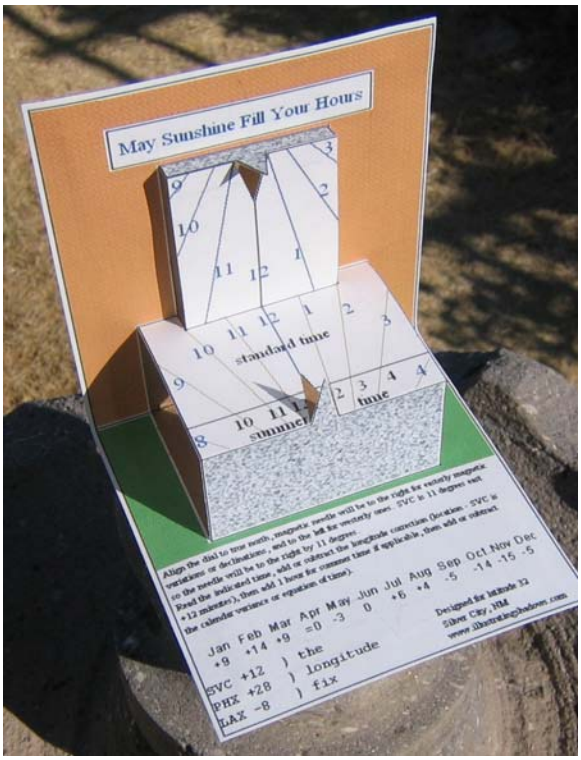
CUTTING Shadows



SOME CUTOUT DIALS FOR YOUR AMUSEMENT. ALL YOU NEED ARE SOME SCISSORS, AND YOUR LATITUDE, AND LONGITUDE.

Simon Wheaton-Smith
December 2009

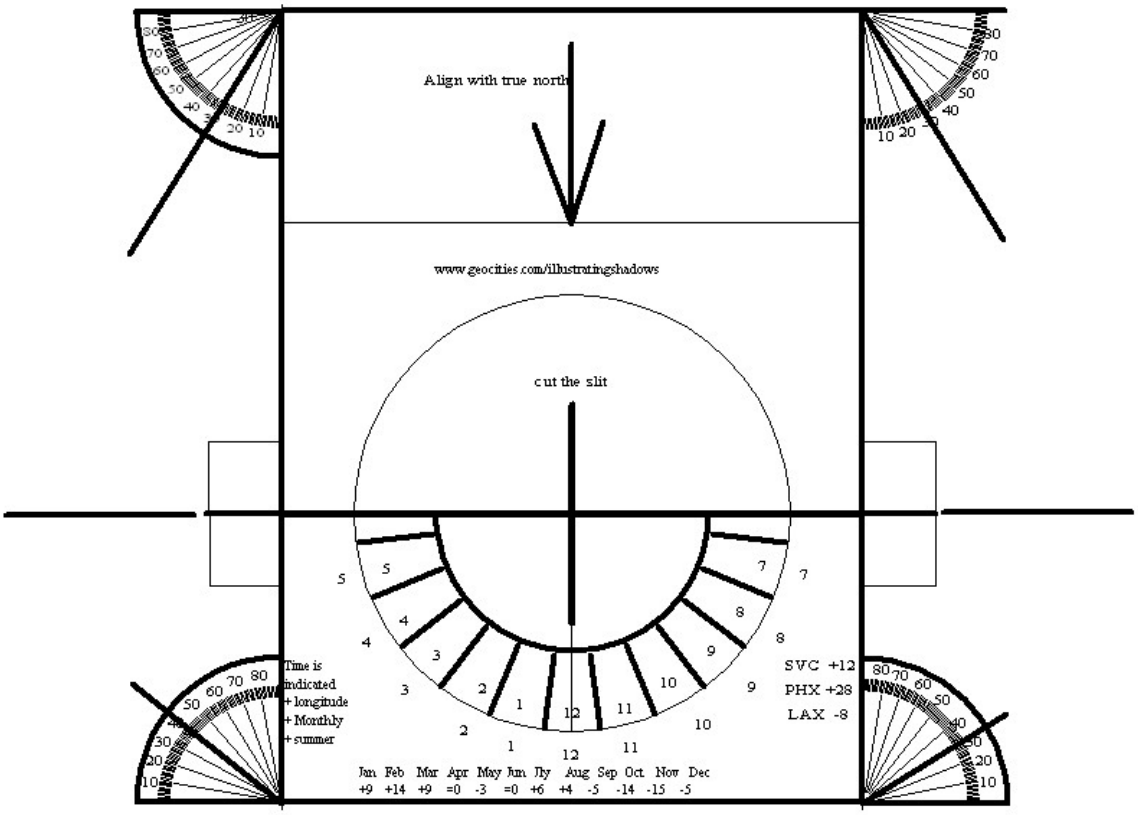
CUTOUTS FOR PAPER SUN DIALS

- armillary (also equatorial in summer months only)
- meridian - between viewer and the sun as in stained glass dials
    - – west facing
    - – east facing
- polar
- horizontal dial latitudes 0 to 65 (base is lat 32)
  or dial latitudes 20 to 65 (base is lat 50)
  use either, they should give the same results!
- popup cutout paper dial lat 32 (two dials)
- EOT and longitude corrections
- Italian and Babylonian line data

