Making An Analemmatic Sundial

R.L. Kellogg, Ph.D.
North American Sundial Society
www.sundials.org
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Analemmatic Sundials – The Human Sundial

- **The Analemmatic Sundial or "Human" Sundial was first described by M. de Vaulezard in 1640 in a "Treatise on the Usage of the Analemmatic Dial"**

- **The dial consists of a central way for the shadow casting gnomon.**
  - The gnomon is positioned according to the date
  - The gnomon height is of no consequence, hence ideal for human gnomons of varying size

- **The hour markers are positioned on an ellipse surrounding the central way**
  - The size of the ellipse is designed to fit human proportions é typically with an east-west radius of 6 to 8 feet
  - The shape of the ellipse is set by latitude

Step 1 Decide on the Sundial Location

- **Find a level, sunny area**

- **Could be a level grassy area away from trees.**
  - Use pavers to create a walk way where the person will stand to cast his/her shadow
  - Use pavers or other markers for the hour marks
  - Use acrylic paint to create the monthly standing marks on the walkway and hour marks

- **Could be unused, level area of a sidewalk or playground away from basketball hoops or other equipment**
  - Use acrylic paint to create the monthly standing marks on the walkway and hour marks

Step 2 Tools and Materials Required

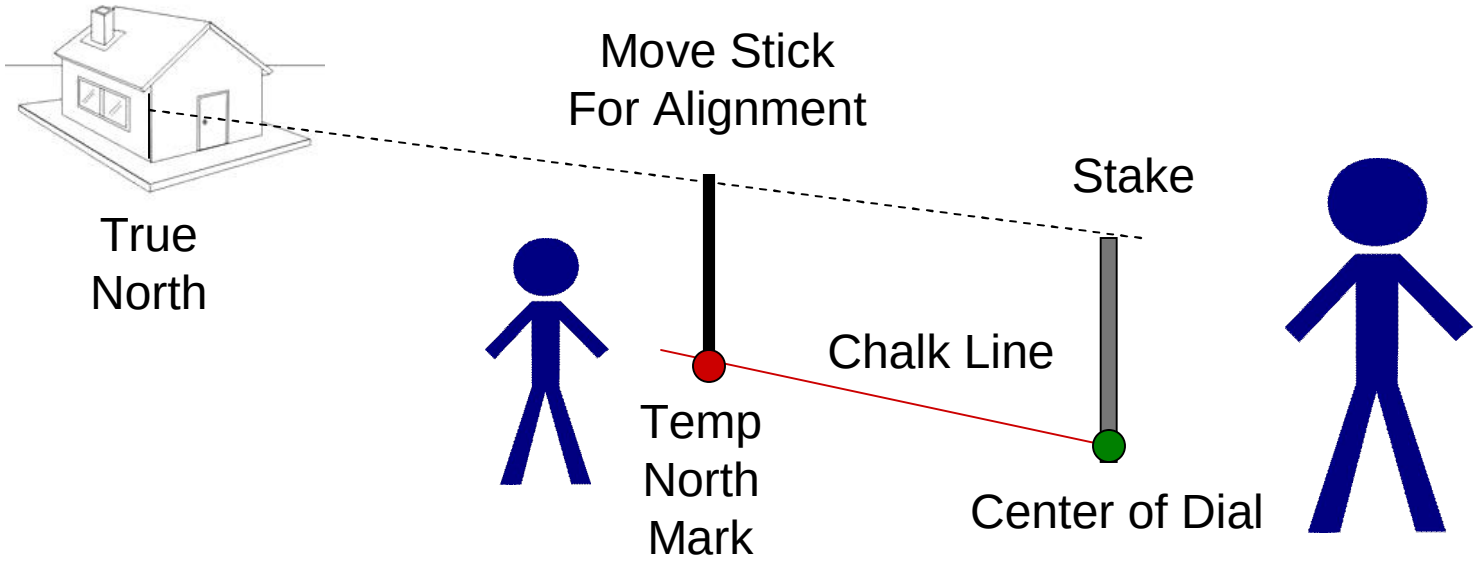
- **Markers**
  - **Grass:** use wooden stakes or long nails with ribbons so they don't get lost
  - **Asphalt or Concrete:** use colored chalk.
- **Chalk Line**
  - Works best on asphalt or concrete for drawing the sundial ellipse and circular hour markers.
- **Two Tape Measures**
  - Must extend at least 12 feet
- **Paint and Masking Tape**
  - **Asphalt:** Use regular acrylic latex paint. Some acrylic paint comes by various names such as "Parking Lot Striping Paint", "Traffic Paint" or "Athletic Field Paint". Behr, Glidden and Rustoleum all sell versions of this "traffic paint" at Home Depot and Lowe's.
  - **Concrete playgrounds and pavers stones:** may require a sealant before applying the acrylic latex paint. This is available at Home Depot and Lowe's as well.
  - **BEWARE:** Masking tape may not work well and may allow "run under" of the paint. Nevertheless, it provides a good guiding line and prevents small mistakes.

