COMPENDIUM*

Journal of the North American Sundial Society

Volume 3 Number 1

March 1996 ISSN 1074-3197

Heaven itself is but a generall dial, and a dial it, in a lesser volume.

- Robert Hegge 1630
Heliotropum Sciothericum

Contents

* Compendium..." giving the sense and substance of the topic within small compass." In dialing, a compendium is a single instrument incorporating a variety of dial types and ancillary tools.

The Sundial On A Wet Day

Thomas Hardy (1840-1928)

I drip, drip here
In Atlantic rain,
Falling like handfuls
Of winnowed grain,
Which, tear-like, down
My gnomon drain,
And dim my numerals
With their stain, -
Till I feel useless,
And wrought in vain!

And then I think
In my despair
That, though unseen,
He is still up there,
And may gaze out
Anywhen, anywhere;
Not to help clockmen
Quiz and compare,
But in kindness to let me
My trade declare.

A Sand Dial

Woody Sullivan (Seattle WA)

A sundial constructed from driftwood and sand by Woody Sullivan and friends on Shi-Shi Beach on the Olympic Peninsula of Washington State. The dial operated for the last few hours of the day. Hour lines are indicated by the small "towers" on the perimeter wall. The dial's motto (on the gnomon) was "Time and tide wait for no man." Photo taken at 18:00 PST on 16 July 1995 by Woody Sullivan.

Sundial Operating Limits

Harold E. Brandmaier

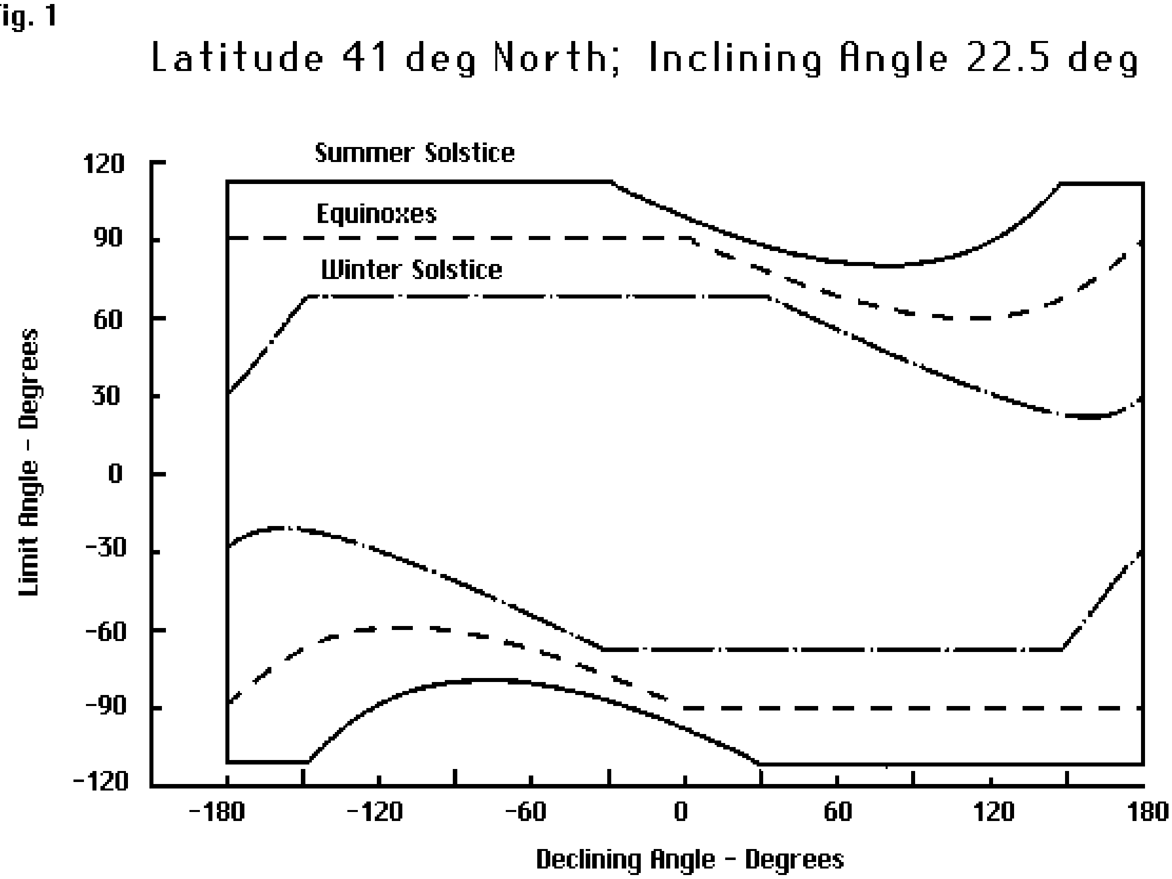
One question not usually answered in books on sundials is "What are the limits of operation of sundials with an arbitrary orientation of their dial-faces?" The answer to this question helps to determine whether a particular combination of latitude and dial-face orientation will result in a useful sundial, and what range of hour-lines to inscribe on the dial-face. This article presents one answer in a graphical form useful, at least, for preliminary sundial design purposes.

One approach to sundial design is described by Frederick Sawyer in his series on the spherical triangle and the equivalent horizontal dial (Compendium 1:3, 1:4 and 2:1). Another, used by the author, is based on the transformation from horizon coordinates in which, for example, the +X-axis is South, the +Y-axis is East , and the +Z-axis points toward the Zenith to dial coordinates in which the X and Y axes are in the plane of the dial-face and the Z-axis is perpendicular to the dial-face. The orientation of the dial-face is defined in horizon coordinates by the inclining angle IA and the declining angle DA. DA can be measured in the horizontal (X-Y) plane between South (+X-axis) and the projection of the perpendicular to the dial-face in the horizontal plane. It is positive from South toward East. IA is measured from the +Z-axis to the perpendicular to the dial-face and is always positive or zero for DA as defined. As examples, IA = 0° defines a horizontal sundial for any value of DA; IA = 90° and DA = 0° defines a vertical sundial facing due South; and IA = 90° and DA = -90° defines a vertical sundial facing due West.

Sparing the reader the mathematical details, the transformation of the Sun vector S from horizon to dial coordinates results in, for the component of S perpendicular to the dial-face SZD,

SZD = (CT cos HA – ST sin HA) cos D – TD sin D
where: CT = sin IA cos DA sin P + cos IA cos P
ST = sin IA sin DA
TD = sin IA cos DA cos P – cos IA sin P

Fig. 1



In these equations, P is the latitude at which the sundial is located, D is the Sun's declination, and HA is the hour-angle (+ in the PM, − in the AM); all angles are in degrees. HA can be converted to sundial time based on 4 minutes per degree relative to noon.

It is of interest to note that, using the coordinate transformation approach, the shadow of a point, for example, the tip of a gnomon or a point along a style, is determined by the intersection of the straight line connecting the center of the Sun and the point with the dial-face. The operating limits, however, only depend on SZD.

Sundial operating limits correspond to those values of HA for which SZD = 0 not earlier than sunrise and not later than sunset. These limits, simply referred to as LIMIT, can be determined for any day of the year by varying D. However, in addition to the effect of day of the year on sundial response, what is needed from a design viewpoint is the earliest time that the Sun strikes the dial-face on any day of the year and the latest time that it goes behind the dial-face on any day of the year. This determines the maximum range of hour-lines to be inscribed on the dial-face. Typically, these earliest and latest times do not occur on the same day. For a dial-face orientation defined by IA and DA, it is generally sufficient to determine LIMIT for the summer solstice (D = +23.441°), for the winter solstice (D = −23.441°) and for the equinoxes (D = 0°). Although SZD = 0 has two solutions for LIMIT, sundials usually operate between sunrise and one LIMIT or the same LIMIT and sunset.

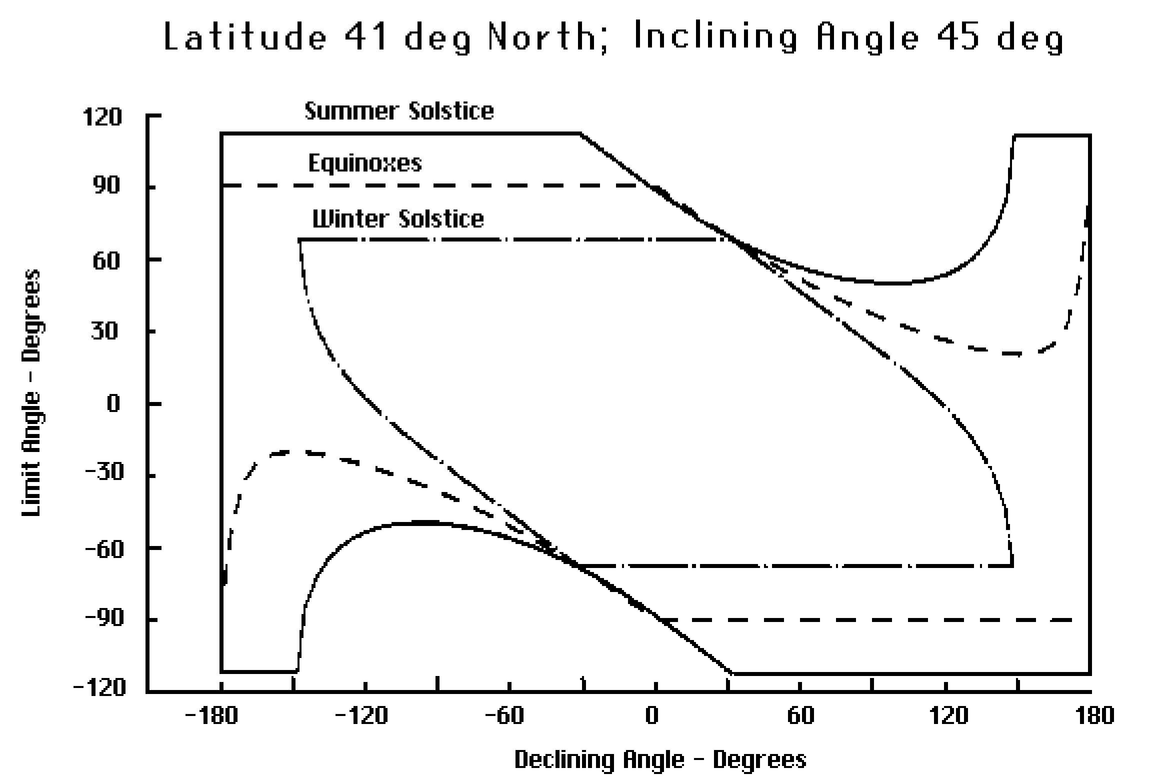
LIMIT for a specified D can be determined in a number of ways, for example:

If the sundial design equations are programmed for a computer or programmable calculator, it is convenient to test SZD for an hour-angle sequence between sunrise and sunset. If SZD ≥ 0, calculate the shadow; if not, continue to the next hour-angle.

On a more sophisticated level, solve the SZD = 0 equation for LIMIT for selected values of D. The results are the same as given by Frederick Sawyer in his Compendium articles.

Prepare LIMIT graphs for selected latitudes and inclining angles. Figures 1 to 5 show the effects of IA for 41° North while Figures 6 and 7 show the effects of latitude for a declining sundial, IA = 90°.

Fig. 2



As their preparation requires solving the SZD = 0 equation, they provide a rapid answer to the question posed herein.

Referring to Figure 1, for which IA = 22.5°, each graph defined by one value of the Sun's declination, is an envelope within whose boundaries a sundial operates. For all graphs, the range of declining angles extends from −180° to +180°; the operating limits are expressed in units of hour-angle, although time units could have just as easily been used. From Figure 1, the maximum hours of operation, and therefore the maximum hours to be inscribed on the the dial-face, occurs on the summer solstice for any declining angle. For the trivial case of a horizontal sundial, the limit envelopes are rectangular, since the declining angle has no effect, and a horizontal sundial operates between sunrise and sunset on any day of the year. Inserting DA = 0 and IA = 90° into the SZD = 0 equation directly gives this result. As IA increases, the limits decrease over much of the useful DA range, but the maximum number of operating hours still occurs on the summer solstice.

As IA increases above P, which for DA = 0 defines a polar sundial, the dependence of the operating limits on D changes for a range of declining angles centered on D = 0. Now, one limit corresponds to the winter solstice and one limit to the summer solstice. Further, there is a smaller range of declining angles for which LIMIT corresponds to sunrise or sunset on days other than the solstices or equinoxes. This is shown by the series of dots connecting the corners of the solstice and equinox envelopes in Figures 3 to 5. The value of D at which this occurs is the solution to:

$$\sin D = \pm \sin DA \ \cos P$$

which does not depend on IA. Also, since +23.441° ≥ D ≥ −23.441°, the range of declining angles over which LIMIT = sunrise or sunset for a specified latitude is uniquely determined. Thus, for P = 41°, 31.8° ≥ DA ≥ −31.8°.

