APPENDIX A
A METHODOLOGY FOR CONSTRUCTING AN ENCLOSURE FOR INDIRECT OBSERVATION OF THE SUN

The steps described below use published data for only one purpose – to assure the analemma will fit within the apparatus. Once observing begins, the observer is expected to proceed *only* using measured dimensions of the analemma and the apparatus.

Although the steps described below are for an enclosure with an opening to transmit a light ray, they will also suffice for an apparatus with a gnomon to cast a shadow.

STEP 1: Specify the Observing Location. In this example, we will be using a location in southwest Denton, Texas:

Latitude: 33°09’ N ; Longitude: 97° 07’ W
Magnetic Variation ~ 6° E

STEP 2: Specify the Clock Time for the observations.

Standard hour divisions are on multiples of 15° of longitude, and the Observing Location described in **Step-1** is bracketed by the 90°W and 105°W lines of longitude. Local Noon is found by linearly interpolating east-to-west to the Observing Location’s longitude; hence:

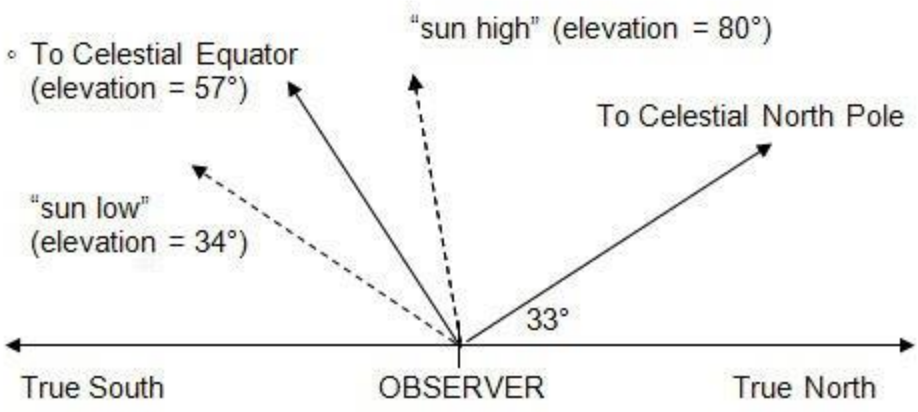
$$(97°07' - 90°) * \frac{60 \text{ clock minutes}}{15°} = \frac{7°07'}{15°} * 60 = 28.5 \text{ minutes}$$

Therefore, readings should be taken at 12:28:30pm
(add 1 hour if Daylight Savings Time is in effect)

Care should be taken in regions where clock time is based on factors other than longitude; it is possible for Local Noon not to occur during the “Noon Hour” (clock time).

STEP 3: Specify Maximum and Minimum Solar Elevations

Consider the plane containing both the true north/south line at the Observer’s location and the Zenith. At Local Noon, the time of the observations:



a) Specify the line towards the Celestial North Pole (90° North Declination). Numerically, it is the same elevation as the Observer's Latitude – here, ~ 33°.
b) Specify the line towards the Celestial equator; it is 90° away from the line towards the Celestial North Pole. Looking at the 180° "straight angle" between true north and true south:

   [Observer's Latitude] + 90° + [Altitude of Celestial Equator] = 180°

   Rearranging shows the line to the Celestial Equator will have an elevation of 90° minus the Observer's Latitude,

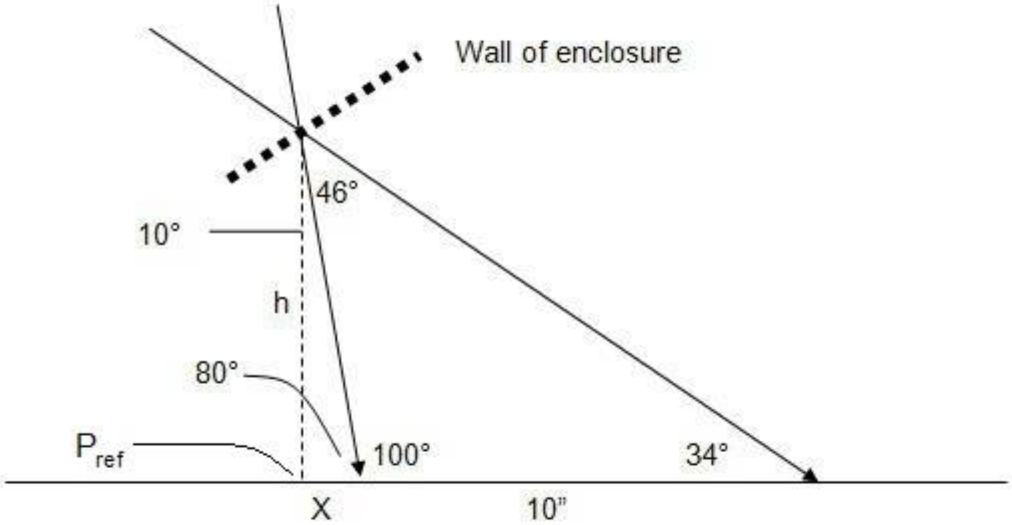
   [Altitude of Celestial Equator] = 90° - [Observer's Latitude]

   here, [Altitude of Celestial Equator] = 90° - 33° = 57°

c) Specify the lines of maximum and minimum solar elevations (these are the Summer and Winter Solstice points). These will be the elevation of the line to the Celestial Equator plus/minus the tilt of the Earth's axis relative to the orbital plane (~ 23°).