Step 3 Need to Find true North

- **Method 1: Finding North Using Google Earth**
  - Use Google Earth on Computer to find your position on the earth and orientation of buildings, sidewalks, etc. with respect to true North.
- **Method 2: Finding North Using Noon Shadow (Asphalt/Grass)**
  - 1. Find the Equation of Time from NOAA: **http://www.esrl.noaa.gov/gmd/grad/solcalc/azel.html**
  - 2. Set your watch to time from USNO atomic clock: **http://tycho.usno.navy.mil/simpletime.html**
  - 3. Put a vertical stick in the ground (use carpenter level) or use a tripod with a plumb bob at the center of where you want the dial.
  - 4. Do calculations from next pages to tell when the shadow of the stick or plumb bob points exactly due North. Wait for that moment and mark the direction of the shadow.
- **Method 3: Finding North Using Stick Shadow (Grass)**
  - 1. Put a vertical stick in the ground (use carpenter level)
  - 2. Follow instructions for Method 3. It will take several measurements from morning to afternoon. Be patient.

Method 1 Find North Using Google

- **This takes two people**
- **Use Google Earth to locate your position and a distant (~300 feet) identifiable object that is directly north, such as a portion of a building, a tree, a distant sign, etc.**
  - Place a stake or tripod at the start position (center of the dial)
  - About 5 feet away have someone move a second stake until it aligns to the background object. Hammer it in the ground (grass) or mark the position on asphalt with chalk