As IA increases above about 72°, the operating region becomes fragmented in the region around DA = 180° as shown in Figure 4 for a vertical sundial. This leads to the well-known behavior of a declining dial facing due North; that is, it operates between sunrise and some time in the morning, does not operate until sometime after noon, and then continues to operate until sunset. But only near the summer solstice! Finally, Figure 5 for IA = 105° may be appropriate for a sundial to be located on top of a tall building

Fig. 3

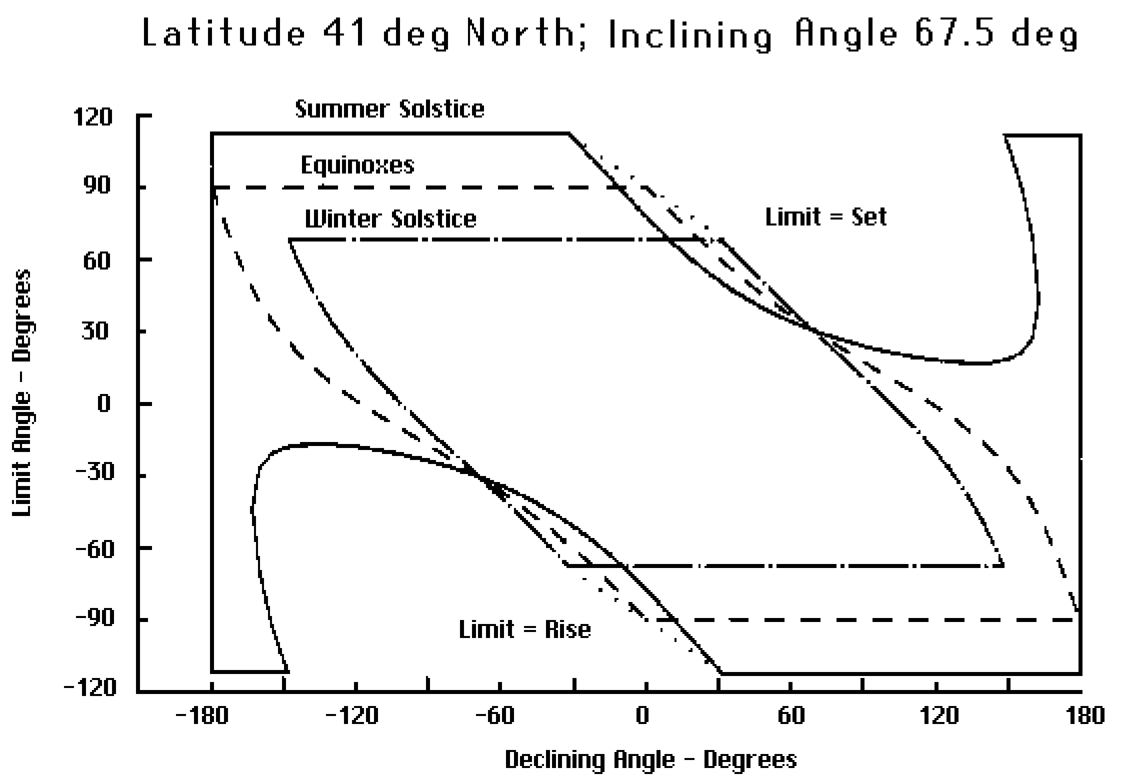


Fig. 4

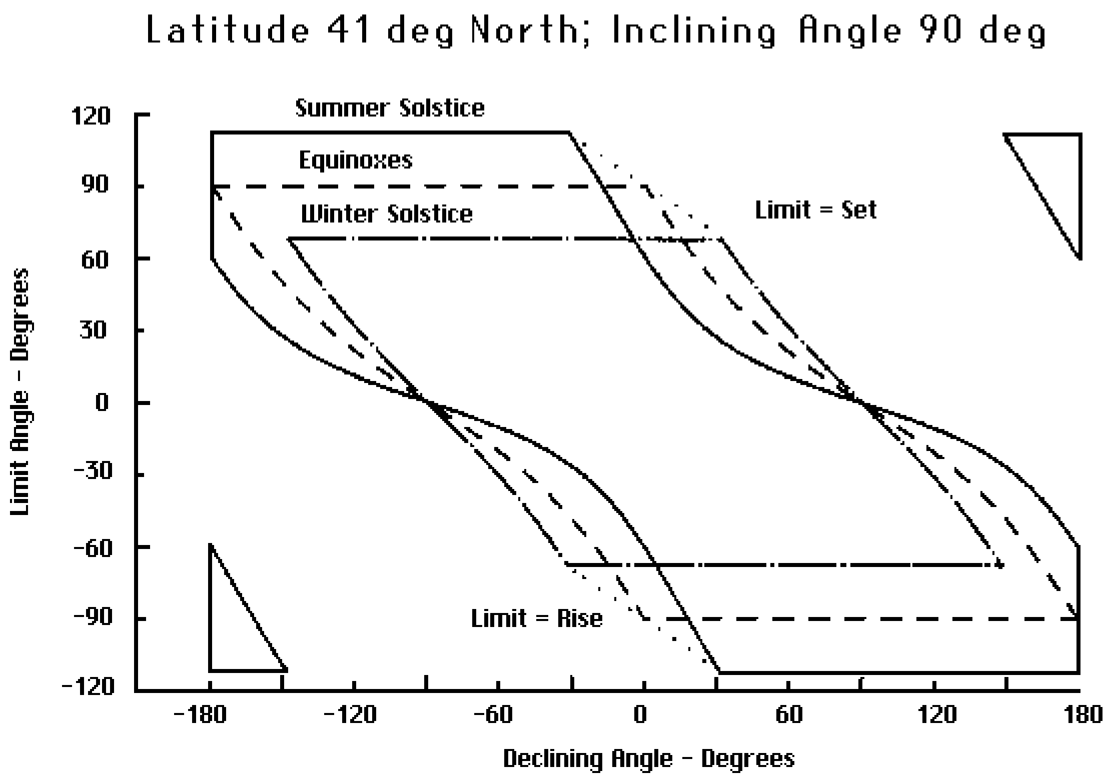

Latitude 41 deg North; Inclining Angle 90 deg
Summer Solstice
Equinoxes
Winter Solstice
Limit = Set
Limit = Rise
Limit Angle - Degrees
Declining Angle - Degrees
120
90
60
30
0
-30
-60
-90
-120
-180
-120
-60
0
60
120
180

Fig. 5

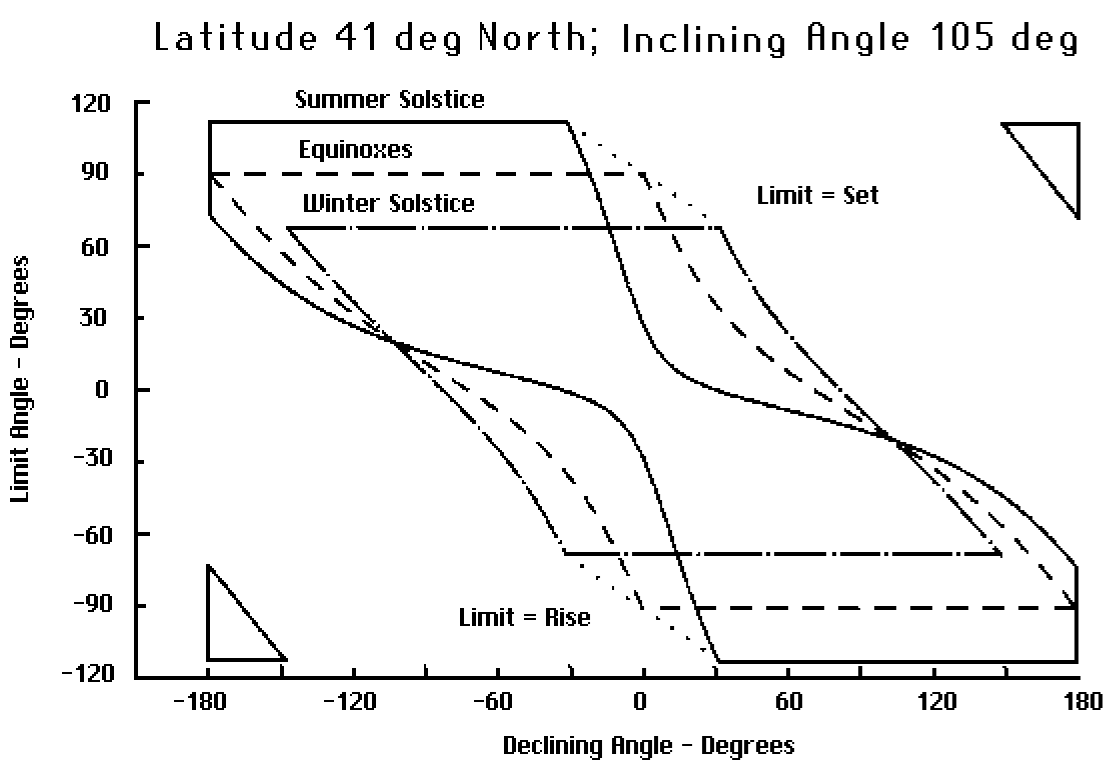

Latitude 41 deg North; Inclining Angle 105 deg
Summer Solstice
Equinoxes
Winter Solstice
Limit = Set
Limit = Rise
Limit Angle - Degrees
Declining Angle - Degrees
120
90
60
30
0
-30
-60
-90
-120
-180
-120
-60
0
60
120
180

Fig. 6

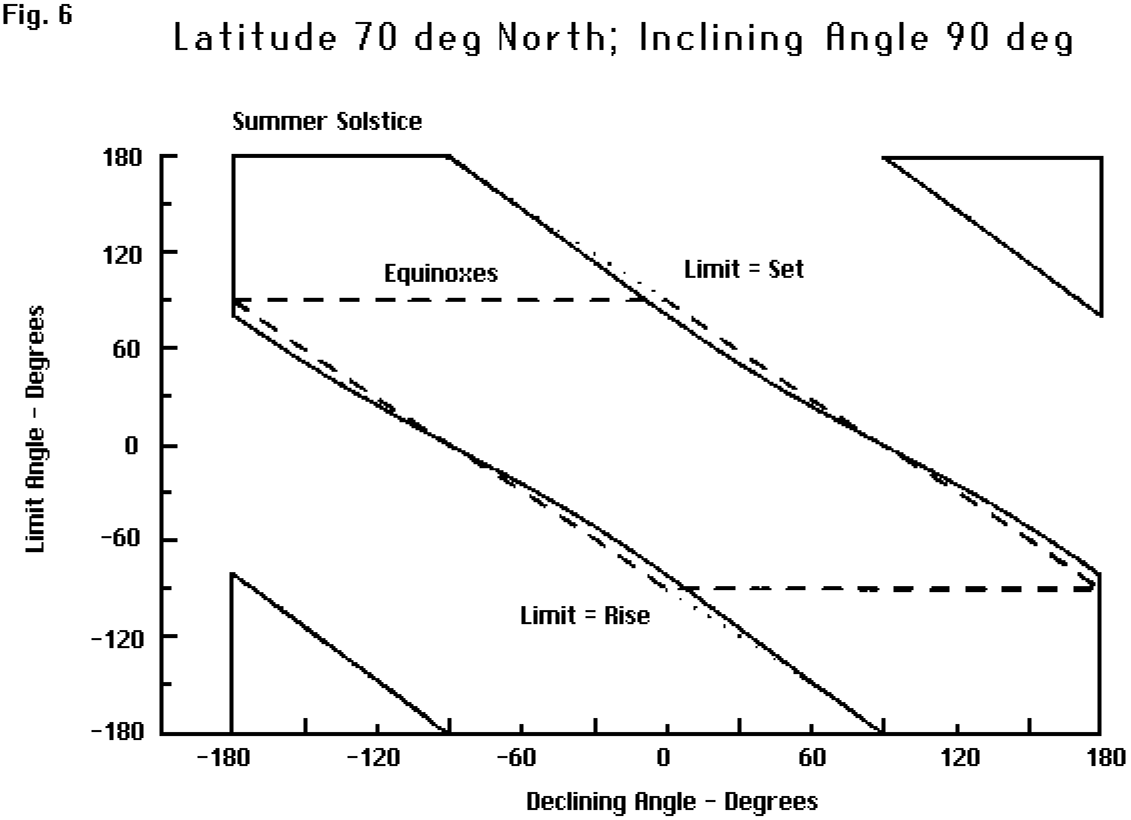
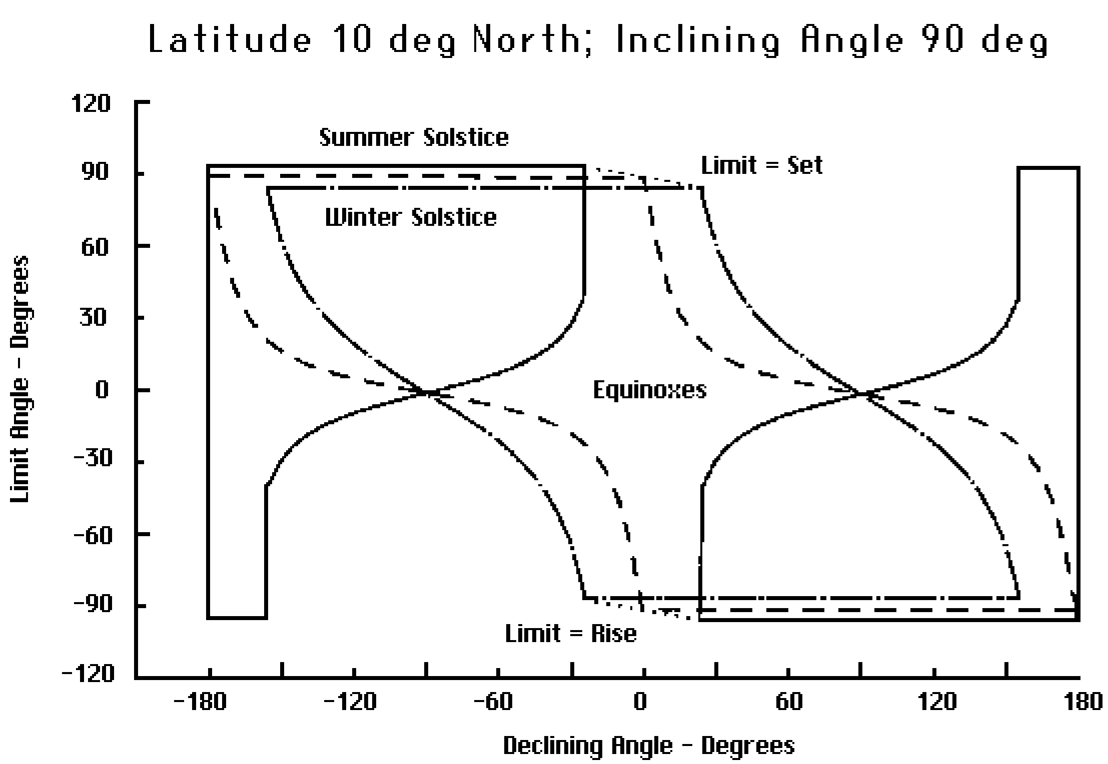

Latitude 70 deg North; Inclining Angle 90 deg
Summer Solstice
Equinoxes
Limit = Set
Limit = Rise
180
120
60
0
-60
-120
-180
-180
-120
-60
0
60
120
180
Limit Angle - Degrees
Declining Angle - Degrees

Fig. 7


Latitude 10 deg North; Inclining Angle 90 deg
Summer Solstice
Limit = Set
Winter Solstice
Equinoxes
Limit = Rise
120
90
60
30
0
-30
-60
-90
-120
-180
-120
-60
0
60
120
180
Limit Angle - Degrees
Declining Angle - Degrees

and read from the street level.

Figures 6 and 7 show the effects of latitude for a vertical declining sundial. Figure 6 for a sundial located in the North Frigid Zone is similar to that for a sundial located in the North Temperate Zone except that it does not operate on the winter solstice.