www.illustratingshadows.com
ISBN 0-9765286-2-2

ISBN 0-9765286-2-2 ISBN13 978-0-9765286-2-3

A PAPER CUTOUT OF AN ARMILLARY DIAL



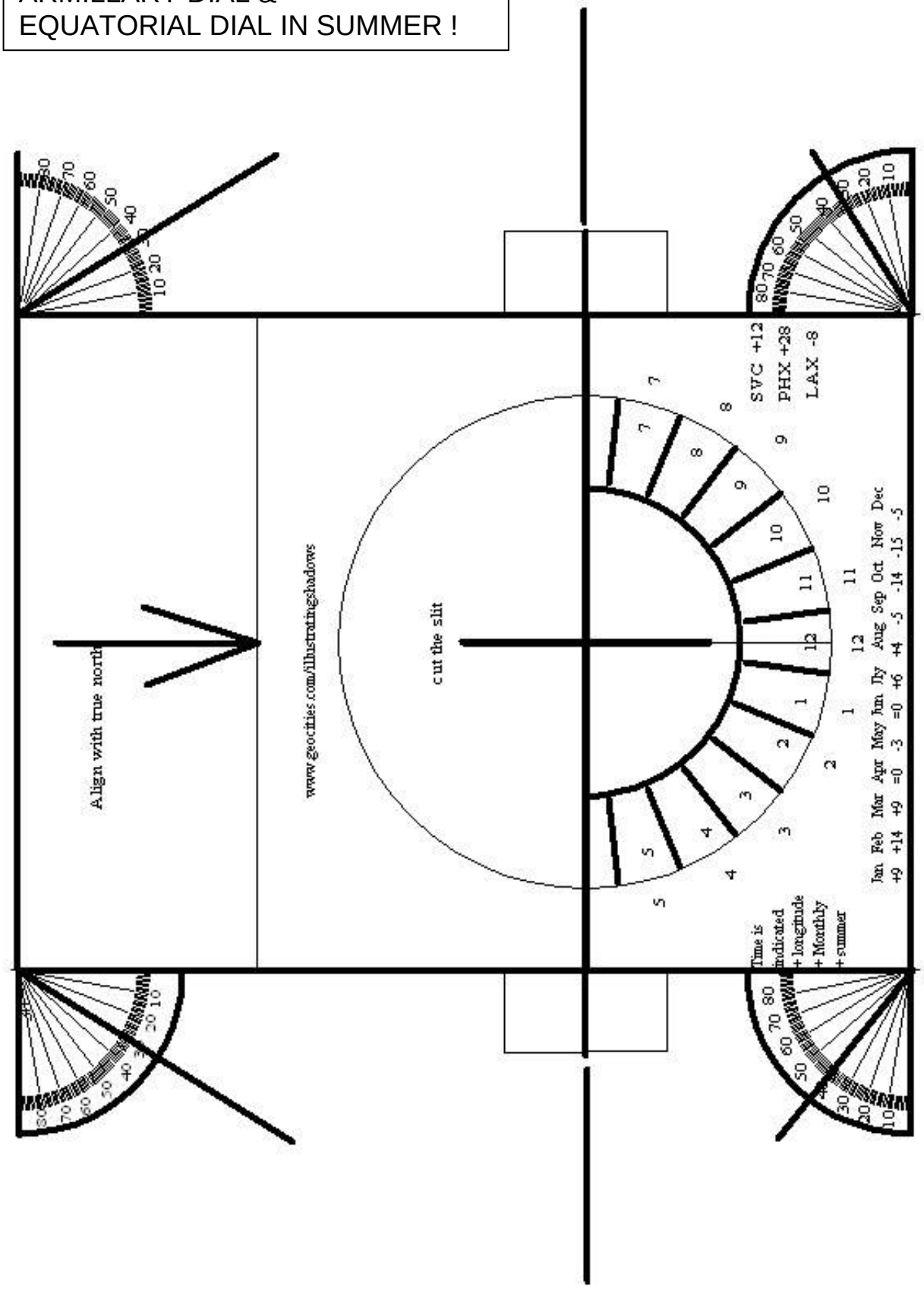
Above is a template for a paper cutout partial armillary dial. The lower quarter protractors are used to draw a line at the dial's design latitude, climbing upwards. That line is extended to intersect the horizontal line which is where the dial will be folder horizontally.

A latitude line is drawn on the upper quarter protractors this time downwards. That line will also intersect the horizontal line. If the descending and climbing line meet at the same place, simply cut and fold and you have an equatorial dial.

If they do not meet, which probably they will not, simply slide the descending lines upwards, or the climbing lines downwards, until they meet. The effect is that either the top or the bottom boundary line will be widened. Then simply cut and fold and you have an equatorial or armillary dial.

Why armillary and not equatorial? The light line falls on folded tabs which form a dial plate paralleling the gnomon (slit for light), thus it is armillary. To be equatorial the dial plate would have to be perpendicular to the gnomon. This specific dial would also be an equatorial dial in the summer months because the sun would be north of that vertical plate perpendicular to the tabs.

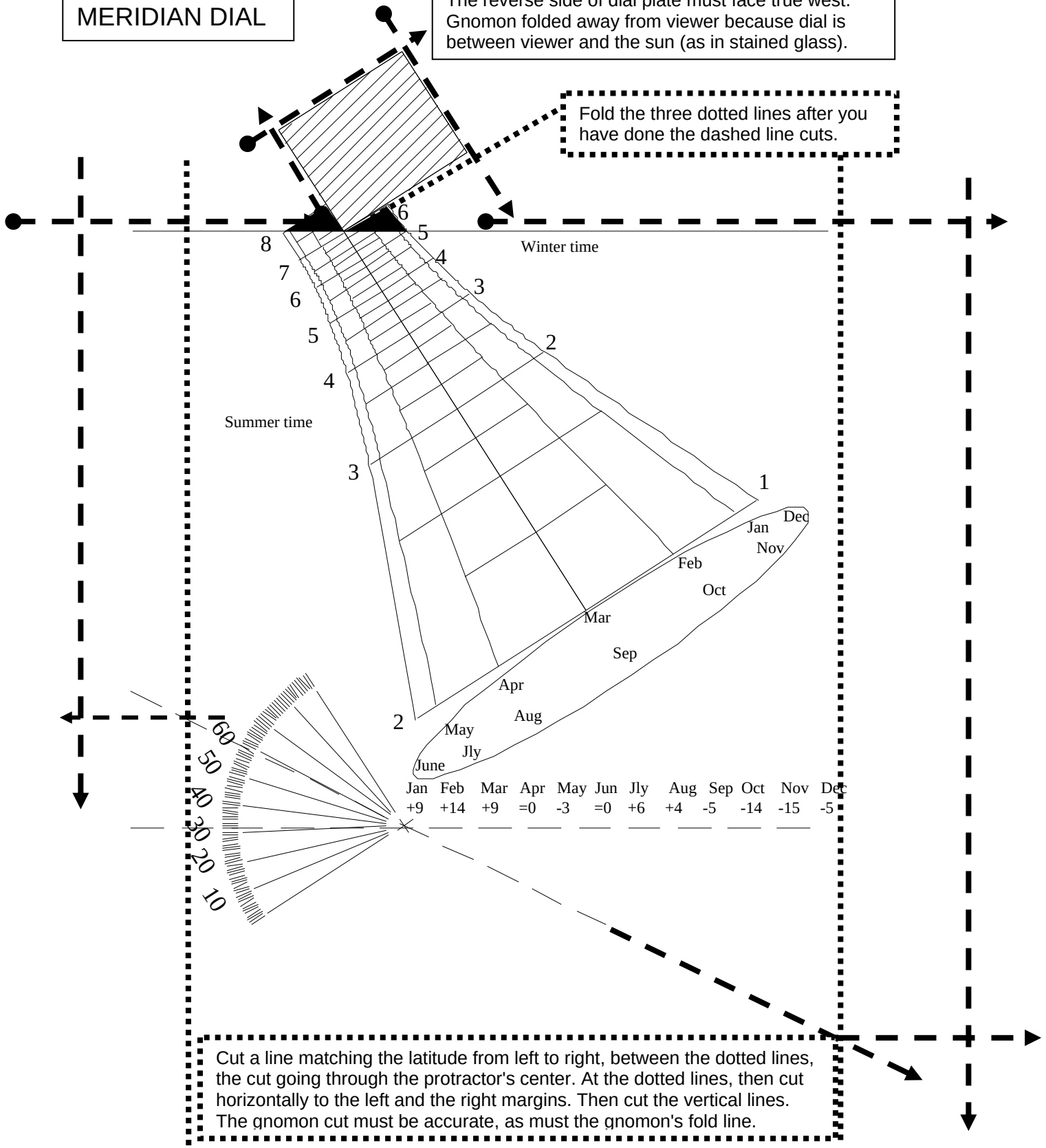
ARMILLARY DIAL &
EQUATORIAL DIAL IN SUMMER !



WEST MERIDIAN DIAL

The gnomon cut and fold must be accurate.
The reverse side of dial plate must face true west.
Gnomon folded away from viewer because dial is between viewer and the sun (as in stained glass).