Method 2A Find North at the Start Position - Plumb

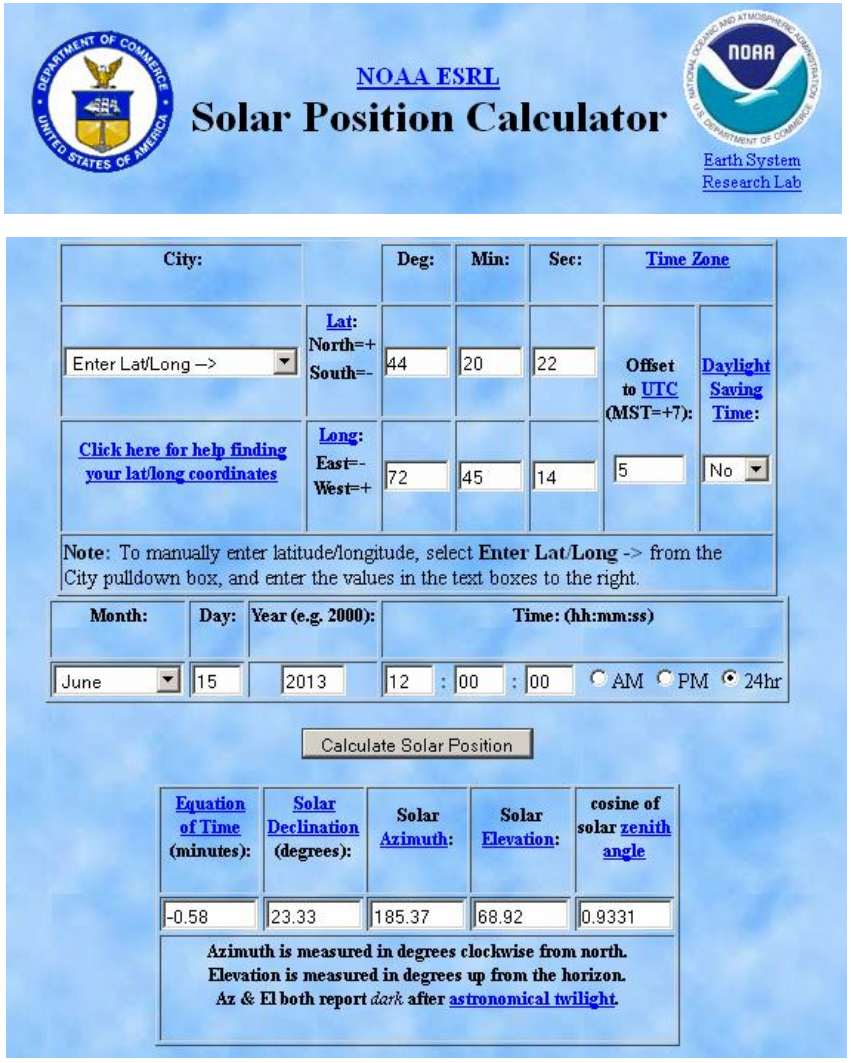
- **Use NOAA Solar Calculator**
- **http://www.esrl.noaa.gov/gmd/grad/solcalc/azel.html**
- **Example:**

  Lat: 44° 20ô 22ò
  Lon: 72° 45ô 14ò

  Select ñEnter Lat/Longò
  Select Date (e.g. June 15 2013)
  Select Offset to UTC = 5hr for Eastern Time Zone
  Select 12:00:00 (24hr)

  Click Calculate Position and read Equation of Time

  EOT = -0.58 min



Method 2B Find North at the Start Position - Plumb

- **Set a tripod with a hanging plumb bob directly over the Dial Center (nail, pebble, chalk mark)**
- **When the sun is on the local meridian, the shadow points due North. We need math to find Local Solar Time**

Start with your longitude	72.75389 W	Dial Longitude (W)
Subtract time zone meridian	75.00000 W	Eastern Time Zone
Difference (could be +/-)	-2.43611 deg	(Minus is East of Meridian)
Multiply by 4 deg into minutes	-9.74444 min	
Subtract NOAA Equation of Time	- -0.58 min	June 15, 2013 12pm EDT
(notice here we subtract a minus sign that actually Adds the 0.58 min)		
Time Correction	-9.16 min	Standard Time
Add Daylight Saving Time	60.00 min	(Depends on time of year)
Adjust	-50.84 min	
Clock Time = Local Solar Time – Adjust		(be careful of the signs)
Clock Time = 12 hr (noon) + 50.84 min		
Clock Time = 12: 50: 50		(time when shadow points due North)