The behavior of the Figure 7 sundial located in the Torrid Zone, that is for 23.441° ≥ P ≥ −23.441°, is considerably different from that for the same sundial located in the North Temperate Zone. The limit envelope for the summer solstice is now fragmented and a dial facing due South does not operate between the equinoxes and the summer solstice.

The author has also attempted, with no success to date, to determine the maximum hours to be inscribed on a sundial using optimization techniques. Fortunately, blockage due to trees and neighboring buildings may make the results of a limit analysis such as described of only secondary importance. It was, however, an interesting mathematical study.

Harold E. Brandmaier, 63 Florence Road, Harrington Park NJ 07640

Four Noons

Roderick Wall (Melbourne, Australia)

I found the article "A Tale of Three Noons" by Allan Pratt (Compendium **2**:2) to be very interesting. I liked his story book style of describing the three noons. However I think that Allan left out a 4th noon called: World Noon or Cyberspace Noon. With the event of the INTERNET there are now problems whenever standard time is used around the world via Cyberspace. Maybe the terms used to describe the four Noons, and the four kinds of time; Apparent, Mean, Standard and World time (GMT) would be more accurate if they were; Natural noon, Scientific noon, bureacratic noon and Cyberspace noon? Or can someone think of a better term for the 4th noon? It is also interesting to note the different distances of communication used in these times with respect to the different noons.

Local Apparent Noon / Local Mean Noon
Communication was local only within the village with the time requirement being only local within the village. Like all having dinner at the same time. Or milking the cows.

Standard Noon
With the advent of railways and the telegraph, communication was now across many local mean time zones, thus the requirement for standard time. Also we all had better be on the same time, if we don't want two trains to arrive at the same points at the same time thus causing an accident.

Cyberspace (World) Noon
With the advent of shortwave radio, wars around the world and the INTERNET, communication is now around the world in seconds. This e-mail should arrive in America in about 4 seconds all for the cost of a local phone call AU$00.25. Who would use snail-mail that would take at least one week (4 weeks in some parts of the world) and cost AU$1.00? Thus there is a need for the 4th noon.

Question
Which noon corresponds to the way we think: local, standard time or cyberspace? Standard noon I suspect with the way many sundial books are written. They are written with the impression that the sun is always in the south, the tip of the gnomon always points directly at the North Star.

One day we all may think in cyberspace noon and think that there are also people down south in Australia (down under in OZ). Where: the sun is in the North, the gnomon tip points south, the gnomon point points to the north star which we can't see here in Australia without a tunnel through the earth, and the dial is anticlockwise.

R. Wall, P.O. Box 2000, Dandenong East L.P.O.,
Victoria 3175, Australia.
rwall@pyromania.apana.org.au

A Dial Spotted By Woody Sullivan : *"In the recent excellent 4-hour television version of "Gulliver's Travels", NASS members will be interested to learn that an 18th c.-style universal ring dial (perhaps 6-8 inches in diameter) was used prominently as a prop, albeit for only 5 seconds. The scene occurred when Gulliver was being fitted for the End of the World Ball by the inhabitants of the flying island of Laputa. The "mysterious instrument", however, was certainly not used *as* a sundial, but rather as some sort of measurer for proper sized clothes!"*

Doing It With Style

William S. Maddux (Princeton NJ)

Some Notes on Practical Aspects of Orienting The Elements of a Sundial.

Once we have accurately aligned a polar style by using methods of the sort described, we can empirically place hour-marks and their subdivisions on any surface upon which the shadow of the style falls. We can do so without further calculations or projections by using the Equation of Time to reset a watch to apparent time (standard or local, as preferred) and marking the location of the style's actual shadow at each desired interval. By this method we not only can mark a dial on a declining-reclining plane, but we also can place dials on non-planar, compound-curved or irregular, natural or artificial, surfaces. (For example, make a dial on a declining and reclining cedar-shingled roof.)

Our polar style must, of course, be aligned within the local meridian plane, that is, in the plane extending vertically through a "true" south to north line that we have determined at our dial site. The style also must be inclined upward from the horizontal at an angle equal to the latitude of the site so that it points at the center or pole of the apparent rotation of celestial bodies as seen during the daily rotation of the earth. Since a local horizontal or vertical reference is easily available by use of a level or plumb line, we will give greater attention to the south to north alignment problem.

As dialers, we are accustomed to reckoning time from the angular position of the sun, but of course we can, conversely, reckon the angular position of the sun from (clock) time. Assuming that we know the latitude and longitude of a place, and also that we know the Equation of Time and the sun's declination, we can use the sun as a "true compass." In the simplest application, at local apparent noon the shadow cast by a vertical style (*e.g.*, a plumb line) will lie within the local meridian plane and so it will show a south to north shadow-line where its plane intersects a surface. (Usually, for our measurement convenience, a horizontal one.) For a particular place (of known longitude) on a given day, find Standard Time ST of the sun's local meridian crossing (*i.e.* local noon or sun's "southing") as follows: Add (algebraically) the Equation of Time value for that day to 12 hrs ST, which gives the time of the sun's crossing of the Standard Time Meridian STM. (Here

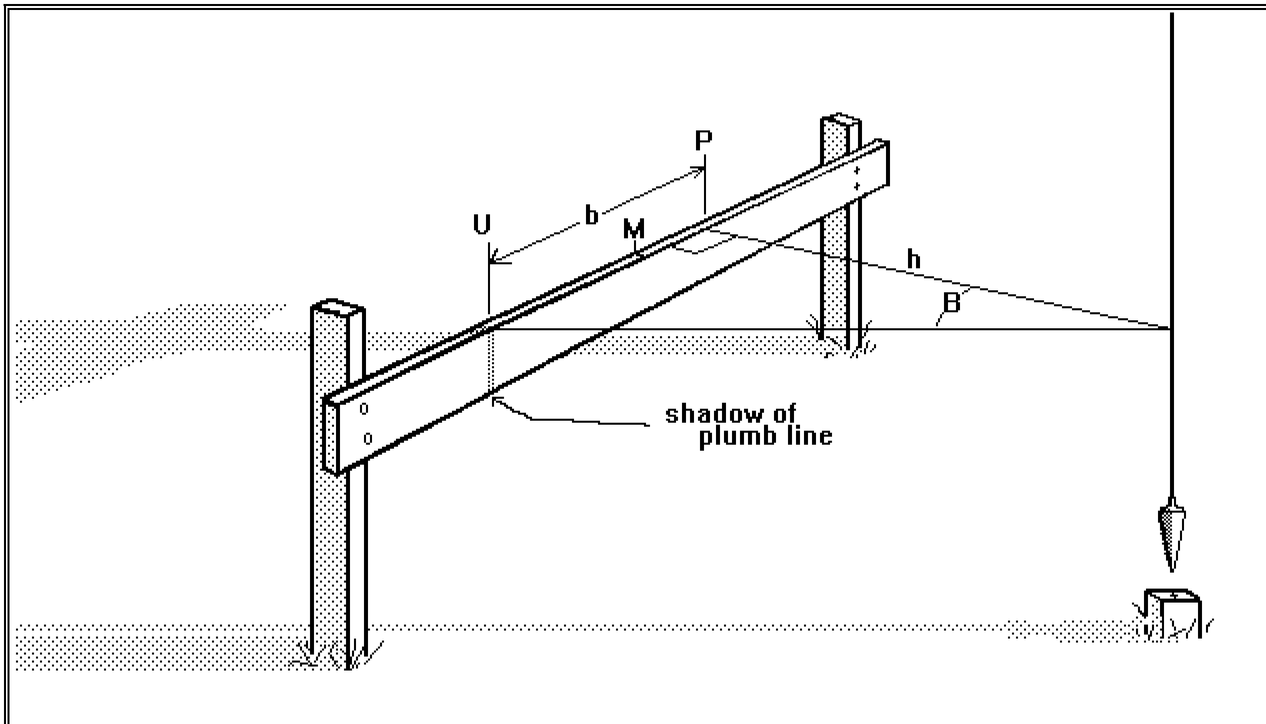


Fig 1. Batter Board As Horizontal Reference.

the Equation of Time is assumed to be in the sign convention for correcting "sun time" to "clock time." If the opposite convention applies, the Equation of Time value should be algebraically subtracted from 12 hrs ST.) Find the difference in degrees of longitude of the place from the STM's longitude (for example: the STM of the Eastern Time Zone is 75°W longitude). Multiply the degree-difference by 4 minutes of time per degree to convert to its time equivalent, and then subtract the time-difference from the sun's STM crossing time if the place is east of the STM, or add it if west of the STM. (The *Equation* program published electronically in NASS *Compendium* Vol.2, No.1, produces values for the Equation of Time and also for declination at any local meridian's noon.)

It is not very convenient to have a compass that can only be read once a day, at the moment of noon. However, we can, for <u>any time</u> that the sun's shadow can be seen, find the horizontal angle that a point on the horizon directly beneath the sun subtends relative to true south. This angle is the azimuth of the sun. To calculate the azimuth for a specific ST of observation, we first calculate the sun's hour angle H. Take the difference between the ST specified and the ST of local noon as found above. Then divide the minutes of time-difference by 4 minutes per degree to obtain H in degrees. H in the following equations should be entered always as a positive-signed (absolute) quantity. To find the sun's azimuth Z (and also its altitude A), we can then use the following equations:

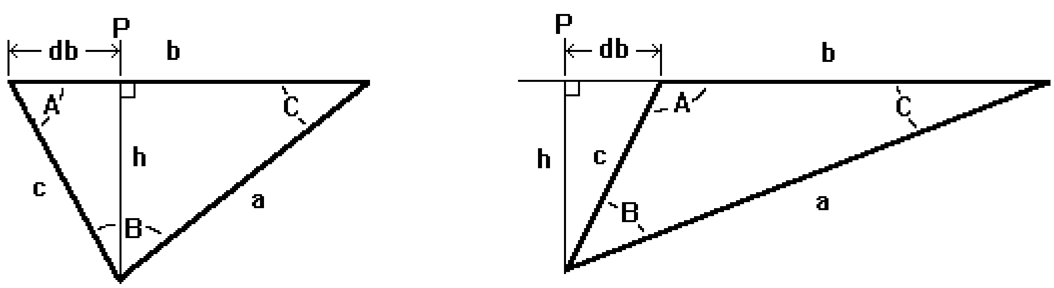
(1) tan M = tan D / cos H
(2) tan Z = (cos M) x (tan H) / sin (f - M)
(3) tan A = cos Z / tan (f - M)

M is an intermediate value used to facilitate the calculations. H is the sun's hour angle as above, f is the latitude, and D (use + or - sign) is the tabular value of the sun's declination for the day. Z is measured from south, eastward for before, westward for after, local noon. (For example, if for a pre-noon H the value of tan Z is 0.3639702, with arctan Z = 20^o, it might be written as "azimuth = south, 20^o east." It is often convenient to give the azimuth as a bearing on a 360^o circle where 0^o is north, 90^o is east, 180^o is south, etc., in which case, the same value would be written as "bearing = 160^o.")

A scientific calculator (*i.e.*, one with trigonometric

LAW OF COSINES:

(1) $a^2 = b^2 + c^2 - 2 * (b * c) * \cos A$



(2) Hence $\cos A = \dfrac{(b^2 + c^2 - a^2)}{2 * b * c}$, and $A = \arccos\left[\dfrac{(b^2 + c^2 - a^2)}{2 * b * c}\right]$

(If $a^2 > b^2 + c^2$, then A is greater than 90^o, as in right-hand figure.)

(3) $h = c * \sin A$

(4) $db = c * \cos A = \not{c} * \dfrac{(b^2 + c^2 - a^2)}{2 * b * \not{c}}$ and so also $db = \dfrac{(b^2 + c^2 - a^2)}{2 * b}$

Fig 2. (Side b, and segment db, should be laid off along the established horizontal reference line.)

function keys) can be used to solve the above equations. It also will be of great help in applying the results to a variety of practical dialing problems. For example, if we want to measure angles at a prospective dial site, cheap stationery-store protractors are of quite limited usefulness, while an expensive, precision-graduated, instrument such as a surveyor's theodolite is hardly likely to be found in the usual dialer's tool kit. By using plane trigonometry as implemented by a fifteen dollar calculator, along with a steel tape, a carpenter's level, a plumb line, and some furring-lath "straight-edges", we can measure and lay out angles to better than a minute of arc tolerance, if need be. (For ordinary dialing purposes, such precision often may neither be needed nor attained, but it is nice to have some extra margin available.)

A horizontal reference line may be established by setting up a batter board (using a carpenters level), by drawing it on a vertical wall with a straight edge and level, or by making use of an architectural feature such as the top of a wall, a horizontal trim piece, etc., that has been checked by level test. Lines may be marked non-permanently by stretched line and chalk, "washable markers" (often found for sale along with toys) or may be delineated by, or upon, masking tape.

If no handy, fixed, solid object is available, a plumb line may be suspended from an improvised support such as a camera tripod, a coat rack, a music stand, a sawhorse, or a stepladder. If the plumb line is hung from a piece of scantling C-clamped to a ladder, it can be extended clear of the ladder's shadows and may be "fine positioned" before final tightening of the clamp(s). If, due to air currents or other small disturbances, the line tends to swing about, an open-mouthed jar of water positioned to immerse the bob may dampen the oscillations sufficiently to permit reliable readings.