Fold the three dotted lines after you have done the dashed line cuts.



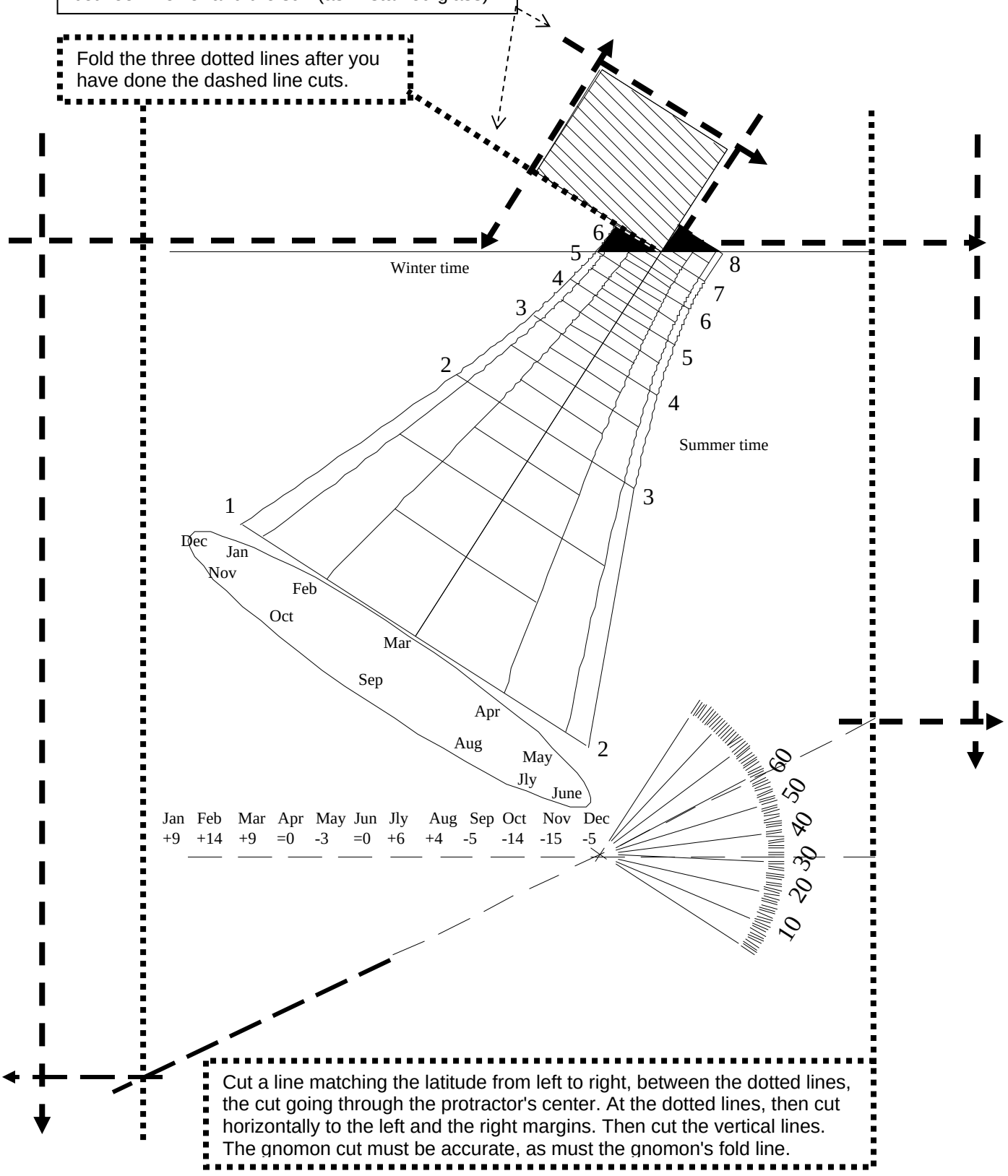
Winter time

Cut a line matching the latitude from left to right, between the dotted lines, the cut going through the protractor's center. At the dotted lines, then cut horizontally to the left and the right margins. Then cut the vertical lines. The gnomon cut must be accurate, as must the gnomon's fold line.

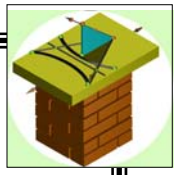
The gnomon cut and fold must be accurate.
The reverse side of dial plate must face true east.
Gnomon folded away from viewer because dial is between viewer and the sun (as in stained glass).

EAST MERIDIAN DIAL

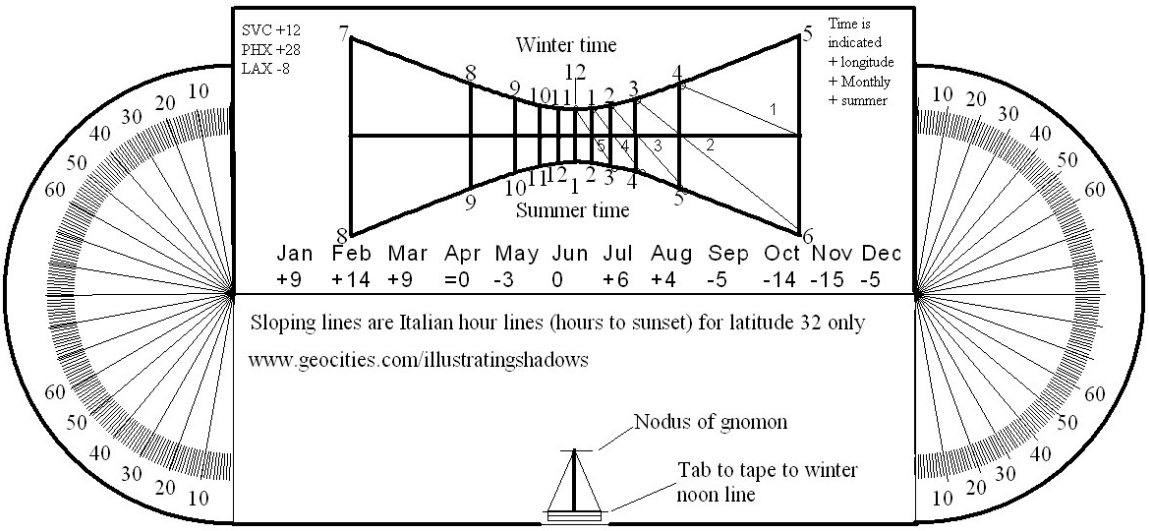
Fold the three dotted lines after you have done the dashed line cuts.



Cut a line matching the latitude from left to right, between the dotted lines, the cut going through the protractor's center. At the dotted lines, then cut horizontally to the left and the right margins. Then cut the vertical lines. The gnomon cut must be accurate, as must the gnomon's fold line.



A PAPER CUTOUT OF A POLAR DIAL



The above paper cutout is a polar dial, each of the four protractors (top left, bottom left, top right, bottom right) are cut on their latitude lines, the dial folded in the horizontal middle so that the protractor's remainders are taped together to form the latitude angle.

And the gnomon cut out and taped on the noon line.