Method 2C Find North at the Start Position - Plumb

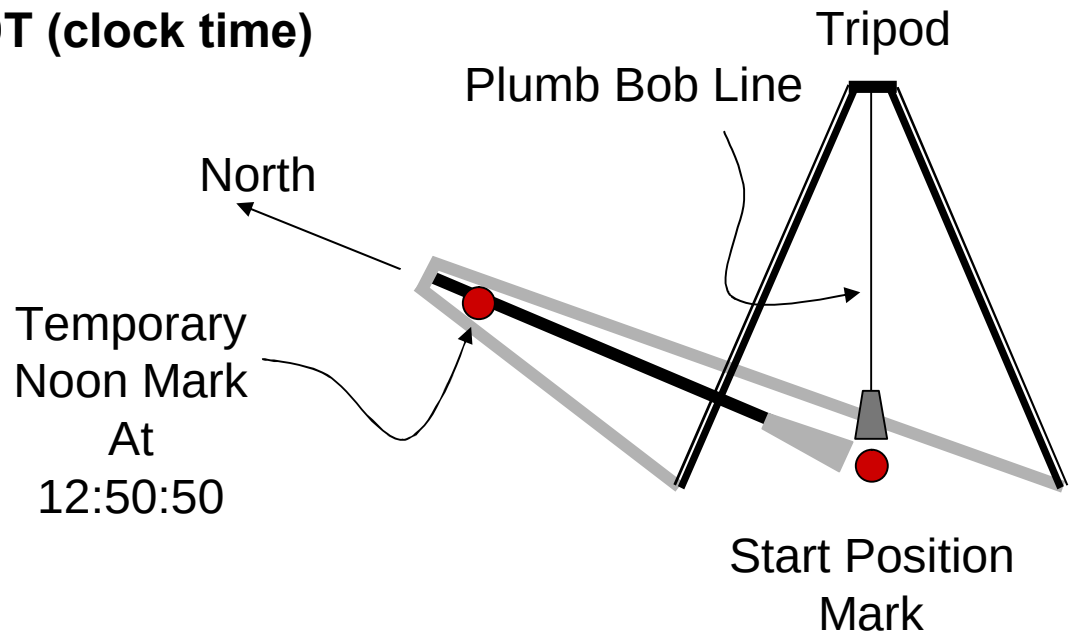
- **In our example, we've determined that the shadow of the plumb bob string will point due North:**

Date: June 15, 2013

Time: 12: 50: 50 EDT (clock time)

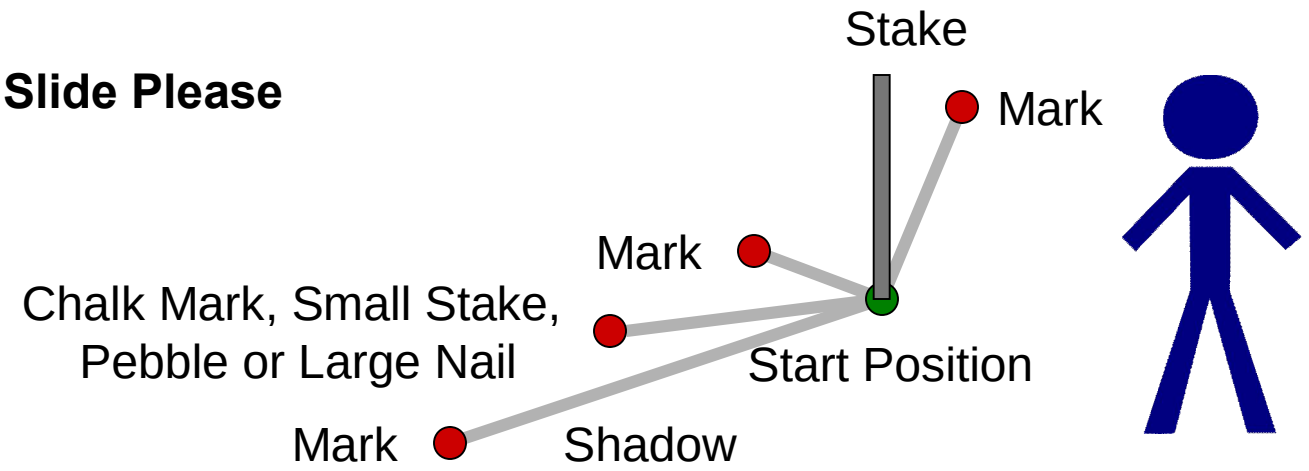
For Lat: 44° 20' 22"

Lon: 72° 45' 14"