Referring to Fig 1, the plumb line marks a site for installing a horizontal dial. To apply plane trigonometry to the problem, we will wish to work with triangles in a horizontal plane. One such triangle is defined by the line segment connecting the plumb line to point U, the line segment b, between points U and P, and the line segment perpendicular to b and

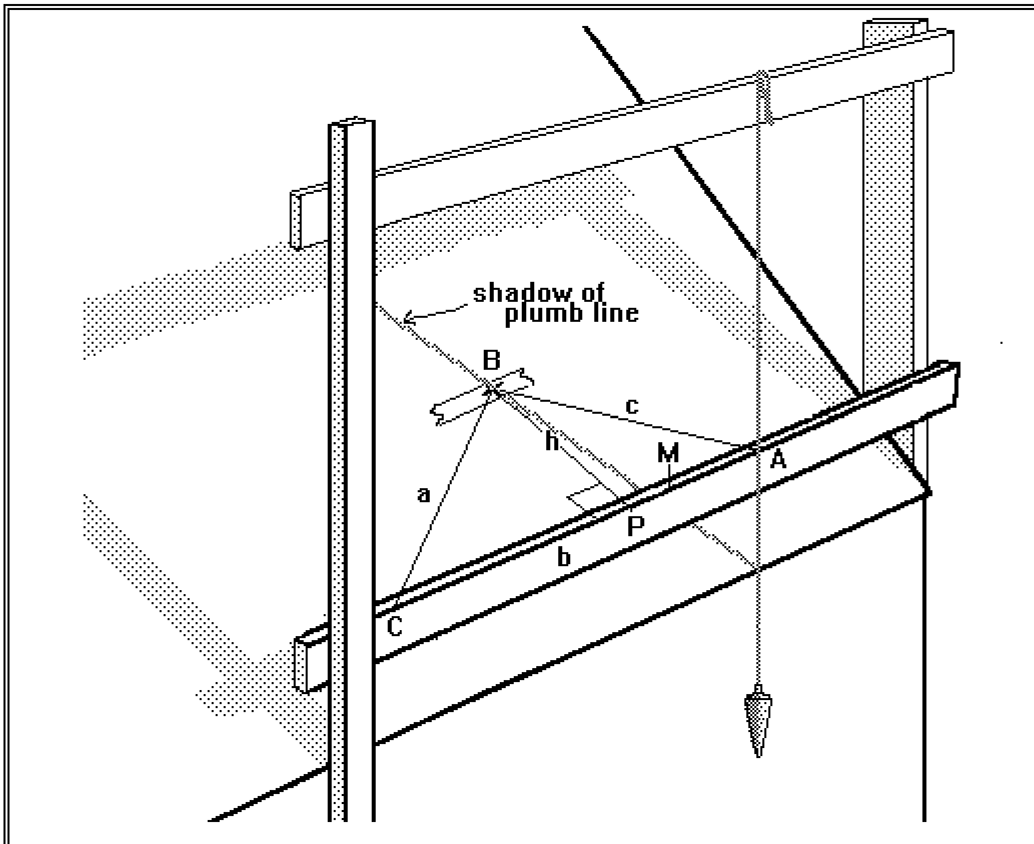


Fig 3. Declining & Reclining Surface. The reference line and point B should be at the same level.

extending from P to the plumb line. Although we could employ a level to establish the horizontal plane from the reference line, to measure distances to the plumb line, we can, in practice, have a helper hold one end of the steel tape fixed at the desired point on the batter board reference line, and with the edge of the stretched tape next to the plumb line, "swing" the tape up and down until the shortest-length measurement position is obtained and read. (For the purpose, this is as close to horizontal as need be, since it is commensurate to the limitation of resolution of our length measurement.)

To locate the perpendicular from the plumb line (the triangle's side labeled "h" in Fig. 1) which meets the horizontal reference line at the front edge of the batter board at point P, we could use a carpenter's square, the corner of a plywood sheet, or the like. It is a good idea to turn the "square" over after lightly marking one location for P, and to then repeat the process with the inverted "square" being brought up to the string from the opposite side. If the second position for P differs from the first, place the final mark halfway between the two. This symmetrical procedure cancels any error in the "square's" right angle, and can also "average out" some other small uncertainties as well. ---- (To find the perpendicular to a glazed window in a vertical wall and hence its azimuth, *e.g.*, for making a vertical declining dial, we might sight past the plumb line to its reflection in the glass, and mark a piece of horizontal tape on the glass at the point where the aligned image intersects the tape.) ---- When the distance from the plumb line to the horizontal line is too great for the use of a "square" to be practical, we can use a steel tape to lay off two well-separated points on the horizontal line that are radially equidistant from the plumb line. The halfway mark of the horizontal distance between the points is then P, the intersection of the perpendicular. For a more generalized method, we can measure the distances from the plumb line to <u>any</u> two well-separated points on the horizontal reference line b, and then use the law of cosines to find the perpendicular's intersection P.

After solving the cosine law equations for lengths, db and h, and locating the perpendicular intersection P, we can directly measure the distance h, and compare it with the calculated h as a check on our work.

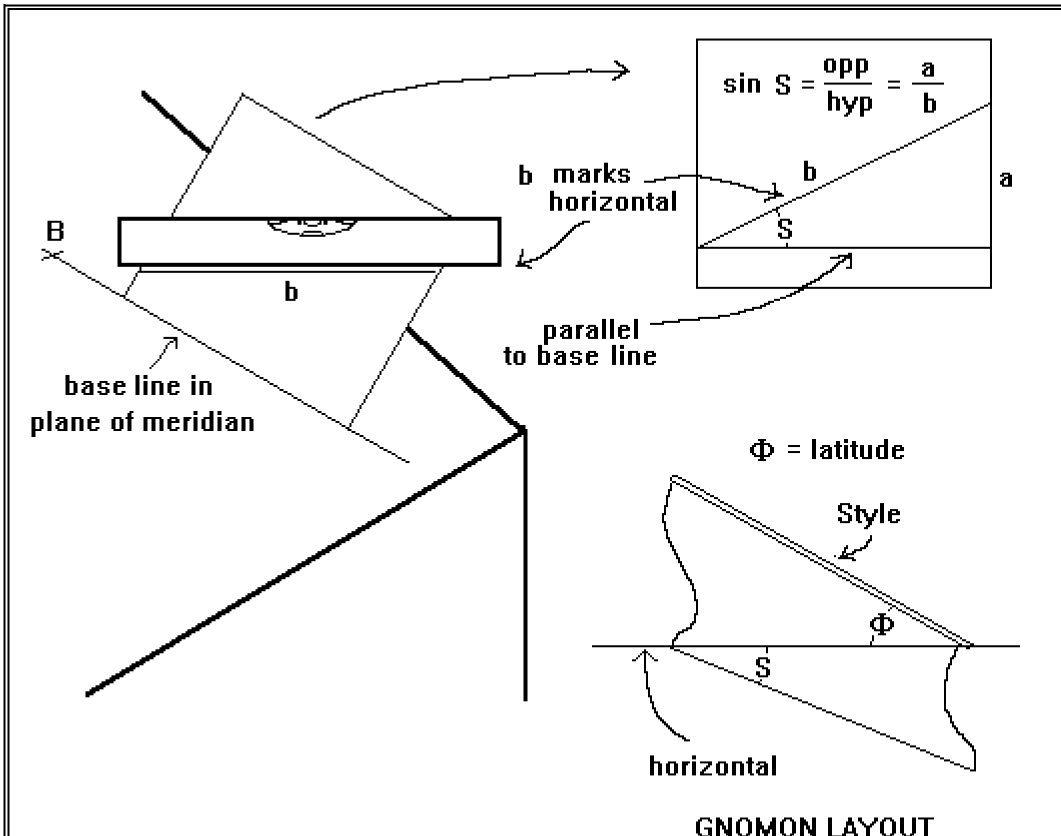


Fig. 4 Finding meridian base line slope, and laying out a gnomon.

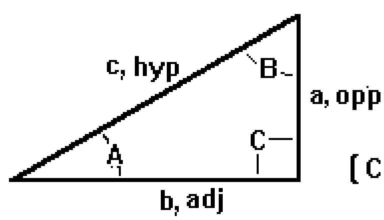
Once we have located the perpendicular and are dealing with right triangles, we can easily use the trigonometric functions (as reviewed in the appended "capsule") with the known measured lengths of the related sides to evaluate angles that we wish to know. or we can lay out new triangles with desired angles (*e.g.* the meridian's direction) as subtended from the horizontal reference line to the plumb line. For example, with reference to Fig 1: If we divide the length P to U by the length h, we obtain the value of the tangent (opp/adj) of angle B. Let us assume that tan B = 0.63707, and so by the INV TAN function, B = 32.5°. Let us also assume that at the time the shadow was at point U, the calculated bearing of the sun was 160°, as in the example used earlier. Since the sun's direction is east of the perpendicular h, then h must point 32.5° west of the sun or at bearing 192.5°. That means the meridian must be 12.5° east of the perpendicular h. TAN 12.5° is 0.2216947 and if we multiply h by this, we obtain the value of the length of a new opposite side for a right triangle with a 12.5° angle of shadow to perpendicular reference. We can now lay off the distance 0.2216947 * h from point P, and mark point M. Now if we sight back over point M to the plumb line, we will be looking true south, at bearing 180°. If we were to place a horizontal dial centered beneath the point of the plumb bob, we could align the style with that sight-line.

So far we have considered the plumb line as at a fixed location, and with the horizontal reference line northward of it where it intercepts various lines radiating from the plumb line's location. For other purposes we might wish to establish a fixed central point B, for example: as the location for a gnomon, and have the horizontal reference line southward of it. A minor complication is that we must arrange to moveably support the plumb line high enough above the common plane of the horizontal reference and location B, for the plumb line's shadow to reach B. Fig. 3 shows schematically how this might be done for a declining and reclining surface, such as a roof. The plumb line should be shifted along the horizontal reference until its shadow falls a little to the west of B and fastened there. We then observe and record

Trig Review In Capsule:

Sine, cosine, tangent, cotangent, secant, cosecant (abbr: sin, cos, tan, cot, sec, csc.), hypotenuse, opposite, adjacent sides (abbr: hyp, opp, adj.)

For Angle A:



[C = 90°]

$$\sin A = \frac{opp}{hyp} = \frac{a}{c}$$

$$\cos A = \frac{adj}{hyp} = \frac{b}{c}$$

$$\tan A = \frac{opp}{adj} = \frac{a}{b}$$

$$\cot A = \frac{adj}{opp} = \frac{b}{a}$$

$$\sec A = \frac{hyp}{adj} = \frac{c}{b}$$

$$\csc A = \frac{hyp}{opp} = \frac{c}{a}$$

Co-functions (Complementary angles):

since: $A = (90^\circ - B)$ or $B = (90^\circ - A)$

sin A = cos B or sin B = cos A

tan A = cot B or tan B = cot A

sec A = csc B or sec B = csc A

Reciprocal functions (bracketed):

csc A = 1 / sin A or sin A = 1 / csc A

sec A = 1 / cos A or cos A = 1 / sec A

cot A = 1 / tan A or tan A = 1 / cot A

Finding an angle corresponding to a given value of a function is known as taking the inverse of the function. The inverse of sin A might be written as arcsin A, $\widehat{\sin}$ A, $\sin^{-1}$A, or INV sin A.

[For example: if sin A = 0.5, then arcsin 0.5 = 30°. That is, A = 30°.]

the time when the shadow moves across point B, and proceed to find the perpendicular from B to P on the horizontal reference line, and the distance h as before. Having calculated the azimuth of the sun for the moment its shadow was at B, we can also, as before, then find a new point M on the horizontal reference that corresponds to the meridian that passes through B. By moving the plumb line to location M, we now can, by observation at local apparent noon, mark the shadow-line passing through B to delineate the intersection of the meridian plane with the roof to serve as the base line for a gnomon. (Actually, we needn't wait for noon, but can sight from directly behind the plumb line at M to point B, and simultaneously mark points to define the base line on the sloping roof surface in line with the plane so defined. We can, of course, check our work at local noon.)

Using a level for horizontal reference in the plane of the meridian above this base line, we can measure the required slope for the support base of the gnomon with the aid of a piece of rigid panel material. An edge of the panel is placed on the base line where the meridian plane intersects the roof. With the plane of the panel vertical, we then use the level to mark a horizontal line on the panel. As shown in the sketch, we then find the angular value of the base line's slope S, as measured in the meridian plane. With the values of S and the latitude known, we can use tangents of those angles to construct triangles whose hypotenuses correspond to the gnomon's base and to the style respectively as seen in the lower right of the sketch. Obviously, the exact outline of the gnomon will vary widely according to latitude, the angles of the surface, and the height appropriate for the size of the dial. The worker will be well advised to make a temporary gnomon and check to see that at local noon, the plumb line's shadow coincides with the stile and its foot, and that the hours away from noon are well scaled as they meet the surface. Although the angles must be maintained, it may be desirable to adjust the height and/or length of the style.

William S. Maddux, 265 Snowden Lane, Princeton NJ 08540.

From The Tove's Nest

Fred Sawyer

Tidbits from around the Nest....

Mark Gingrich has noted that Dover Publications plans to publish a paperback edition of René Rohr's well-known but not readily available book *Sundials: History, Theory, and Practice* sometime around May, 1996.

Robert Adzema, whose *Great Sundial Cutout Book* provided us with an interesting dial in our prior issue, asks that we note the price for his book is $20 postpaid within the US.

Tom Shepard's keen eyes found another apparent problem with Albert Waugh's morning dial at Mystic Seaport, which was discussed in our last issue: *"I never would have noticed the misplaced 11:00 line if you had not mentioned it But there is also something wrong with the labelling of the hour lines. The space between the hourlines should gradually increase, as it does between 5 and 6, and between 6 and 7. The space between 7 and 8 is narrower than the space between 6 and 7, however."*

Readers who would like to reconstruct the dial can use the following parameters in the Zonwvlak software available through NASS: latitude 41°, inclination 90° and declination -80.83° .

Members Klaus Eichholz and F.J. deVries (author of Zonwvlak) noted that the universal horizontal dial face discussed in Compendium 2-3 is a design originally developed by Jacques Ozanam in the 17th century. They each sent very welcome copies of articles on Ozanam's work. Perhaps the most accessible reference for English speaking readers is René Rohr's article (translated by A.R. Somerville) "The Universal Sundials of Jacques Ozanam", *Antiquarian Horology*, Summer 1989, pp.171-177. In addition to the rectilinear, Ozanam had parabolic, hyperbolic and elliptical versions of the dial.

Error Analysis Of The Horizontal Sundial - III

T. J. Lauroesch and J. R. Edinger, Jr. (Rochester NY)

INTRODUCTION

Installments I and II dealt with sources of error found in parts fabrication, specifically incorrect gnomon angle (*Compendium*, **2**:3, September 1995, pp. 18-23) and incorrect hour lines (*Compendium*, **2**:4, December 1995, pp. 10-12). This installment deals with the first of four sources of error encountered in parts assembly: substyle decentering along the noon line.

Of the nine sources of error examined in this study, this one stands apart from the others in two ways. First, the amount of time error (which is manifested as an angular difference resulting from a linear displacement) depends on the radial location on the dial plate selected for determination of time. Second, scaling from a dial of one size to another, for a specific amount of substyle displacement, is treated as a percentage operation. In short, while describing the source of error is rather simple in terms of magnitude and direction, assessing the resultant time error is "dial specific" as is shown in the following procedure.

PROCEDURE FOR CALCULATION

Since the main purpose of this error analysis, along with the others in the study, is to accentuate the need for quality workmanship, it was convenient and sufficient to evaluate the time errors which come about on a simplistic sundial. To carry out the work, a representative sundial with specific dimensions was used. Results are reported for that particular sundial in such a way as to be applicable to dials of different designs and dimensions.