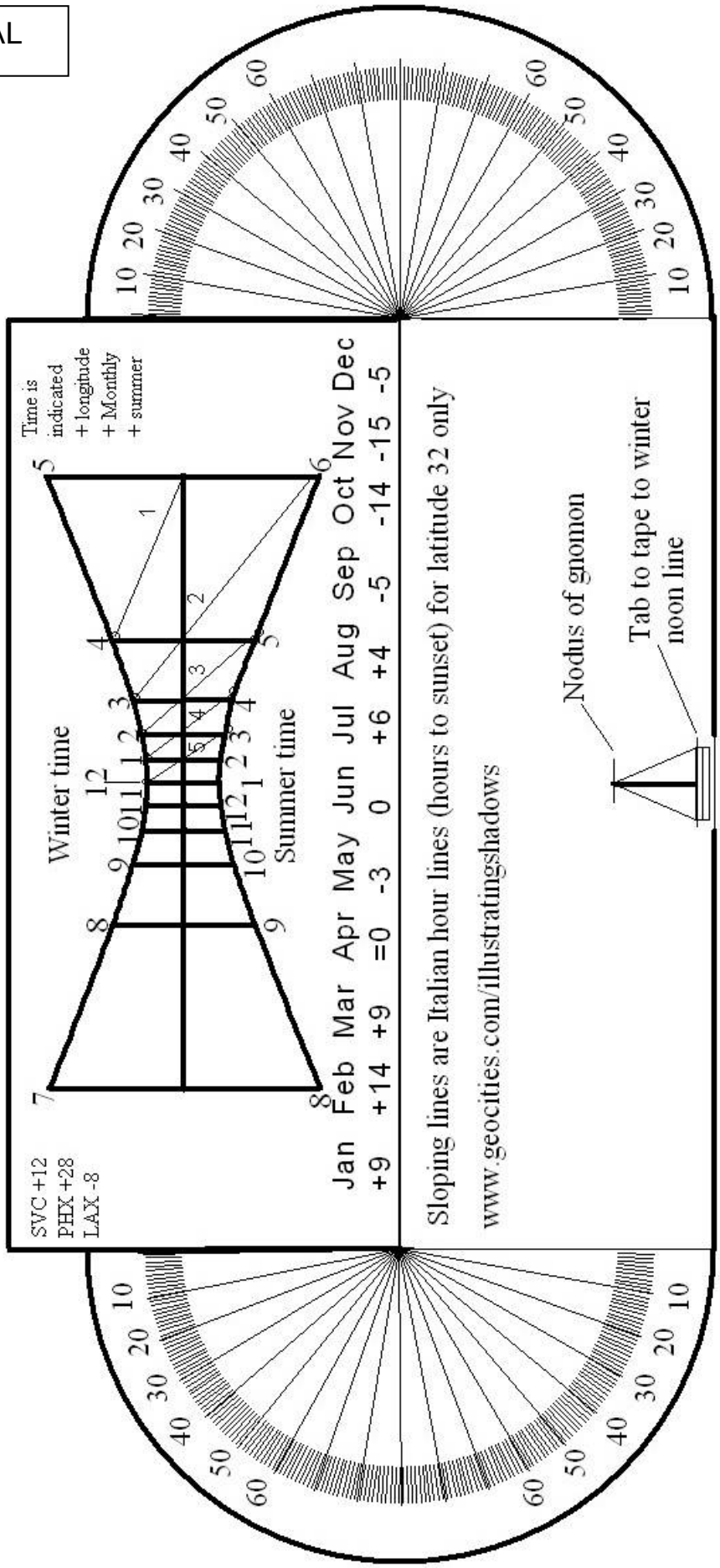
Thus this dial is universal.

Actually, almost universal. The sloping lines on the right of the dial plate, the afternoon hour display area, are specific to latitude 32 (in the above specific case), and are discussed later, they are "Italian" hour lines. When the shadow is on one, the Italian line shows the number of hours until sunset. Since sunrise and sunset times are latitude dependant, their usage is only valid for their design latitude.

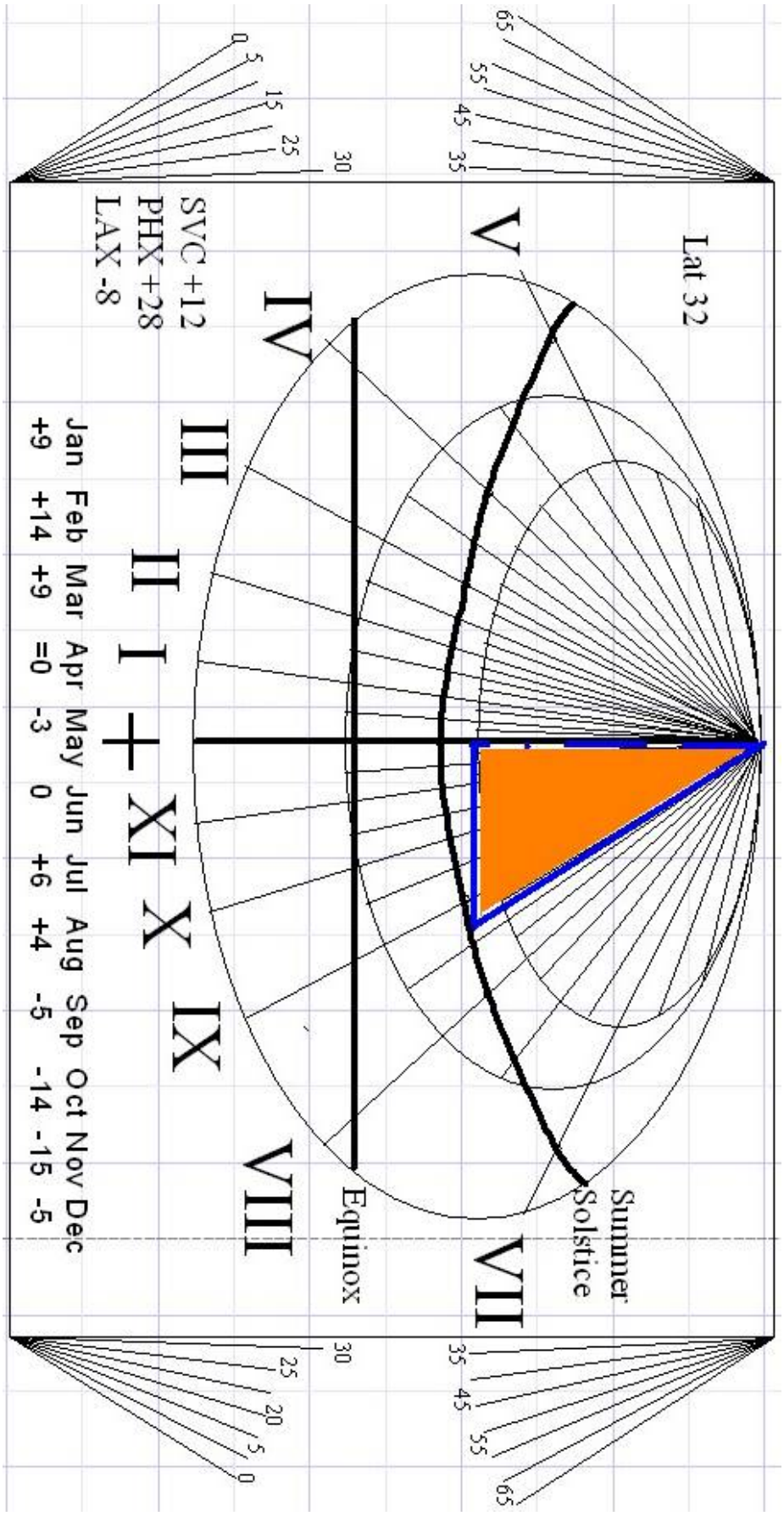
A separate chapter has a discussion on Italian hour lines, and table A6.4 in the appendices provides sunrise, sunset, and day-length data in true solar time (LAT, local apparent time] for latitudes 30 through 60 degrees to facilitate this dial plate furniture.