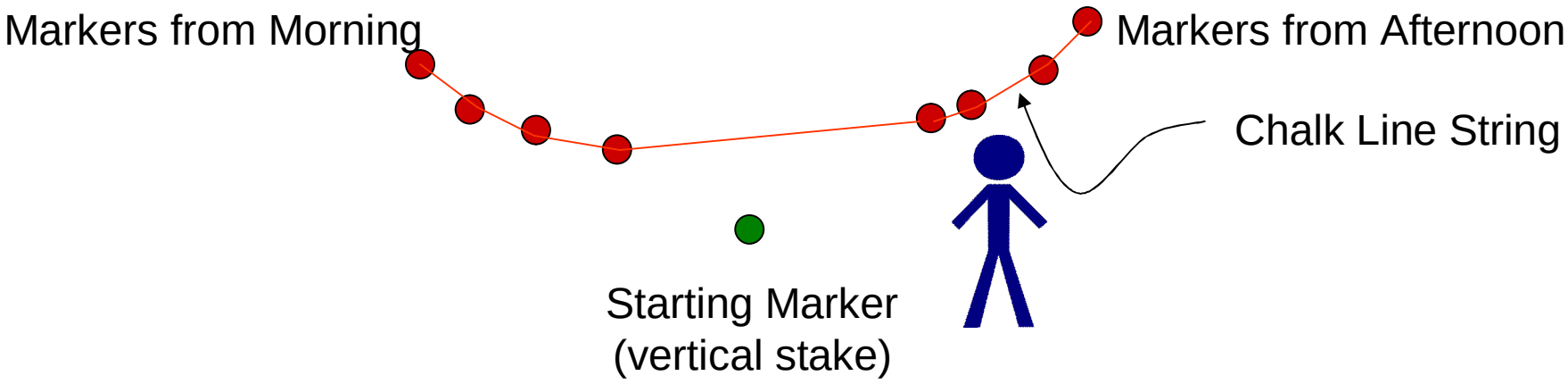
Method 3A Shadow Through the Day

- **This takes one person for most of the day. At late afternoon, need second person**
- **Place a vertical stake at the dial center**
- **Measure stake's shadow in morning and afternoon**
  - In the morning, from 9am to noon, every half hour place a marker at the position of the shadow's tip.
  - In the afternoon, from 1pm to 4pm, every half hour place a marker at the position of the stake's shadow tip.
  - IMPORTANT: the marker must be at the tip of the shadow!
  - IMPORTANT: using pebbles or chalk is best. Lightly hammer the nails or stakes. They are temporary and will be removed after we're done
- **Next Slide Please**