Figure 1. Illustration of simplistic sundial used for error analysis of subtyle decentering.

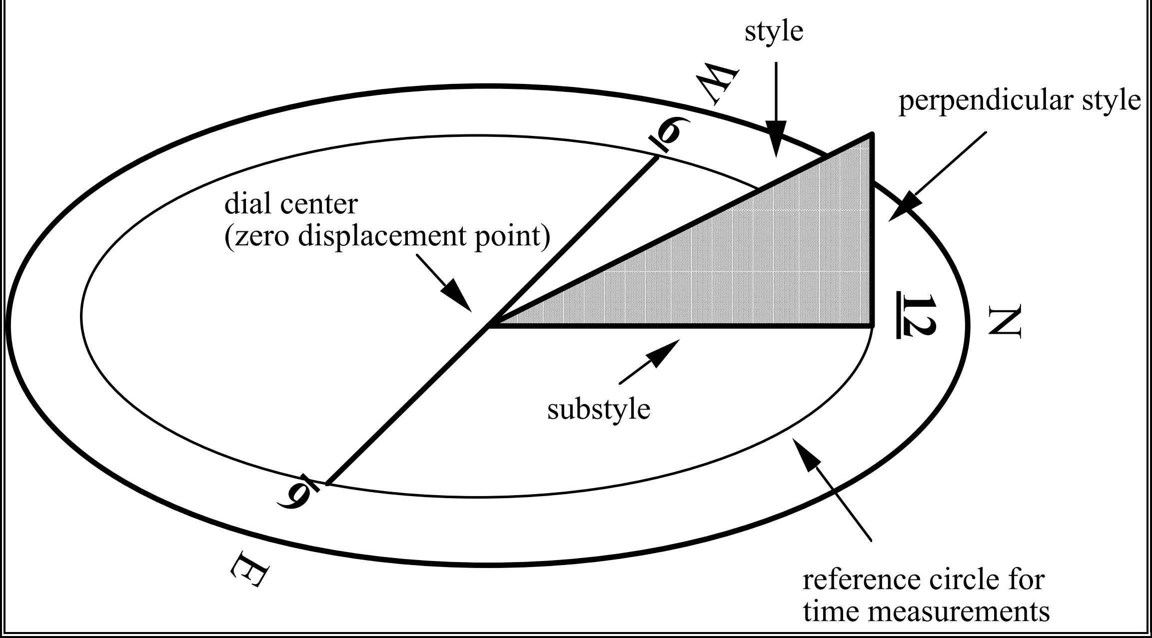


Figure 2a. Illustration of sundial with displaced substyle when ET is equal to zero.

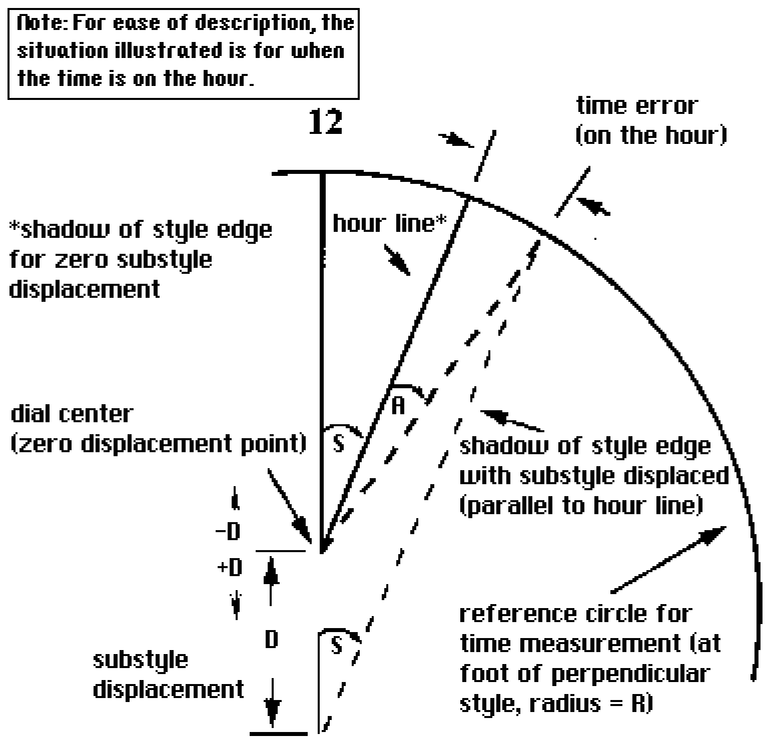
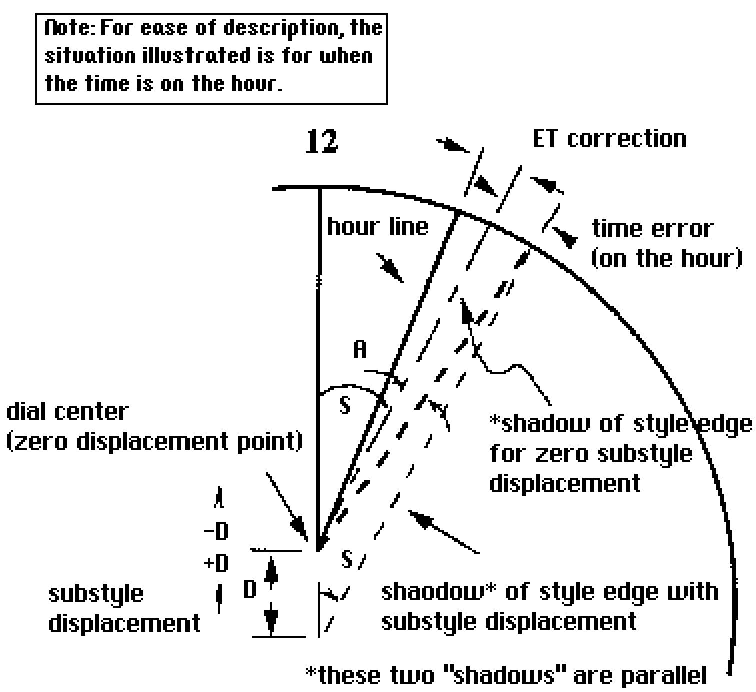


Figure 2b. Illustration of sundial with displaced substyle when ET is <u>not</u> equal to zero.



The sundial used for calculations has a substyle 100 mm long (The terms in this article are according to definitions used by Cousins: Frank W. Cousins, *Sundials: A Simplified Approach by Means of the Equatorial Dial*, John Baker, London, 1968). The perpendicular style intersects a reference circle with its center at the apex of the triangular gnomon. See illustration in Fig. 1. For purposes of this analysis, all measurements of time were made along this reference circle although on actual dials they may be made in other locations depending on the maker's design, use of nodus, etc.

Decentering errors along the noon line in both directions were considered for 1/8, 1/4, 1/2, and 1 mm displacements. As in previous installments, the time error was analyzed for thirteen selected dates spread throughout the year at each hour from 7 a.m. to 5 p.m. Solar data for the year 1994 were used.

A noteworthy consideration in this analysis was recognition of the fact that the sun is "not aware" that the substyle has been displaced. As an obvious consequence, the shadow of the displaced style is parallel to the shadow of a style without displacement. What is important to the reading of time is the fact that the shadow of the displaced style does not lie directly along a radial line emanating from the center of the dial. Thus, when the Equation of Time (ET) equals zero and the time is on the hour, the angular separation (seen from the dial center) between the hour line and the shadow of the displaced style is a function of the distance from the dial center. A comparable situation exists when ET is not equal to zero but requires a more elaborate explanation. By combining this fact with the use of an arbitrarily chosen reference circle for time measurements, the resultant time error was evaluated by a simple calculation. The procedure for the calculation is the same whether or not ET equals zero and, of course, would hold true whether the time is on the hour (as illustrated) or not. Refer to Figs. 2a and 2b for the following discussion.

With knowledge of the sun's altitude and azimuth, the style shadow angle (S) can be calculated (NASS *Compendium*; **2**:3, September 1995, p. 20) for any hour of any date. The sine of the error angle (A) is then calculated from the shadow angle, reference circle radius, and displacement:

$$\text{Sin A} = (\text{Sin S})\text{D/R}$$

where D is the substyle displacement and R is the radius of the reference circle. D is considered negative when the substyle is displaced toward the noon mark (or "top" of the dial's perimeter) and positive when displaced away from the noon mark.

The time error resulting from a displaced substyle, then, equals the difference between the times corresponding to the ideal style shadow angle (S) and the substyle-displaced shadow angle (S+A).

Examination of the above procedure makes it quite apparent why the magnitude of the time error

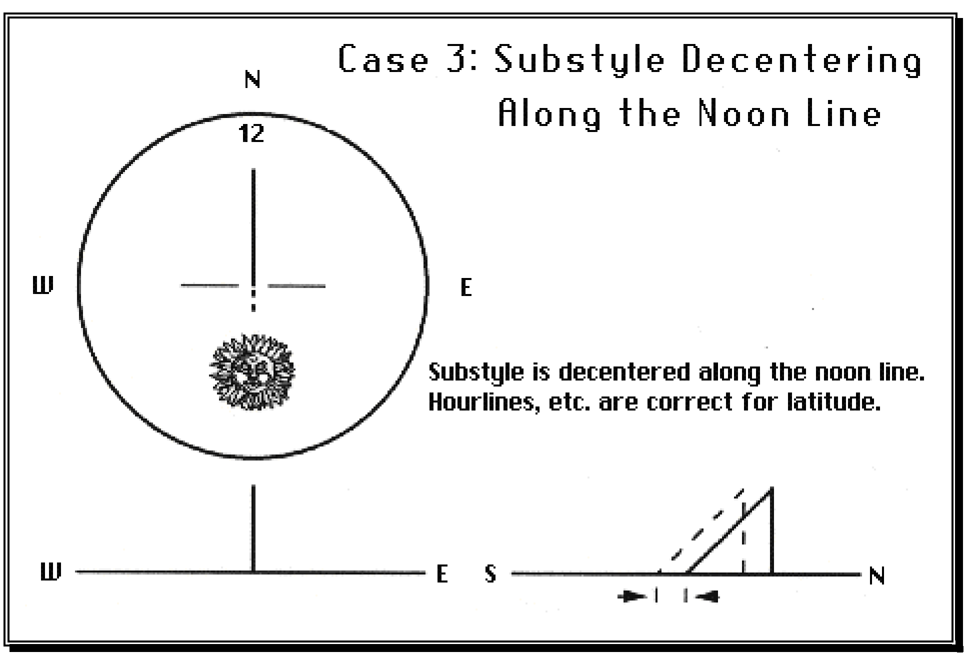


Figure 4. Error in sundial time increases with increasing time fron noon

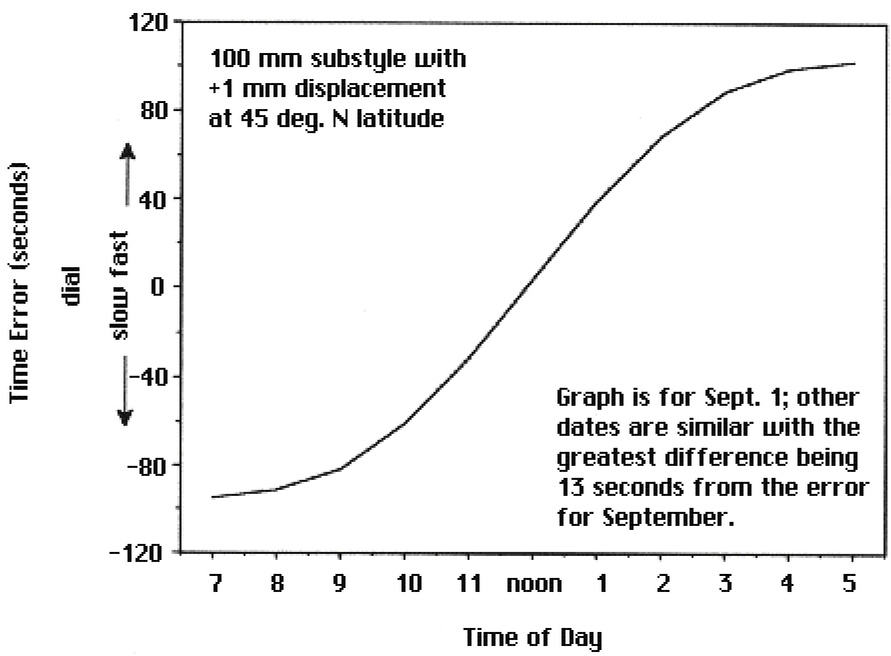
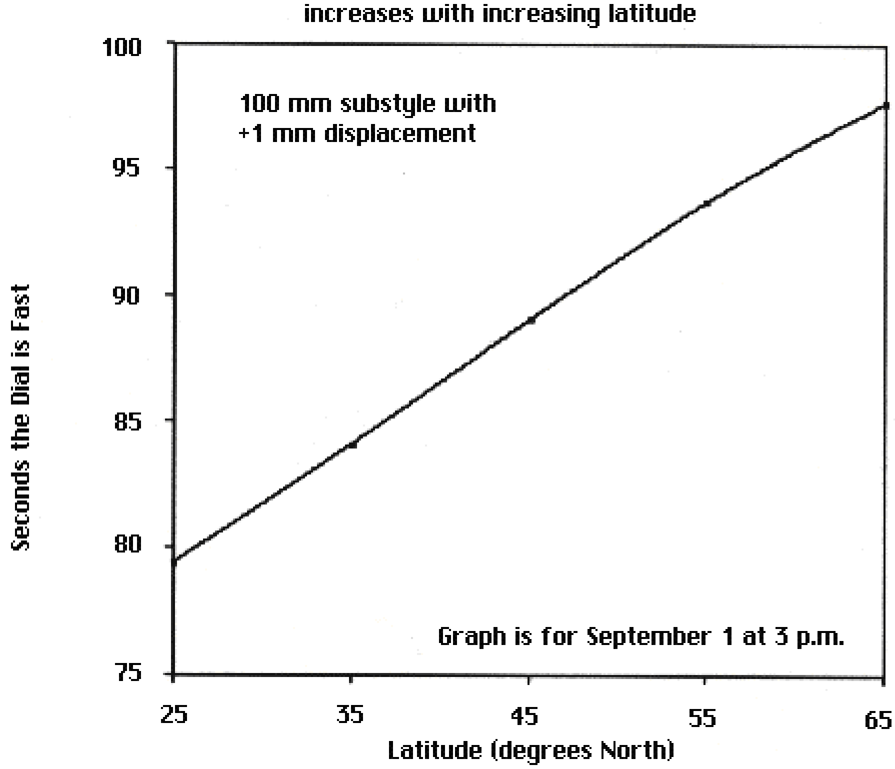


Figure 5. Sundial time error increases with increasing latitude



depends markedly on the choice of the location of the time-measuring reference circle. It also shows why the magnitude of the substyle displacement alone is an incomplete descriptor: the key is the ratio of the substyle displacement to the radius of the reference circle—which arbitrarily equals the substyle length in the calculations reported in this installment. This ratio can be used to apply results from one sundial size to another.