   here, 57° + 23°, or 80° to maximum "sun high"
   57° - 23°, or 34° to minimum "sun low"

<u>STEP 4</u>: Delineate the boundaries of the analemma. The analemma should be as large as possible to highlight differences in day-to-day movement of the Sun. In this example, we'll be calculating how to generate an analemma, which is 10" between solstice points, and where to place a single sheet of paper to capture the analemma.



a) Specify the sun-high and sun-low lines; here, they are lines with elevations of 80° and 34°, respectively.
b) Specify the supplementary angle to the sun-high line on the base of the enclosure; here, 180° - 80° = 100°
c) Specify the two angles at the opening of the wall of the enclosure:
    i. 46° between the sun-high and sun-low lines (this is twice the tilt of the Earth’s axis relative to its orbital plane)
    ii. 10° between the sun-high line and the vertical
d) Specify the two unknowns:
    i. “x” = the distance from the southern edge of the analemma (i.e., the Summer Solstice) to the point directly below the opening in the wall of the enclosure (“P_{ref}”).
    ii. “h” = the height of the opening in the wall of the enclosure above the base of the enclosure
e) The math; the definition of a tangent and a little algebra is all that is required:

    i. $\text{Tan}(10°) = x/h$

    ii. $\text{Tan}(10° + 46°) = (10" + x) / h$

Put x in terms of h and equate:

$$x = h * \tan(10°) = h * \tan(56°) - 10"$$

$$h = \frac{10"}{\tan(56°) - \tan(10°)} \qquad h = 7.65"$$

$$x = h * \tan(10°) \qquad x = 1.35"$$

Therefore, poke the hole ~ 7 5/8" above the base of the enclosure.

Observers will probably find it most practical to orient a single sheet of 11"x14" paper with (1) the 14" length in the true north/south direction, and (2) the southern edge ~ ½" south of P_{ref} (i.e., providing a ~ ½" margin between P_{ref} and the edge of he paper).

The location of P_{ref} should be marked on the paper after the observing site is identified. A heavy sewing needle works well when suspended through the opening by a thread on a windless day with the enclosure in its observing position.

STEP 5: Complete the Enclosure: in this example, a double-layered cardboard box with a 14" x 18" base was used:

- A 2" bolt with washers and locking nuts ~ 2" in from each corner were added to provide a level surface.
- The enclosure (with the internal sheet of paper) was aligned with the long dimension in a true north / south line. The alignment was done using a magnetic compass.

  Observers using a magnetic compass for true north / south alignment should be aware that what is commonly referred to as "Compass Error" comes from two sources:

  (1) **Variation:** the difference in direction to the true north pole and the magnetic north pole; this difference is available on the Internet, aviation charts, etc.

  (2) **Deviation:** the difference in direction between the magnetic north pole and where the compass actually points. Deviation arises whenever the magnetic field in the compass' location is perturbed, usually due to either presence of iron-containing material or stray magnetic fields due to operation of electric or electronic equipment.

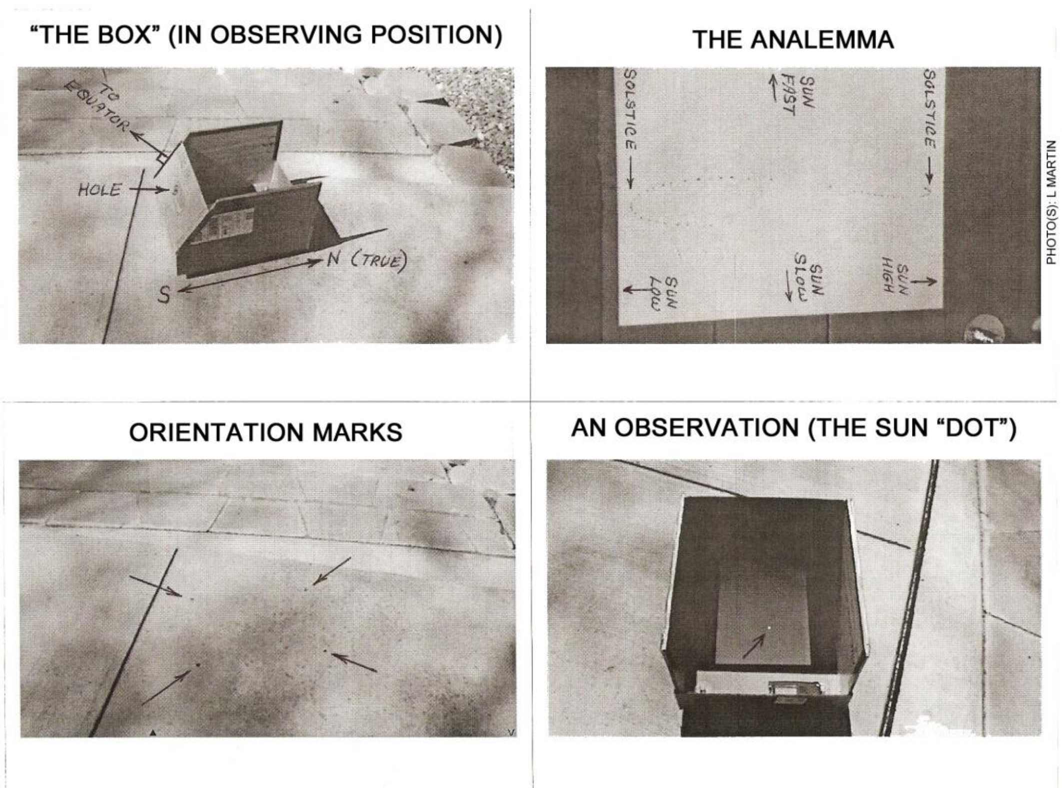
- The concrete walkway under the enclosure was marked to permit accurate relocation.