APPENDIX 9 of the book Illustrating Time's Shadow has various paper cutout dials, they can be used to enhance understanding. They can be manipulated to see the results of changing direction, and tilt angle. They can also be of interest to the upcoming youth of the country and instill an interest in sundial activities.

POLAR DIAL

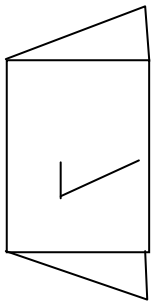

SVC +12
PHX +28
LAX -8
Time is
indicated
+ longitude
+ Monthly
+ summer
Winter time
Summer time
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
+9 +14 +9 =0 -3 0 +6 +4 -5 -14 -15 -5
Sloping lines are Italian hour lines (hours to sunset) for latitude 32 only
www.geocities.com/illustratingshadows
Nodus of gnomon
Tab to tape to winter
noon line

HORIZONTAL DIAL

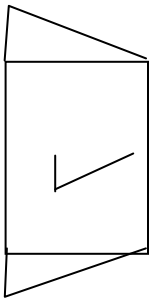


If latitude of the location is 32 degrees, cut out the dial and ignore the protractors off to the side.

If latitude of the location is less than 32 degrees, locate the latitude on the scale 0-30 and extend the angled line out on both sides, then cut out the dial. And fold those two triangles.



If latitude of the location is more than 32 degrees, locate the latitude on the scale 35-65 and extend the angled line out on both sides, then cut out the dial. And fold those two triangles.



Cut out the gnomon's two sides and rotate it up. Align to true north.

Strengthen the middle so the dial center won't sag.

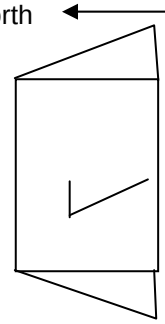
Base latitude is 32

HORIZONTAL DIAL

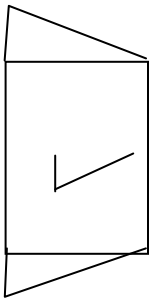
If latitude of the location is 50 degrees, cut out the dial and ignore the protractors off to the side.

If latitude of the location is less than 50 degrees, locate the latitude on the scale 20-45 and extend the angled line out on both sides, then cut out the dial. And fold those two triangles.

North



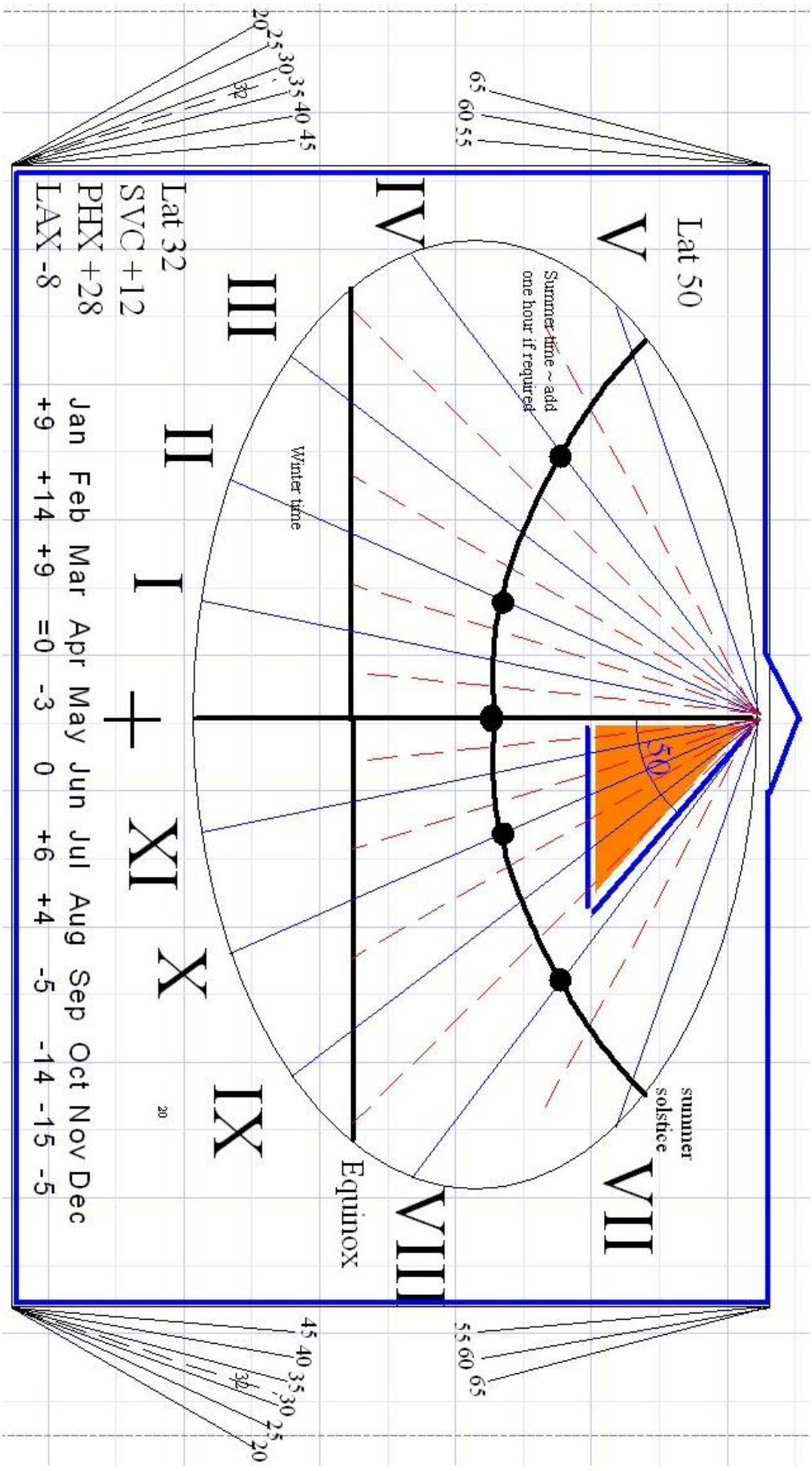
If latitude of the location is more than 50 degrees, locate the latitude on the scale 55-65 and extend the angled line out on both sides, then cut out the dial. And fold those two triangles.