TIME ERROR RESULTS

Case 3: Substyle Decentering Along the Noon Line

In this case, fabrication, assembly, and installation all have been properly completed except for linear displacement of the (triangular) gnomon in either direction along the noon line/NS direction as illustrated in Fig. 3. For the results reported in this installment, decentering was positive; i.e., the substyle was displaced away from the noon mark. The error caused by a displaced substyle was found to change in proportion to the magnitude of the substyle's displacement.

From Fig. 4 we see that, with increasing time from noon, the error in indicated time caused by a displaced substyle increases in a somewhat linear fashion and then levels off as either 6 a.m. or 6 p.m. is approached. With latitude, the error was found to increase as latitude increased (see Fig. 5). And finally, at 45° South latitude, the magnitude of the error was found to be virtually identical to that at 45° North.

CONCLUSION

From these results we can see that correct centering of the gnomon is an important consideration. Misplacement by as little as one millimeter can result in up to two minutes error for a dial with a 100 mm substyle. Fortunately, the same 1 mm displacement in a larger dial results in a proportionately smaller error according to the equation presented in the Procedure for Calculation section above.

The magnitude of the time error resulting from a specific substyle displacement is not only related to the size of the sundial but also depends on the radial position on the dial selected for measurement of the "angular" separation of the shadow and the base line for time measurement.

[Editor's Note: An example of such an error is found in this photo of the sundial at the headquarters of Harcourt Brace Jovanovich located in Orlando FL.]

J.R. Edinger Jr., 295 Burley Road, Rochester NY 14612

A Kitchen Ceiling Analemma

Woody Sullivan (Seattle WA)

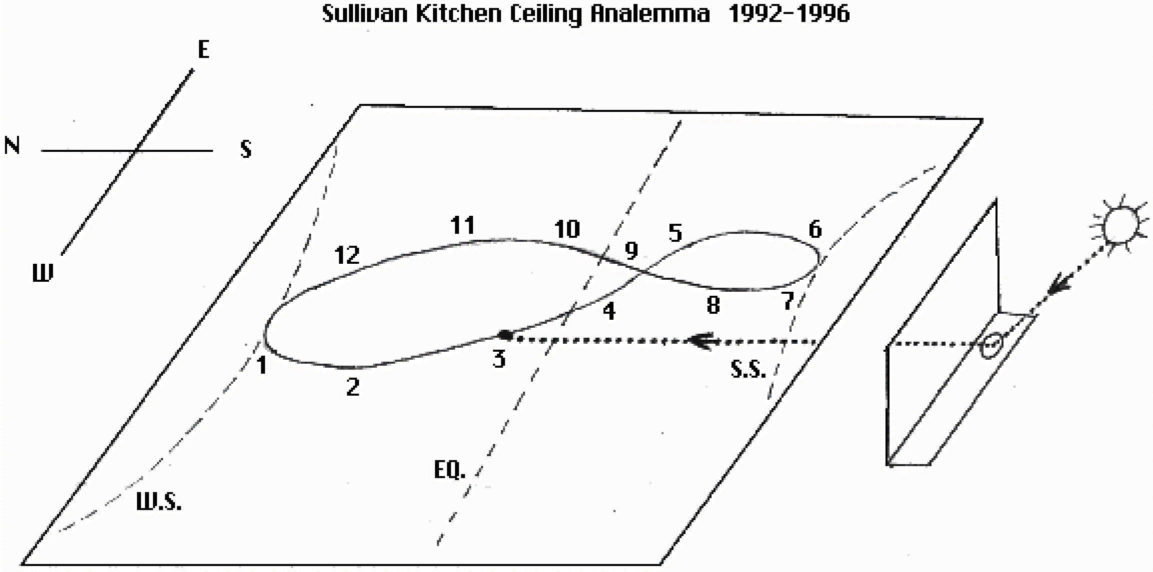
The article on reflected sundials in the December 1995 Compendium prompts me to report on a project of mine that many reader-gnomonicists may wish to try for themselves. As before, a small mirror on a window sill brings a spot of sunlight into a room and projects it on the ceiling. But instead of first laying out calculated dial lines, I determined empirically through frequent observations where they should be. Furthermore, rather than laying out a full set of hour lines on the ceiling (which requires a very large area), I marked the ceiling for only a single time each day. If this observation is taken at a given local or true solar time, then the spot of light will always fall on a single (straight) hour line. But if taken at a fixed mean solar time (the most convenient being one's standard zone time), then the changing equation of time and declination of the sun cause the spot of light over a year to trace out a figure-eight-shaped analemma. Such an analemma makes an attractive and fascinating addition to any dialist's ceiling.

As an example, consider a noon analemma observed through a south-facing window (see Figure). On its sill or another horizontal surface exposed to the sun, attach a small mirror. The overall size of the resultant analemma is proportional to the distance of the mirror below the ceiling. Whether inside or outside, be sure to securely glue the mirror into place, for it needs to stay fixed for at least one year. Also check that the mirror will not be shaded during any season of the year from the "southing" sun at noontime. Such shading can be caused by nearby buildings or trees, or structures near the window such as an overhanging roof or gutter. (For some guidance, the noontime altitude angle of the sun ranges from [90° - lat. + 23.4°] on the summer solstice to [90° - lat. - 23.4°] on the winter solstice.) Once set up, on as many days as possible over the course of a year, at the exact hour of 12:00:00 standard zone time (try to stay within 10-15 seconds accuracy), mark the position of the center of the spot of light. Ideally one should observe at least once per week, but the analemma can still be adequately defined even with an occasional gap of two or three weeks.

In my own case I set a 2.5 cm square mirror on the outside sill of a south-facing kitchen window. The mirror was 190 cm below the height of the ceiling and produced an analemma 310 cm long by 40 cm wide. On sunny days it cast a ~410 cm wide spot of light that moved along the ceiling for several hours at a rate of 1-2 cm per minute. The sill had an outwards slope of ~10°, but to make the projected spot of light fit on the ceiling from solstice to solstice I shimmed the mirror to an angle of ~5°. In order to avoid the shade of an overhanging gutter I wanted the sun a bit lower during observations and so chose a time of 11:15 Pacific Standard Time rather than 12:00 noon.

My first observation was on 26 March 1992 and as the weeks passed and the sun steadily moved higher the reflected spot of sunlight on the ceiling moved closer and closer to the window. But at three weeks before the summer solstice I ran into a serious problem -- despite my calculations, the gutter was now shading the mirror! Should I toss out ten weeks of good data and start over with a relocated mirror? No -- instead, drastic action was called for. For the next six weeks I climbed a ladder outside and held the gutter away from the house (allowing the sunlight to pass through the gap thus created) while an accomplice inside (my older daughter, who was well experienced in humoring Dad's wacky projects) marked the ceiling! During these solstitial weeks it was exciting to see a loop take shape as the spot of light "turned the corner," and then in late August cross its earlier track , thus defining one lobe of the figure-eight. As we went through the equinox period

Sullivan Kitchen Ceiling Analemma 1992-1996



A Sketch (not to scale) of the ceiling analemma defined by 160 observations spread over four years. The viewpoint is from above the ceiling as if it were transparent. The mirror on the window sill is 190 cm below the ceiling; the analemma is 310 cm long by 40 cm wide. Labels 1 through 12 on the analemma correspond to the first day of each month; the reflected sunbeam is illustrated for 11:15 PST March 1. East-west daily tracks for the solstices and equinoxes are also shown.

the change from day to day grew greater (due to the larger daily change in the sun's declination); furthermore, the daily shift increased as the beam of sunlight was projected at much more of a grazing angle to the ceiling. The daily progress of the spot along the analemma varied from a crawling 0.2 cm (at the summer solstice) to 2 cm (at the equinox) to a galloping 3 cm (midway between the equinox and winter solstice). As we approached the winter solstice I was delighted to see that at least part of my calculations had not gone astray -- the sun was stopping and reversing direction before it ran out of ceiling at the north end of the kitchen (I had all of 50 cm to spare).

But now I had another problem as the low winter sun was partially obstructed by the branches of a small tree (our latitude of 47.4° means only a 19° high noontime sun on those rare December days when we Seattlites see it at all!). The solution: have my younger daughter shake the tree back and forth so that my eye could better estimate the position of the spot centroid. As the winter wore on and the sun headed northwards to our hemisphere and the spot of light headed southwards on our ceiling, I eagerly anticipated the closing of the curve. One last potential obstacle loomed, however, and indeed the spot collided in early February with a fluorescent light fixture that I had long been worrying about. For two weeks I was forced to remove its plastic housing in order to mark the ceiling, but fortunately the spot never actually ran into the fluorescent bulbs themselves.

This third trial was to be the final one, and at last, in March 1993 with the 82nd observation and great huzzahs, the analemma closed. The length of the completed figure turned out to be 310 cm, with the large winter lobe about 40 cm wide by 250 cm long and the summer lobe only 8 by 60 cm. For good measure I had also traced a ~3-hour-long east-west daily track of the spot at the times of the solstices (hyperbolae) and the equinoxes (a straight line) (see Figure).

Our kitchen ceiling was now splendidly marked up in pencil. But my wife, who had often assisted with observations and who, after lengthy, good-natured negotiations ("And what will you be giving up in return?") had initially given her consent , now drew the line at making the analemma more permanent with tape or paint. What to do now? I had no choice but to record the analemma for a second year, filling in gaps from the first go-around and checking for possible changes in the elements of the earth's orbit and axis tilt or, more likely, the geometry of my house. In fact I did measure a shift of ~0.5 cm between the initial months of the first and second years. Was it epoxy settling under the mirror? The ceiling or window sill settling? (Our 80-year-old house is definitely somewhat out of plumb, although I detected no measurable effect from the 5.0 earthquake that noticeably shook us on 28 January 1995.) On the whole the second year turned out consistent with the first at a level of 0.5-1.0 cm (which translates into an angular accuracy of 5-15 arcmin or a time accuracy of 20-60 sec), as was the third year and the fourth, now almost completed after a total of 160 observations. I intend to continue at least until the kitchen is next repainted....

I hope this story inspires other NASS members to likewise create ceiling analemmas and report on them. If you don't have a south-facing window, then another hour of the day must be chosen and planning is a bit trickier, but I would be happy to help out with the necessary calculations to ensure that the entire analemma will indeed fit on the ceiling for the proposed set-up. It obviously also helps to have a supportive family! One other tip: if intermittent clouds or simple tardiness mean that you miss your appointed time by, say, 5 minutes, then simply record a second point (and ideally a third) at further intervals of 5 minutes and then extrapolate backwards to the desired time (many of my points were done this way).

If the reflected dial concept won't work for your home, then consider observing your own analemma in a more conventional manner by simply observing the shadow of any object (a small sphere is best) on any receiving surface (a vertical or horizontal plane is easiest to plan for). No matter which way you choose to trace the analemma, it's fun and very satisfying to see it take shape as the months pass by. There's a world of difference between actually experiencing the analemma for yourself and mere theoretical knowledge of this beautiful figure at the heart of gnomonics.

For further reading:

diCicci, D. (1979). *Sky & Telescope*, Vol. 54, 537-40. "Exposing the analemma" -- the story of an amazing year-long, multi-exposure photograph of the sun's position taken at weekly intervals and at the same mean solar time each day, revealing the analemma on the sky itself. *[Editor's Note: A 16" x 20" photographic print of this time lapse analemma is available for $24.95 plus s/h from Sky Publishing, 800-253-0245 or +1-617-864-7360, order # P0023.]*

Harvey, D. A. (1982). *Sky & Telescope*, Vol. 60, 237-9. "The analemmas of the planets" -- fascinating diagrams showing the varied solar analemmas that would be observed from each of the nine planets!

Oliver, B. M. (1972). *Sky & Telescope*, Vol. 44, 20-2. "The shape of the analemma" -- calculations of the slowly changing shape of the analemma over several 100,000 years due to changes in the earth's orbit and axis tilt.

Rohr, R. R. J. (1990). *Bulletin of the British Sundial Society*, No. 90.3, 5-11. "On reflected ceiling dials" -- detailed descriptions of four extant reflected dials, complex and marvellous, from the 17th century in France and Italy.

Sawyer, F. W., III (1994*). Bulletin of the British Sundial Society*, No. 94.2, 2-6. "Of analemmas,mean time and the analemmatic sundial - Part 1" -- includes a short history of the concept of the analemma and the differing meaning of the word since ancient times.

Shrader, W. W. (1975). *Sky & Telescope*, Vol. 46, 217-8. "A sundial on an office ceiling" -- a complex reflected ceiling dial on a Raytheon engineer's office in Massachusetts.

Taylor, P. O., and Hendrickson, N. L. (1995). *Compendium*, Vol. 2, No. 4, pp.17-9. "A reflected sundial" - A detailed description of how to set up a ceiling sundial (ghost-written by Fred Sawyer).

Woody Sullivan, 6532 Palatine Ave N
Seattle WA 98103, USA.
Tel. 206-784-1052 (hm) or 206-543-7773 (wk).
woody@astro.washington.edu

SunWeb : A Proposal

Joshua R. Smith (Cambridge MA)

SunWeb
http://physics.www.media.mit.edu/~jrs/sunweb.html

SunWeb is an effort to create a global network of sundials linked through the World Wide Web. This node is the seed. I will install a sundial and video camera on the roof of the Wiesner building (which houses the Media Lab at the Massachusetts Institute of Technology in Cambridge, MA), and make a realtime image of the dial accessible through the SunWeb page.

My hope is that at least a handful - and hopefully hundreds - of the millions of Web users will be inspired enough to add their own sundials; these will be linked together to form SunWeb. Please contact jrs@media.mit.edu if you want advice on how to add a node to SunWeb, or if you have added a node, so I can link this site to yours.

The goal of SunWeb is to produce a sensation of "being-on-the-world." By hopping rapidly from one dial to another several hundred miles away, one will have a first-hand, visceral, and intuitive version of the experience Eratosthenes must have had when he used the difference between the sun's shadow in Alexandria and Syene to measure the curvature of the earth. Does one really know the earth is round if one has not experienced it directly? Would one know after using SunWeb?