- The section of the enclosure wall with the opening was cut and repositioned to be perpendicular to the Celestial Equator. This was to minimize difficulty in getting the "sun-high" beam through the wall.

Shown below are some examples of observing apparatus:

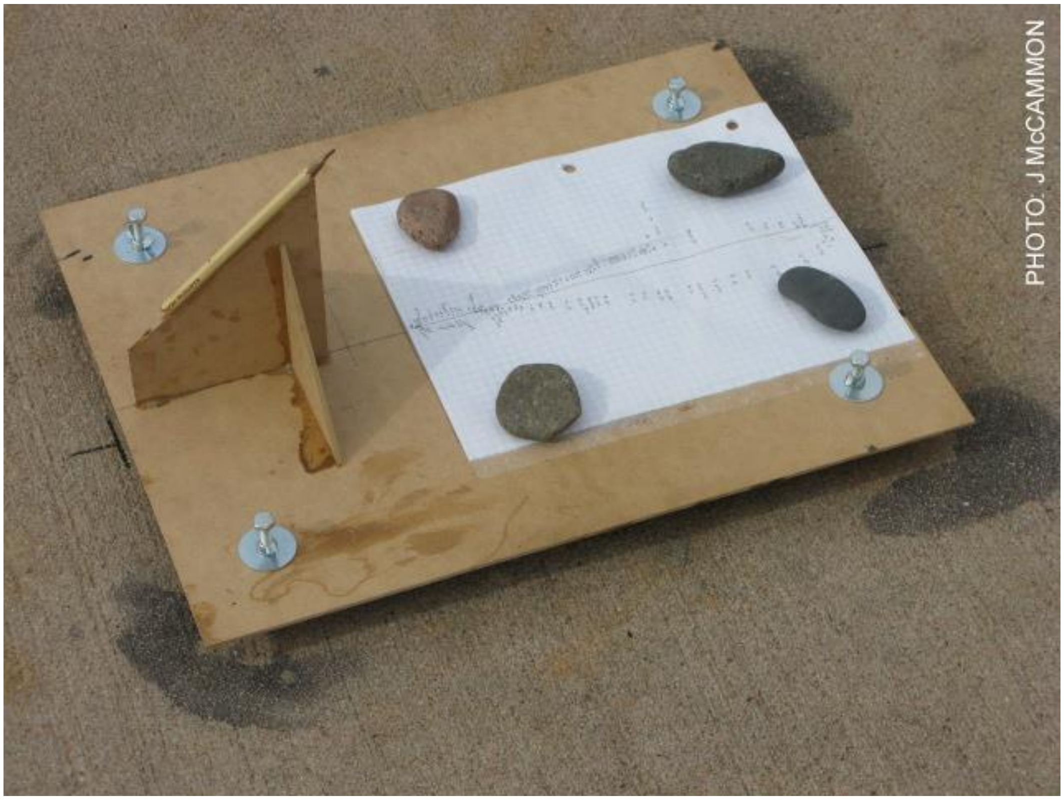
1) An enclosure with a small opening to transmit a light ray (the construction, of which, was described above):

- "The Box" shows the enclosure aligned on a true north / south line in its observing position
- "The Analemma" shows an analemma "in progress"
- "Orientation Marks" shows the marks upon which the four 2"-bolts rest for alignment of the enclosure
- "An Observation" shows a typical observation



2) A gnomon to cast a shadow; as with the previous example …

- the apparatus is in its observing position
- an analemma "in progress" is shown
- the markings used for realign the apparatus are shown
- an observation is also shown (the shadow of the tip of the pencil)



Additional Links

Printable Version of this page
Return to Introduction page
Appendix B – Overview of Non-Local Noon Observing
Appendix C – Unattended Photography
Appendix D – * * *   Reserved for Future Use   * * *
Appendix E – * * *   Reserved for Future Use   * * *
Appendix F – Activity #1 (Tilt of Earth's Axis and Observer's Latitude)
Appendix G – Activity #2 (Path of the Sun in the Sky)
Appendix H – Activity #3 (Equation of Time)
Appendix I – Activity #4 (Eccentricity of Orbit)