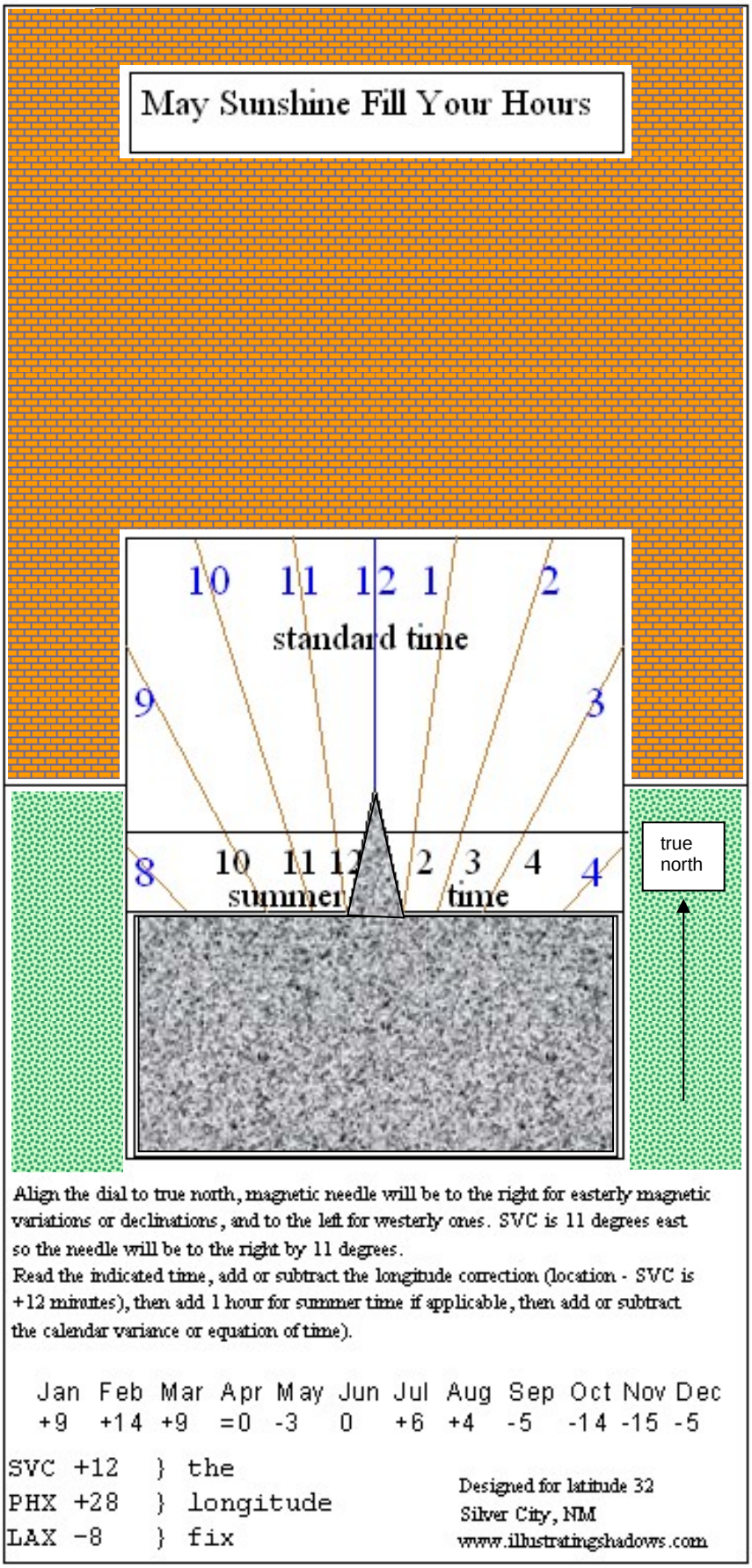
Cut out the gnomon's two sides and rotate it up.

Align to true north. Strengthen the middle of the dial so it will not sag.

Base latitude is 50



PAPER POPUP
CUTOUT
HORIZONTAL DIAL



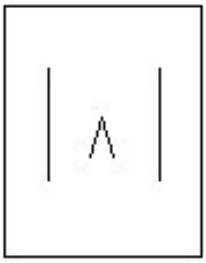
Align the dial to true north, magnetic needle will be to the right for easterly magnetic variations or declinations, and to the left for westerly ones. SVC is 11 degrees east so the needle will be to the right by 11 degrees.
Read the indicated time, add or subtract the longitude correction (location - SVC is +12 minutes), then add 1 hour for summer time if applicable, then add or subtract the calendar variance or equation of time).

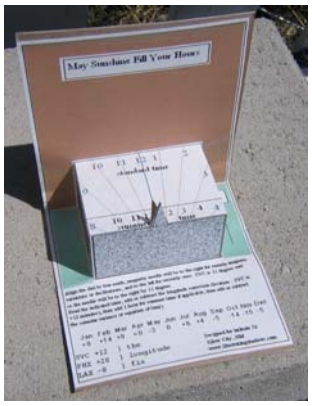
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
+9	+14	+9	=0	-3	0	+6	+4	-5	-14	-15	-5

SVC +12 } the
PHX +28 } longitude
LAX -8 } fix

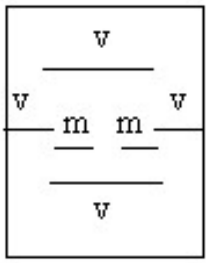
Designed for latitude 32
Silver City, NM
www.illustratingshadows.com

Cuts





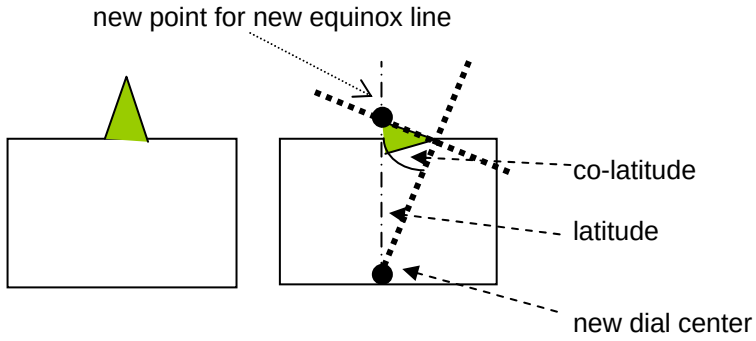
Folds



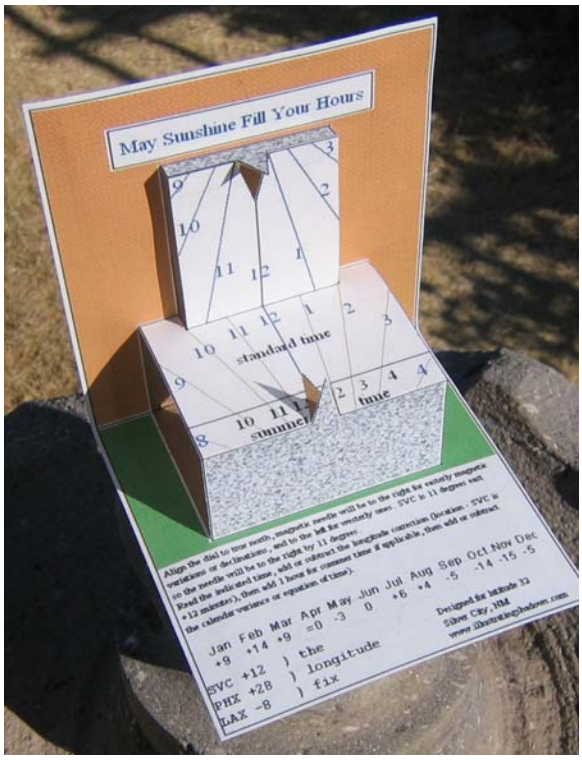
v = valley fold
m = mountain fold

Designed for latitude 32, this dial only needs the hour lines to be altered to match the latitude, and of course the equinox line.