So one aspect of being-on-the-world is the sense of being on a globe, a sphere. But I also hope SunWeb will lead participants to consider the condition of being on the world, as opposed to being in a smooth, seamless electronic alternative world, one in which one neither knows nor cares about the position of the sun in the sky. SunWeb is, of course, part of just such an electronic space, and therefore represents an ironic attempt to disrupt its smoothness, and to represent its boundaries and geography to the viewer. To that end, SunWeb pages will also contain a map highlighting the location of the video camera currently being visited, and indicating the locations of all the other dials comprising SunWeb. I will also make it possible for visitors to register the location they are visiting from. SunWeb may provide a dramatic map of the geographical and cultural boundaries of the Internet, a map that needs to be made, particularly given the increasing prevalence of the notion of "cyberdemocracy" in American political discourse.

Though the global collaboration is the ultimate objective, I want my dial to be interesting enough to stand alone. I have designed a dial that I hope will be both beautiful and well-suited to the constraints and possibilities of the Internetworked medium. The face of the dial is glass, with a frosted central disk for the shadow to be cast on.

The remaining area of the dial's face, the area between the disk and the corners of the video frame, is mirrored, so that one will be able to see reflections of the sky. Since it is only to be viewed electronically, normally fixed elements of the dial's design can become dynamic. Instead of static ornamentation, an image of the current sky will decorate the corners of the dial, and the hour marks will be superimposed electronically. In order to make it more interesting as a standalone object, it will also be possible to view a high-speed sequence of the frames collected over the previous 24 hours, to visualize the rotation of the earth.

Of course I cannot guarantee that SunWeb will grow as I hope it will, but therein lies one of the most interesting features of this new form: the structure is grown collaboratively, rather than planned or designed. By consciously attempting to harness the force that gave us the World Wide Web, we can explore powerful new modes of collective human endeavor. Hopefully SunWeb will grow in ways I cannot imagine, just as the Internet has grown into a structure unlike anything its creators could have conceived.

Joshua R. Smith E15-492, MIT Media Lab, 20 Ames Street, Cambridge MA 02139

DESIGN & CONSTRUCTION FORUM

Robert Terwilliger, Moderator

The Design and Construction Forum begins a new occasional feature this year, a question and answer dialog aimed at solving problems encountered by practical dialists. If you have any questions, we will try to answer them. Those of general interest will be published here in the Forum. The Forum is open to all, and can only thrive on your input. We encourage the contribution of articles, tips, or comments. Tell us about dials you have built, any problems you encountered, and how you solved them.

The Design and Construction Forum has a **new address** - c/o Robert Terwilliger, 2963 Bird Avenue, Coconut Grove FL, 33133-4501. The Email address is unchanged, 71034.3445@compuserve.com.

Q. I have a question about the program included with the article *A Sundial to Enjoy* by Mac Oglesby in Compendium Vol 2 No 3 Sept 1995 page 24.

I think there is a problem when the program is used for latitudes south of the equator as here in Melbourne Australia (lat 38° South).

The program indicates that the month of December and the winter solstice should be at the north end of the dateline (Y being negative), and the month of June and the summer solstice to the south (Y being positive). I think that the December end of the dateline should be south of the dial center at Southern latitudes. Our summertime is in December. Note also that the AM and PM hour points should be south of the dial center south of the equator. (*from Roderick Wall, Melbourne Australia*)

A. Mr. Wall is correct. The layout of an analemmatic sundial will vary depending on the latitude for which it's designed. At northern latitudes the ellipse of hour points lies to the north and is open to the south. At southern latitudes the ellipse inverts and lies to the south. The length of the dateline will increase as the latitude decreases. To address Mr. Wall's concern, at <u>all</u> latitudes the dateline should be a north-south line with June 21 at the north end and December 21 at the south.

At the poles the ellipse of hour points is a circle with the hour points located 15° apart. The dateline is a point. At latitude 0° (the equator) the ellipse of hour points becomes a straight east-west line, and the dateline reaches its maximum length.

The morning hours will always lie to the west of the dial center. At northern latitudes the hour points increase along the northern ellipse in a clockwise direction (this is why clocks go clockwise). At southern latitudes the hour points increase along the southern ellipse in a counterclockwise direction (evidence that clocks were invented in the northern hemisphere).

As Mr. Wall points out, the program ENJOY.BAS included with the article *A Sundial to Enjoy* needs a correction so it will not reverse the dateline at southern latitudes.

Delete the program line:

```
N=SGN(L): IF N=0 THEN N=1
```

And change program line:

Y=TAN(c*SD)*COS(c*L)*MajDia/2*N to:

Y=TAN(c*SD)*COS(c*L)*MajDia/2 (the same line with "*N" deleted)

If any other readers south of the equator have already used the program, the output can be corrected by reversing the signs for the dateline. A corrected program, ENJOY3.EXE is included with the Digital Edition. (*Mac Oglesby, Putney VT*)

Q. I am planning to make a new sundial. I have designed the face and I am starting on the gnomon. None of my books seem to tell me how long to make the gnomon. Are there any rules for this? *(from John Edelmann, Franklin OH)*

A. There are no definite rules for gnomon length, but I can provide some guidelines. Let's consider a solar time horizontal dial. The critical day of the year will be the summer solstice when the shadows will be shortest throughout the day. The shortest shadow of the day will be at noon.

Some dialists feel the gnomon should be long enough so the shadow will touch, or even cover, the numeral 12 at noon. However, the shadow is only critically short around noon, and only for a few weeks around the summer solstice. At all other times and dates the end of the shadow will fall off the dial. Also, a gnomon this long may be both fragile and ungainly. It may spoil the symmetry of an otherwise well balanced dial. Latitude is also a consideration. I live in Miami, Florida at latitude 25° N. For a shadow to extend 10" from the dial center at noon on the summer solstice here, the gnomon will have to be almost 11" long.

Knowing the location of the shortest shadows of the year for a given gnomon will help you make your own decision about how long the gnomon should be, and how it will relate to the face and the overall appearance of the dial. Keep in mind that the eye will follow the shadow along the hour lines to the appropriate numeral much as we read the hour hand on a clock.

The shortest shadows will fall along a summer solstice curve plotted with the end of the gnomon as the node.

If you are not quite up to nodes and plotting solstice curves, there is a way to approximate this curve. Make a mock-up of your gnomon with a length you find pleasing. Take a piece of wire such as a straightened paperclip and bend it in the middle to an angle of about 23½°. This is the declination of the sun on the summer solstice. Hold one side of the wire along the top of the gnomon with the bend right at the tip. When you rotate the free end of the wire it will point to the summer solstice curve, which traces the ends of the shortest shadows your gnomon will cast.

I should point out that the critical date for a vertical dial is the winter solstice - but you can use the same paperclip, the same way.

Readability should be a prime consideration for any dial. My suggestion would be to make the gnomon long enough so the shadow, extending out from the dial center, will always overlap the hour lines as they extend in from the numerals. In other words, all the hour lines should terminate inside your summer solstice curve. Once you are able to locate the curve for your trial gnomon, you can adjust the length of the gnomon and the hour lines with relationship to each other. Combine with decorative considerations until you get a pleasing balance and overall appearance.

The shape of the underside of the tip of the gnomon is also important. For instance, if the end of the gnomon is rectangular, the shadow of the lower corner of the rectangle will extend further out the dial face than the upper time-indicating corner on dates between the equinox and the summer solstice. This can be avoided by being sure the bottom edge of the gnomon is cut back from the tip so it makes an angle a few degrees smaller than your paperclip. The resulting shadow will always be a distinct pointer. (*Robert Terwilliger, Coconut Grove FL*)

Digital Bonus

Fred Sawyer

[Users of the digital edition of the Compendium will recall that our intention was to provide a DOS-based scientific calculator in this issue - one which could be called from and used within the Compendium environment.

Unfortunately, the shareware program that seemed to accomplish this task the best has been found to have serious flaws in its trigonometric function calculations as well as in some of its simple algebraic logic. The author of the program has promised to try to remedy the problem, but at this point we cannot offer the program. We will be seeking alternatives for a future issue.]

With this issue, the digital edition of the Compendium includes many of the shareware and free programs distributed in our first two years. The focus in developing this disk was to provide those programs which may be assumed as tools in future issues of the Compendium - e.g. the program Graphica, which can transform simple ASCII files into vector graphics displays of sundials. Future articles may well assume that the digital reader has access to Graphica, so that a program designed to create the correct ASCII file can be used to complete a sundial.

As new members elect to receive our digital edition, each will receive a copy of these programs, so all readers will have access to the same software. Please keep in mind that any readers who develop dials or graphics using any of these tools are very welcome to send them to the editor for possible publication or distribution.

Quiz #8

The following verse appears in The Parson's Prologue in Geoffrey Chaucer's Canterbury Tales, written in the late 14th century (circa 1390):

It was four o'clock according to my guess,
Since eleven feet, a little more or less,
My shadow at the time did fall,
Considering that I myself am six feet tall.

Assuming this observation to have taken place at latitude 51° N, on approximately what day of the year was it made? (Submitted by Fred Sawyer)

From Our Last Issue:

Harold loves sundials and is extremely proud of his newly completed precision equatorial dial, which is adjustable for latitude, longitude, Daylight Savings, and the equation of time (by rotating the hour-band). At noon on September 1st this dial was properly set up and adjusted to accurately tell Eastern Daylight Time at his home, located in Vermont at 43° N, 72.5° W.

Harold took the dial with him on a 30 day lecture and sales trip, during which he traveled 1000 miles due north, then 1000 miles due west, 1000 miles due south, and finally 873 miles due east.

Although not yet back home, directly upon ending his trip Harold placed his well-traveled but undamaged dial on a level, sunny spot with the gnomon correctly aligned. Assuming he hasn't changed any of the dial's other adjustments since September 1st, what time, within a couple of minutes, will it show at noon Eastern Daylight Time on October 1st? All directions are true, not magnetic; all distances are statute miles, and you may assume the Earth to be a featureless sphere 8000 miles in diameter. *(Submitted by Mac Oglesby).*

The answer as provided by Fred Sawyer is 11:32:35 am.

Begin at 43.0000°N 72.5000°W on September 1, 1995. At noon EDT: subtract 60:00 to get to EST; add 10:00 to get to local mean time; subtract 00:05 to get to local apparent time. So noon EDT corresponds to 11:09:55 local apparent time. The dial adjustment must therefore be +50:05 in order to record noon at this time.

Given a sphere with diameter D, each degree of latitude measured along a North-South meridian line corresponds to a length of $\pi D/360$; given that D = 8000, each degree of latitude equates to 69.8132. For that same sphere, each degree of longitude measured along an East-West line at latitude L corresponds to a length of $(\pi D \cos L)/360$; which equates to 69.8132 cos L.

Leg 1: Travel 1000 miles north to 57.3239°N, 72.5000°W
Leg 2: Travel 1000 miles west to 57.3239°N, 99.0313°W
Leg 3: Travel 1000 miles south to 43.0000°N, 99.0313°W
Leg 4: Travel 873 miles east to 43.0000°N, 81.9331°W (481.64 miles west of origin)

Harold is at 43.0000°N 81.9331°W on October 1, 1995. At noon EDT: subtract 60:00 to get to EST; subtract 27:44 to get to local mean time; add 10:14 to get to local apparent time. So noon EDT corresponds to 10:42:30 local apparent time. However, the dial has been adjusted to read local apparent time plus 50:05, so it records 11:32:35 am.

Book Notice : Longitude, by Dava Sobel

Tom Kreyche (Seattle WA)

Longitude by Dava Sobel (Walker Publishing Company, New York NY, 1995, ISBN 0-8027-1212-2). Subtitled "The True Story of a Lone Genius Who Solved the Greatest Scientific Problem of His Time."

Longitude is a slim new book which should be of interest to NASS members, especially those who are interested in navigation and the history of timekeeping. The flap describes the book:

"Anyone alive in the eighteenth century would have known that 'the longitude problem' was the thorniest scientific dilemma of the day - and had been for centuries. Lacking the ability to measure their longitude, sailors throughout the great ages of exploration had been literally lost at sea as soon as they lost sight of land. Thousands of lives, and the increasing fortunes of nations, hung on a resolution."

"The quest for a solution had occupied scientists and their patrons for the better part of two centuries when, in 1714, England's Parliament upped the ante by offering a king's ransom (approximately $12 million in today's currency) to anyone whose method or device proved successful. Countless quacks weighed in with preposterous suggestions. The scientific establishment throughout Europe - from Galileo to Sir Isaac Newton - had mapped the heavens in both hemispheres in its certain pursuit of a celestial answer. In stark contrast, one man, John Harrison, dared to imagine a mechanical solution - a clock that would keep precise time at sea, something no clock had ever been able to do on land."

"***Longitude*** is the dramatic human story of an epic scientific quest, and of Harrison's forty-year obsession with building his perfect timekeeper, known today as the chronometer. Full of heroism and chicanery, brilliance and the absurd, it is also a fascinating brief history of astronomy, navigation, and clockmaking."

I found this book fascinating, but when I was finished reading, I found myself hungry for further details. For example, the book makes little attempt at even rudimentary explanation of how clocks work and only describes in general terms Mr. Harrison's improvements such as temperature compensation. I also found it unusual that there were no photographs or drawings bound into the book; instead a small card with color photos was included as a bookmark, almost as an afterthought. I have not read any reviews, but my literary friends tell me that the book has been well received by critics.

Tom Kreyche, 2602 E. Aloha Street, Seattle WA 98112

Book Notice : The Stones of Time, by Martin Brennan

Fred Sawyer (Glastonbury CT)

The Stones of Time*: Calendars, Sundials and Stone Chambers of Ancient Ireland* by Martin Brennan (Inner Traditions International, Rochester VT, 1994, ISBN 0-89281-509-4). This book is a reissue with a new epilog of Brennan's 1983 ***The Stars and the Stones***.

