	23.54	10
2.25	23.24	24.09	24.90	25.29	25.67	26.41	26.76	9.75
2.50	26.25	27.18	28.06	28.48	28.90	29.69	30.08	9.50
2.75	29.41	30.40	31.35	31.80	32.25	33.09	33.50	9.25
3	32.73	33.79	34.79	35.26	35.73	36.62	37.04	9
3.25	36.24	37.34	38.38	38.88	39.36	40.28	40.71	8.75
3.50	39.95	41.09	42.15	42.66	43.15	44.08	44.53	8.50
3.75	43.89	45.04	46.11	46.62	47.11	48.04	48.48	8.25
4	48.07	49.21	50.27	50.77	51.25	52.16	52.58	8
4.25	52.50	53.61	54.63	55.11	55.57	56.43	56.84	7.75
4.50	57.20	58.24	59.19	59.64	60.07	60.87	61.24	7.50
4.75	62.16	63.10	63.96	64.36	64.74	65.45	65.78	7.25
5	67.37	68.18	68.91	69.25	69.57	70.17	70.45	7
5.25	72.81	73.44	74.02	74.29	74.54	75.02	75.23	6.75
5.50	78.43	78.87	79.27	79.45	79.63	79.95	80.10	6.50
5.75	84.18	84.41	84.61	84.70	84.79	84.96	85.04	6.25
6	90.00	90.00	90.00	90.00	90.00	90.00	90.00	6

TIME	50	52	54	55	56	58	59	
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	noon
0.25	2.87	2.96	3.04	3.07	3.11	3.18	3.22	11.75
0.50	5.76	5.92	6.08	6.16	6.23	6.37	6.44	11.50
0.75	8.66	8.91	9.14	9.25	9.36	9.57	9.68	11.25
1	11.60	11.92	12.23	12.38	12.52	12.80	12.94	11
1.25	14.58	14.98	15.36	15.54	15.72	16.06	16.22	10.75
1.50	17.60	18.08	18.53	18.74	18.95	19.35	19.55	10.50
1.75	20.70	21.24	21.75	22.00	22.24	22.70	22.91	10.25
2	23.86	24.46	25.04	25.31	25.58	26.09	26.33	10
2.25	27.11	27.77	28.39	28.69	28.98	29.54	29.80	9.75
2.50	30.45	31.16	31.83	32.15	32.46	33.05	33.33	9.50
2.75	33.89	34.65	35.36	35.69	36.02	36.64	36.93	9.25
3	37.45	38.24	38.97	39.32	39.66	40.30	40.60	9
3.25	41.14	41.94	42.69	43.05	43.39	44.04	44.35	8.75
3.50	44.95	45.76	46.51	46.87	47.21	47.86	48.17	8.50
3.75	48.90	49.70	50.45	50.80	51.13	51.77	52.06	8.25
4	53.00	53.77	54.49	54.82	55.15	55.75	56.04	8
4.25	57.23	57.96	58.64	58.95	59.25	59.82	60.09	7.75
4.50	61.60	62.27	62.89	63.18	63.45	63.97	64.21	7.50
4.75	66.10	66.69	67.24	67.49	67.73	68.18	68.40	7.25
5	70.72	71.22	71.67	71.89	72.09	72.47	72.64	7
5.25	75.44	75.83	76.19	76.35	76.51	76.80	76.94	6.75
5.50	80.25	80.52	80.76	80.87	80.98	81.18	81.27	6.50
5.75	85.11	85.25	85.37	85.43	85.48	85.58	85.63	6.25
6	90.00	90.00	90.00	90.00	90.00	90.00	90.00	6

A DRAFTING SHEET FOR HORIZONTAL DIALS

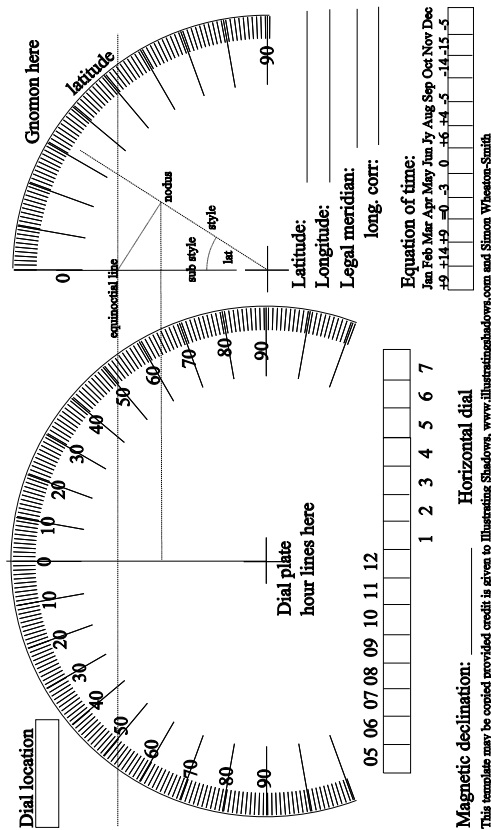
APPENDIX 9

BOOKS

ref 1 Illustrating Time's Shadow, how to make MANY Sundials for anywhere using empirical, geometric, and trigonometric methods as well as computer aided design and the spreadsheet. By Simon Wheaton-Smith

Library of Congress Control Number: 2005900674
 ISBN 0-9765286-1-4
 available from www.illustratingshadows.com

ref 8 Sundials And Roses Of Yesterday, Earle, Alice Morse. A somewhat nostalgic book with interesting pictures and other trivia.



SOFTWARE OF INTEREST TO THE DIALIST

SHADOWS

www.shadowspro.com

most comprehensive, license is reasonable and free version covers many common needs

horizontal and vertical dial nomogram for hour line angles

A nomogram is an alternative to using tables, select latitude on the left, a time on the right, and read the hour line angle in the middle.