To adjust for the latitude change for the horizontal part of the dial, on paper rotate the gnomon 90 degrees to the right, and find dial center by running a line at co-latitude down to intercept the 12 noon hour line at latitude. That is the new dial center. Another line at 90 degrees to the new style goes from the nodus up to intercept the noon line, and that is where the new equinox line goes. A similar process would be used for the vertical part of the dial on the next page.



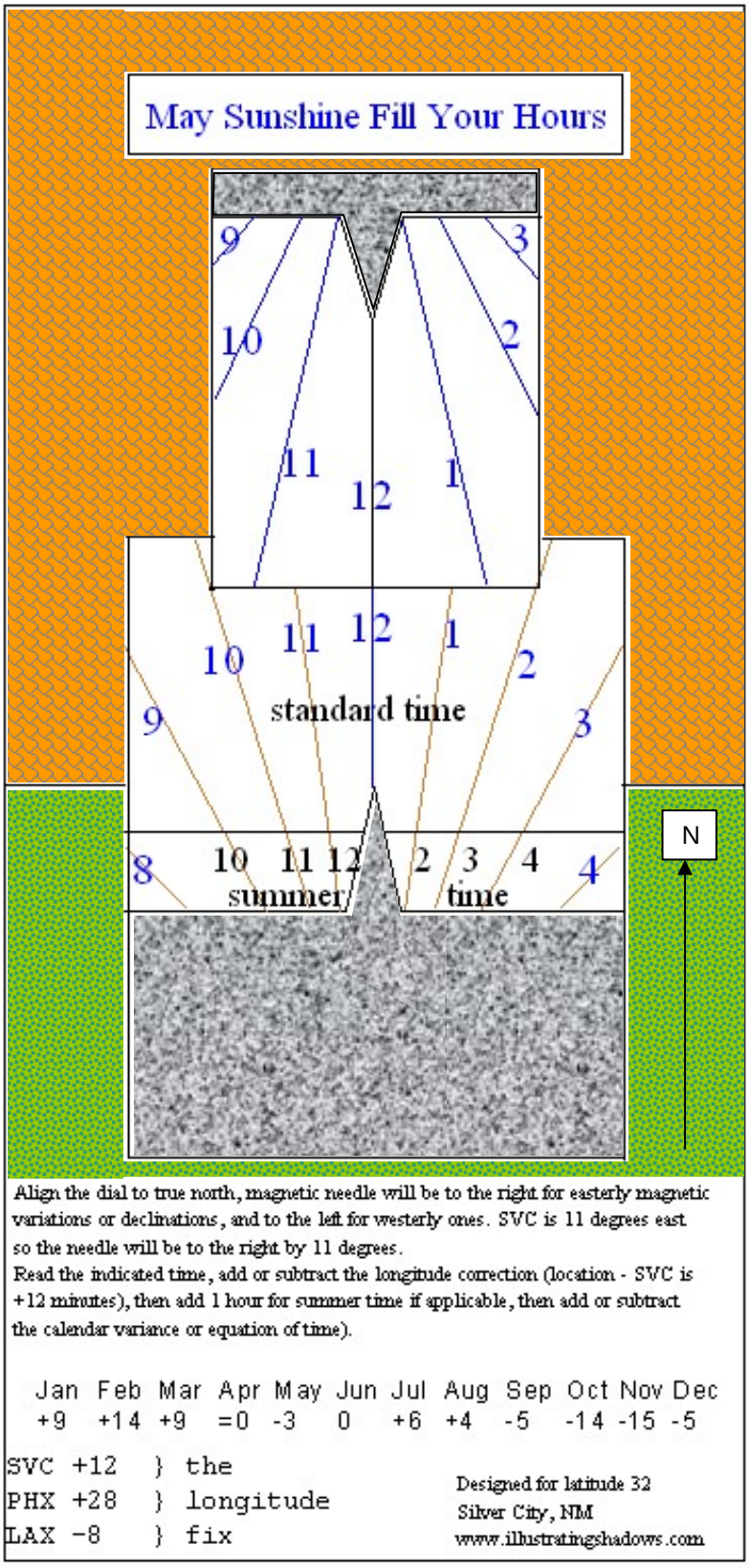
It may be noted that the gnomon's shadow is marginal in the summer months due to the high altitude of the sun.



Not a problem. The next cut out pop up dial has a vertical as well as a horizontal dial. So when the horizontal dial is hard to read in the summer, the vertical dial takes over. Similarly in the winter the vertical dial may be harder while the horizontal dial may be easier.

If the vertical and horizontal dial hour lines do not appear to meet as, or when projected back to the case where the vertical dial is not protruding, this is because the gnomons are not of the same size.

This is not intended to be a definitive work on pop up dials nor pop up figures in general, it is intended to stimulate the imagination.



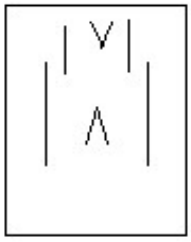
Align the dial to true north, magnetic needle will be to the right for easterly magnetic variations or declinations, and to the left for westerly ones. SVC is 11 degrees east so the needle will be to the right by 11 degrees.
Read the indicated time, add or subtract the longitude correction (location - SVC is +12 minutes), then add 1 hour for summer time if applicable, then add or subtract the calendar variance or 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

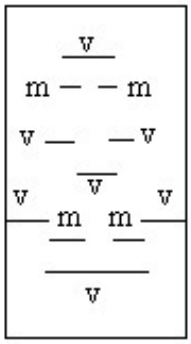
SVC +12 } the
PHX +28 } longitude
LAX -8 } fix