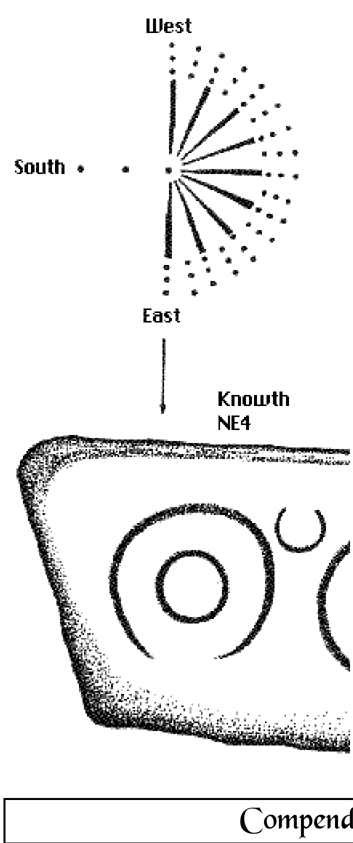
For NASS members whose interest in sunlight and shadow extends to the art and architecture of solar alignments and megalithic monuments, this work will provide a true feast. In considering the essential elements of megalithic art, Brennan notes:

"*There are about 390 stones in Ireland known to be engraved with megalithic art. They are all found in passage mounds and, when these are accessible or intact, they have all been shown to be astronomically orientated, which reveals the context that the art appears in. The relationship between the art and astronomy is further reinforced by the presence of engraved sundials, calendars and explicit solar-lunar imagery.*" (p.132)

In his new epilog, Brennan continues with an interesting claim: "*It is the presence of sophisticated calendars and sundials that completely changes our view of the history of science. Previously such developments were perceived as having first begun in the Middle East, with the earliest known sundials being Egyptian, dating from 1200 B.C. But the fully worked out, correctly aligned dials I describe at Knowth [circa 3500 B.C.] predate the Egyptian devices by thousands of years, making the area of major breakthroughs in sundialling Neolithic Western Europe.*" (p.211)

This is a fascinating claim. In order to make it, Brennan extends the concept of a sundial to solstice and calendrical devices. And yet he does believe he has found at least one true diurnal sundial, dividing each day into smaller units:

"*Images and symbols of the sun are essential characteristics of megalithic art. Perhaps the most critical evidence in support of this is supplied by the sundial on the top of [Stone NE4 at Knowth] ..., which directly leads to the recognition that radials ... are representative of the sun. The fact that this radial is illuminated by a contrived beam of light at equinox substantiates such a conclusion. Radials are the most important compounds in the art and appear on about 10 per cent of engraved stones in Ireland and Western Europe. The image of the cross in the circle is fundamentally the concept governing the basic structure or ground plan of the megalithic mound.*"



"*On the sundial at equinox, the sun rising in the east casts its shadow west, at midday it casts its shadow north and, as it sets, it casts its shadow east, completing a cross in its circle and defining time and space simultaneously. This forms the basis of one of the earliest geometrical expressions and has been regarded as the first and greatest of all talismans.*"

"*The dial measures what are known as the unequal or 'planetary hours', which are shorter in winter and longer in summer. At the equinoxes it divides the day into 8 equal parts, which are further subdivided into 16 parts. This corresponds to the solar division of the year into 8 parts .... The NE4 dial has been shown to a number of professional astronomers who confirm that it is a dial with real and intentional fiducial markings.... The importance of the NE4 dial is immense as it is the earliest sundial known, preceding other known diurnal sundials by thousands of years.*" (pp.158-159)

These passages are interestingly suggestive, but their lack of detail and clear analysis is frustrating - a problem which makes a good assessment of many of the book's claims difficult.

Consider, for example, each of the paragraphs in turn. The first paragraph refers to a "contrived beam of light at equinox" - yet there is no information on how this beam is contrived. The book abounds with alignments that result in beams of light providing illumination at crucial moments on specific dates, but where is the beam for this sundial? And what good would it do? Presumably the horizontal sundial would be usable on any date when the sun hit it, and this contrived beam on the equinoxes would simply be an accent to highlight the solar nature of the dial.

The second paragraph alludes to the sun's shadow - but presumably means the shadow of a (probably vertical) gnomon to be placed at the center of the dial. Otherwise, there would have to be a fairly sophisticated shadow projection system that was being ignored in the text.

Finally, if we assume a vertical gnomon at the center of the dial, the claims at the beginning of the third paragraph are simply demonstrably wrong. Unequal hours are indeed longer in summer than in winter, but this dial measures something very different. Unequal hours result from dividing the period of sunlight on any given day into an equal number of units (normally 12, but the suggestion in this case is 8). If we measure the time a vertical gnomon's shadow takes to progress from the unit mark before noon to the one immediately after noon (i.e. the time required for the sun's azimuth to progress from 22.5° east to 22.5° west), we find at the stone's latitude that this two unit period of time is actually longer in the winter than in the summer.

Further, on any day of the year, if we examine the time it takes for the shadow to move through the first unit on the dial, and compare it to the corresponding time for the unit just before noon, we find that these intervals do not even come close to being equal within the same day (as `unequal' hours are). So, for example, although the dial clearly divides the space that receives the equinox shadows into 8 equal units, the time it takes to traverse the first unit is nearly 2 (of our) hours, while it covers the unit before noon in roughly 1.25 hours. Surely a difference that noticeable between the units in a single day should lead us to wonder if the divisions have some other purpose than what we think of as a diurnal sundial.

None of this is intended to imply that the solar alignments the author identifies do not exist; nor is it to suggest that the possible implications for the history of dialing are not fascinating. However, at this point, the author's claim to having found a neolithic diurnal sundial has not been given the support and investigation it would need to become credible. Clearly, the dial does not record equal hours; but neither does it record traditional unequal hours, as he has claimed. What it appears to provide is simply a division of the horizon into equal azimuthal units. The author might have done better to investigate the obvious similarities between this (horizontal) neolithic dial and the remnants of the (vertical) Saxon or Mass dials found on many of the medieval churches in the British Isles. These poorly understood dials, which appear to spring from an independent tradition, usually feature a simple 8 unit division of the day - allocating an equal portion of the dial face to each unit.

Treasurer's Report 1995

Robert Terwilliger (Coconut Grove FL)

NASS INCOME:	
Dues	8531.11
Contributions	265.74
Back issues	315.00
Advertising revenue	100.00
Conference overage	140.58

	9352.43
EXPENSES:	
Compendium	
Print Production	2773.19
Digital Production	375.76
Compendium Postage	1773.88

Compendium Total	4922.83
Officers	
Treasurer & New Members	350.14
Membership	1055.09
Nominating Committee:	280.00

Total Officers	1686.08
Miscellaneous	342.56

TOTAL EXPENSES	6951.37

------------ SUMMARY --------------

1994 Ending Balance	1607.54
1995 NASS Income	9352.43

Total	10959.97
Less 1995 Expenses	- 6951.37

Closing balance	4008.60

A more detailed version of this report has been filed with the Board of Directors, and is available on request.

BSS Dues Project 1996

Harold E. Brandmaier (Harrington Park NJ)

As a service to our members in 1995, NASS collected dues from its members for first-time and renewed membership in the British Sundial Society (BSS). NASS will continue to provide this service in 1996. These payments in dollars will be converted to British sterling, and a single payment, together with renewal and application forms, will be sent to the BSS.

Current BSS members should not send any payment until they receive their BSS membership renewal forms, in May, as the 1996 U.S. dollar amount will be specified therein.

NASS members wishing to become members of the BSS should send a stamped, self-addressed envelope as soon as possible to NASS's Treasurer: Harold Brandmaier, 63 Florence Road, Harrington Park, NJ 07640 to receive a BSS application form from him.

To benefit from this service, all renewal and application forms, accompanied by a check payable to NASS, must be received by NASS's Treasurer by July 1.

Sales Report 1995

Fred Sawyer (Glastonbury CT)

In March 1995, the Board voted to establish a separate bank account for NASS sales of such items as books, software, and back issues. The following represents the status of that account:

December 31, 1995	
Revenue	
Compendium back issues	509.00
Zonwvlak software	200.00
Sundials, St. Daniel	192.00
Dialling Universal, Serle	1020.59
Extra postage & Contribs.	66.00
Vista dial offer	70.00

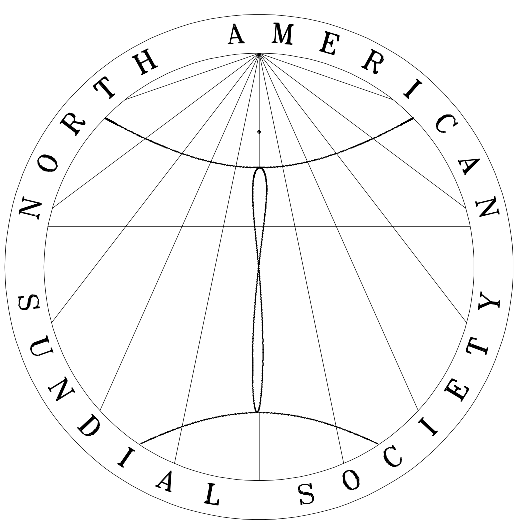
Total	2057.59
Expenses	
Stock	424.31
Postage	343.39
Bank charges	11.97

Total	779.67
Net Balance	1277.92

Logo Selection

Fred Sawyer

To date we have received 71 votes on the suggestions for a NASS logo, 70 of which expressed a preference for one or another of the three. Clearly the most popular of the alternatives, with 45 first place votes, was: **Option Y,** the hour-lines of a vertical direct south dial, featuring declination lines for the solstices and equinoxes, and a noon analemma. If we take preference ranking into account by giving 3 points for a first place vote, 2 for second, and 1 for third, then we obtain the same final result. Option Y scored 175 points, Option Z (the universal horizontal dial face) garnered 114, and Option X (the dial on a pedestal with Greek motto) received 94.



Based on these results the NASS Board of Directors has voted unanimously to adopt Option Y as the logo of the North American Sundial Society!

Three members did express an interest in helping by providing additional graphics. This is a great idea to explore, and we would be happy to receive artwork that can be used in materials for our upcoming Annual Meeting - being planned for Toronto in the Fall. Please send items to any Board Member!

NASS Officers

1996 *Editor & President*
Frederick W. Sawyer III 8 Sachem Drive Glastonbury, CT 06033 fax: (860) 403-5295 71541.1662@compuserve.com
Vice President
Allan D. Pratt 1936 E. Belmont Drive Tempe, AZ 85284 71161.2367@compuserve.com
Secretary
Sara Schechner Genuth 1142 Loxford Terrace Silver Spring, MD 20901 sschech@deans.umd.edu
Treasurer
Harold Brandmaier 63 Florence Road Harrington Park, NJ 07640 75762.3207@compuserve.com
Member-at-Large
David Shayt 214 Cedar Avenue Gaithersburg, MD 20877 fax: (202) 357-1853

Planning has begun for our second Annual Meeting. We anticipate a late Summer or early Fall meeting in Toronto, Ontario Canada. Please check the next issue of the Compendium, which should include final details. We hope to see all of you there!

Equation of Time and Solar Declination

April 1996

Equation of Time and Solar Declination for Noon Standard Time : Standard Meridian 75°W

Day	Equation Min Sec	Declin. Deg Min	Day	Equation Min Sec	Declin. Deg Min	Day	Equation Min Sec	Declin. Deg Min
1	+ 3 42	+ 4 50	11	+ 0 54	+ 8 36	21	- 1 24	+12 7
2	+ 3 24	+ 5 13	12	+ 0 38	+ 8 58	22	- 1 36	+12 27
3	+ 3 7	+ 5 36	13	+ 0 23	+ 9 20	23	- 1 47	+12 47
4	+ 2 49	+ 5 59	14	+ 0 9	+ 9 41	24	- 1 58	+13 7
5	+ 2 32	+ 6 22	15	- 0 6	+10 3	25	- 2 8	+13 27
6	+ 2 15	+ 6 45	16	- 0 20	+10 24	26	- 2 18	+13 46
7	+ 1 59	+ 7 7	17	- 0 34	+10 45	27	- 2 27	+14 5
8	+ 1 42	+ 7 30	18	- 0 47	+11 6	28	- 2 36	+14 24
9	+ 1 26	+ 7 52	19	- 1 0	+11 26	29	- 2 44	+14 42
10	+ 1 10	+ 8 14	20	- 1 12	+11 47	30	- 2 52	+15 1

May 1996

Equation of Time and Solar Declination for Noon Standard Time : Standard Meridian 75°W

Day	Equation Min Sec	Declin. Deg Min	Day	Equation Min Sec	Declin. Deg Min	Day	Equation Min Sec	Declin. Deg Min
1	- 2 59	+15 19	11	- 3 40	+18 5	21	- 3 24	+20 20
2	- 3 5	+15 37	12	- 3 41	+18 20	22	- 3 19	+20 32
3	- 3 11	+15 54	13	- 3 41	+18 34	23	- 3 14	+20 44
4	- 3 17	+16 11	14	- 3 41	+18 49	24	- 3 9	+20 55
5	- 3 22	+16 28	15	- 3 40	+19 3	25	- 3 3	+21 5
6	- 3 26	+16 45	16	- 3 39	+19 17	26	- 2 56	+21 16
7	- 3 30	+17 2	17	- 3 37	+19 30	27	- 2 49	+21 25
8	- 3 33	+17 18	18	- 3 34	+19 43	28	- 2 41	+21 35
9	- 3 36	+17 34	19	- 3 31	+19 56	29	- 2 33	+21 44
10	- 3 38	+17 49	20	- 3 28	+20 8	30	- 2 25	+21 53
						31	- 2 16	+22 1

June 1996

Equation of Time and Solar Declination for Noon Standard Time : Standard Meridian 75°W

Day	Equation Min Sec	Declin. Deg Min	Day	Equation Min Sec	Declin. Deg Min	Day	Equation Min Sec	Declin. Deg Min
1	- 2 7	+22 9	11	- 0 17	+23 8	21	+ 1 51	+23 26
2	- 1 57	+22 17	12	- 0 5	+23 12	22	+ 2 4	+23 26
3	- 1 48	+22 24	13	+ 0 8	+23 15	23	+ 2 17	+23 25
4	- 1 37	+22 31	14	+ 0 21	+23 18	24	+ 2 30	+23 24
5	- 1 27	+22 38	15	+ 0 33	+23 20	25	+ 2 43	+23 22
6	- 1 16	+22 44	16	+ 0 46	+23 22	26	+ 2 55	+23 20
7	- 1 4	+22 49	17	+ 0 59	+23 24	27	+ 3 8	+23 17
8	- 0 53	+22 55	18	+ 1 12	+23 25	28	+ 3 20	+23 14
9	- 0 41	+23 0	19	+ 1 25	+23 26	29	+ 3 32	+23 11
10	- 0 29	+23 4	20	+ 1 38	+23 26	30	+ 3 44	+23 7

Adjust Local Solar Time To Obtain Mean Time