Designed for latitude 32
Silver City, NM
www.illustratingshadows.com

Cuts



Folds



v = valley fold
m = mountain fold

EOT VALUES

EOT WITH A LONGITUDE ADJUSTMENT FOR DIAL PORTABILITY m.ss

Month	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec
Long Diff					EAST	OF	TIME	ZONE				
-8	-23.11	-18.14	-23.23	-31.50	-35.26	-31.30	-26.14	-27.49	-37.08	-46.21	-46.25	-35.47
-7	-19.11	-14.14	-19.23	-27.50	-31.26	-27.30	-22.14	-23.49	-33.08	-42.21	-42.25	-31.47
-6	-15.11	-10.14	-15.23	-23.50	-27.26	-23.30	-18.14	-19.49	-29.08	-38.21	-38.25	-27.47
-5	-11.11	-6.14	-11.23	-19.50	-23.26	-19.30	-14.14	-15.49	-25.08	-34.21	-34.25	-23.47
-4	-7.11	-2.14	-7.23	-15.50	-19.26	-15.30	-10.14	-11.49	-21.08	-30.21	-30.25	-19.47
-3	-3.11	1.46	-3.23	-11.50	-15.26	-11.30	-6.14	-7.49	-17.08	-26.21	-26.25	-15.47
-2	0.49	5.46	0.37	-7.50	-11.26	-7.30	-2.14	-3.49	-13.08	-22.21	-22.25	-11.47
-1	4.49	9.46	4.37	-3.50	-7.26	-3.30	1.46	0.11	-9.08	-18.21	-18.25	-7.47
0	8.49	13.46	8.37	0.10	-3.26	0.30	5.46	4.11	-5.08	-14.21	-14.25	-3.47
1	12.49	17.46	12.37	4.10	0.34	4.30	9.46	8.11	-1.08	-10.21	-10.25	0.13
2	16.49	21.46	16.37	8.10	4.34	8.30	13.46	12.11	2.52	-6.21	-6.25	4.13
3	20.49	25.46	20.37	12.10	8.34	12.30	17.46	16.11	6.52	-2.21	-2.25	8.13
4	24.49	29.46	24.37	16.10	12.34	16.30	21.46	20.11	10.52	1.39	1.35	12.13
5	28.49	33.46	28.37	20.10	16.34	20.30	25.46	24.11	14.52	5.39	5.35	16.13
6	32.49	37.46	32.37	24.10	20.34	24.30	29.46	28.11	18.52	9.39	9.35	20.13
7	36.49	41.46	36.37	28.10	24.34	28.30	33.46	32.11	22.52	13.39	13.35	24.13
8	40.49	45.46	40.37	32.10	28.34	32.30	37.46	36.11	26.52	17.39	17.35	28.13
					WEST	OF	TIME	ZONE				

corr:	SVC	PHX
Apr	12.14	28.14
May	8.25	24.25
Jun	12.00	28.00
Jly	16.54	32.54
Aug	15.22	31.22
Sep	6.09	22.09

corr:	SVC	PHX
Jan	20.38	36.38
Feb	25.39	41.39
Mar	21.04	37.04
Oct	-2.39	13.21
Nov	-2.31	13.29
Dec	7.44	23.44

ITALIAN AND BABYLONIAN HOUR LINES

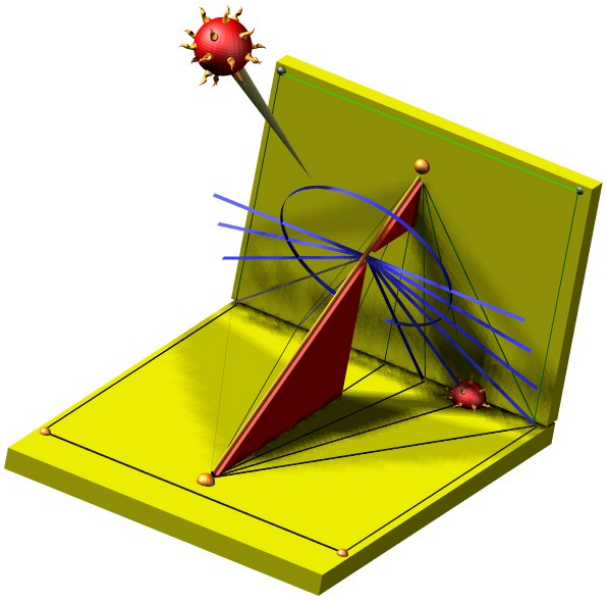
ON A SUN DIAL PLATE USE SUNSET AND SUNRISE DATA RESPECTIVELY.

Babylonian and Italian values by latitude. Times are hh.mm Local Apparent Time
Solstice Sunrise and Sunset (equinox is 6am/pm). No longitude correction. No EOT correction.

Winter solstice: Declination:			-23.5	Summer solstice: Declination:			+23.5
Lat	Rise	Set	Day hrs	Lat	Rise	Set	Day hrs
30	6.58	17.02	10.04	30	5.01	18.59	13.58
31	7.00	17.00	10.00	31	4.59	19.01	14.02
32	7.03	16.57	9.54	32	4.56	19.04	14.08
33	7.05	16.55	9.50	33	4.54	19.06	14.12
34	7.08	16.52	9.44	34	4.51	19.09	14.18
35	7.10	16.50	9.40	35	4.49	19.11	14.22
36	7.13	16.47	9.34	36	4.46	19.14	14.28
37	7.16	16.44	9.28	37	4.43	19.17	14.34
38	7.19	16.41	9.22	38	4.40	19.20	14.40
39	7.22	16.38	9.16	39	4.37	19.23	14.46
40	7.25	16.35	9.10	40	4.34	19.26	14.52
41	7.28	16.32	9.04	41	4.31	19.29	14.58
42	7.32	16.28	8.56	42	4.27	19.33	15.06
43	7.35	16.25	8.50	43	4.24	19.36	15.12
44	7.39	16.21	8.42	44	4.20	19.40	15.20
45	7.43	16.17	8.34	45	4.16	19.44	15.28
46	7.47	16.13	8.26	46	4.12	19.48	15.36
47	7.51	16.09	8.18	47	4.08	19.52	15.44
48	7.55	16.05	8.10	48	4.04	19.56	15.52
49	8.00	16.00	8.00	49	3.59	20.01	16.02
50	8.04	15.56	7.52	50	3.55	20.05	16.10
51	8.09	15.51	7.42	51	3.50	20.10	16.20
52	8.15	15.45	7.30	52	3.44	20.16	16.32
53	8.20	15.40	7.20	53	3.39	20.21	16.42
54	8.27	15.33	7.06	54	3.32	20.28	16.56
55	8.33	15.27	6.54	55	3.26	20.34	17.08
56	8.40	15.20	6.40	56	3.19	20.41	17.22
57	8.48	15.12	6.24	57	3.11	20.49	17.38
58	8.56	15.04	6.08	58	3.03	20.57	17.54
59	9.05	14.55	5.50	59	2.54	21.06	18.12
60	9.15	14.45	5.30	60	2.44	21.16	18.32

Sunset (true time or local apparent time) occurs the same number of hours after noon that sunrise happens before. An 0605 sunrise is 5 hours 55 minutes before noon, thus sunset is 5 hours 55 minutes after it, or 1755. Except for on the hour or half hour, the minutes do not match. For standard time, then the time is shifted by the longitude correction and then by the equation of time, thus the March and September equinoxes do not match due to differing EOT values.

Italian hour lines are commonly used to indicate the number of hours until sunset. For Italian hour lines, exclude the EOT. And exclude the longitude correction unless the dial already has considered longitude in its design. The spreadsheets on the web site allow you to do this, and of course, the above table A6.4 provides all the data needed for Italian and Babylonian lines. The equinox is not shown since true sunrise and sunset occurs at 6am and 6pm LAT.



Don't forget to get the book "Illustrating Time's Shadow" itself which discusses how to make Sundials for almost anywhere using empirical, geometric, and trigonometric methods as well as computer aided design and spreadsheets.

Cutting Shadows
Cutouts for Paper Sundials
Simon Wheaton-Smith
ISBN 0-9765286-2-2 ISBN13 978-0-9765286-2-3