Method 3B Shadow Through the Day

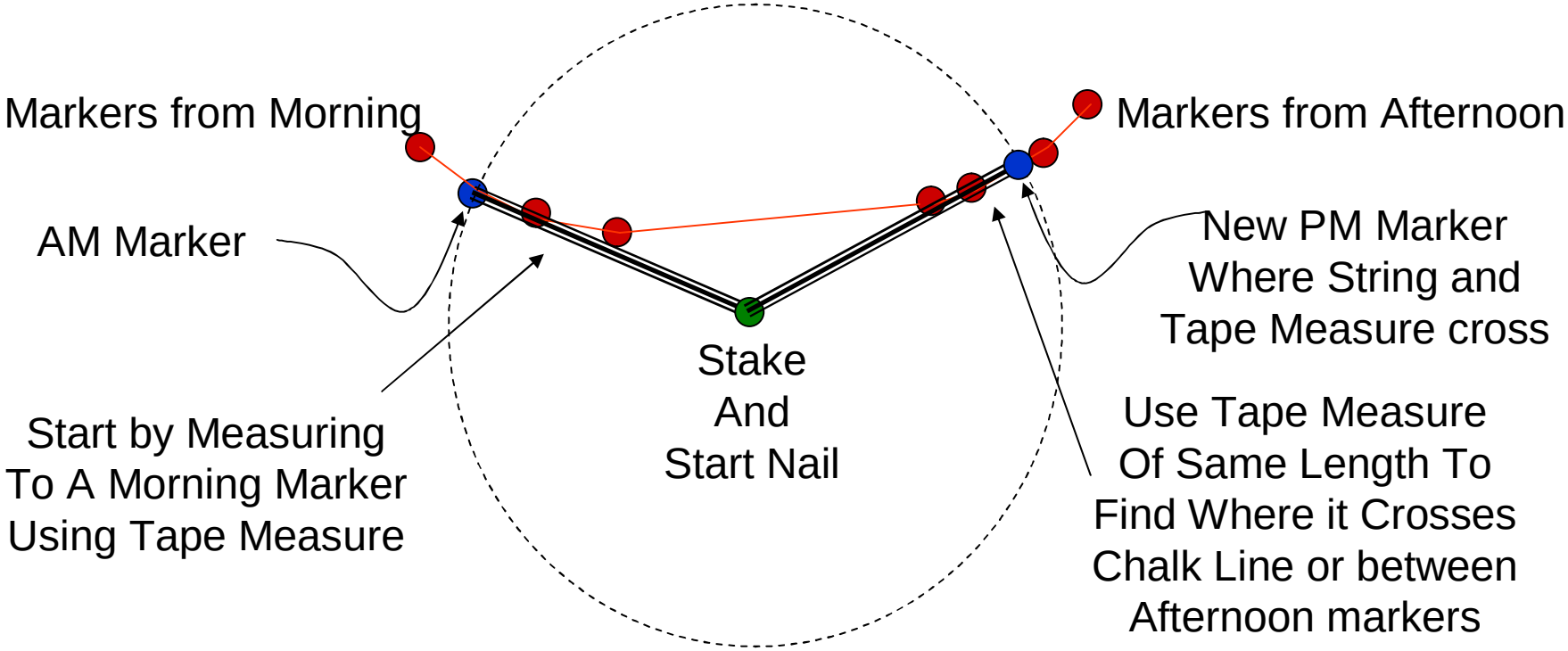
- **When using stakes or nails, use a chalk line string to "connect" the string from marker to marker. Here's the top down view**



- **Now use the tape measure from the starting marker. Measure out to the 9:30am nail (or other early morning nail … it really doesn't matter. Remember the shadow marker**
- **Using the same tape measure length, go to the afternoon side and find where that tape measure length crosses the string or passes between two afternoon markers. Place a new marker at that point.**

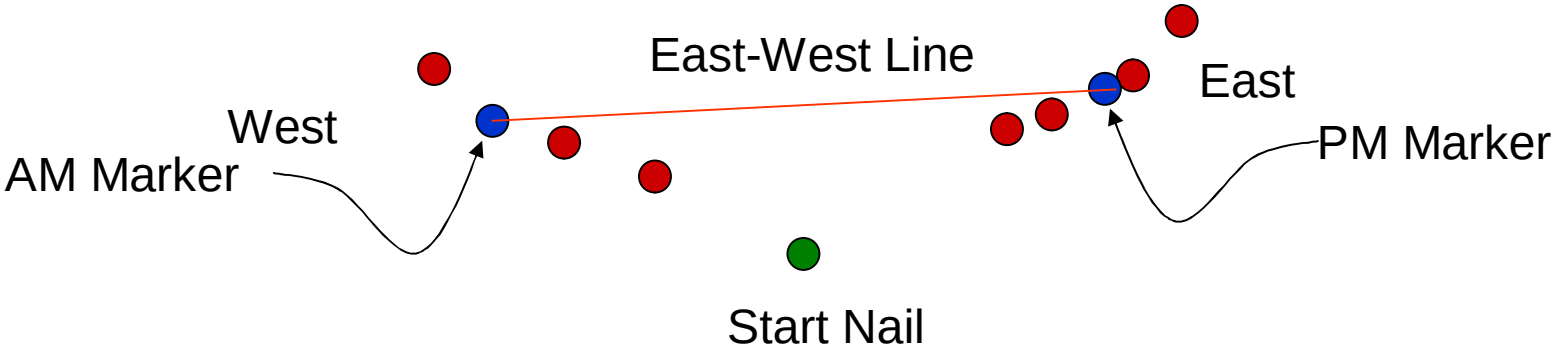
Method 3C Shadow Through the Day

- **Use Tape Measure to Find Places of String Crossing**

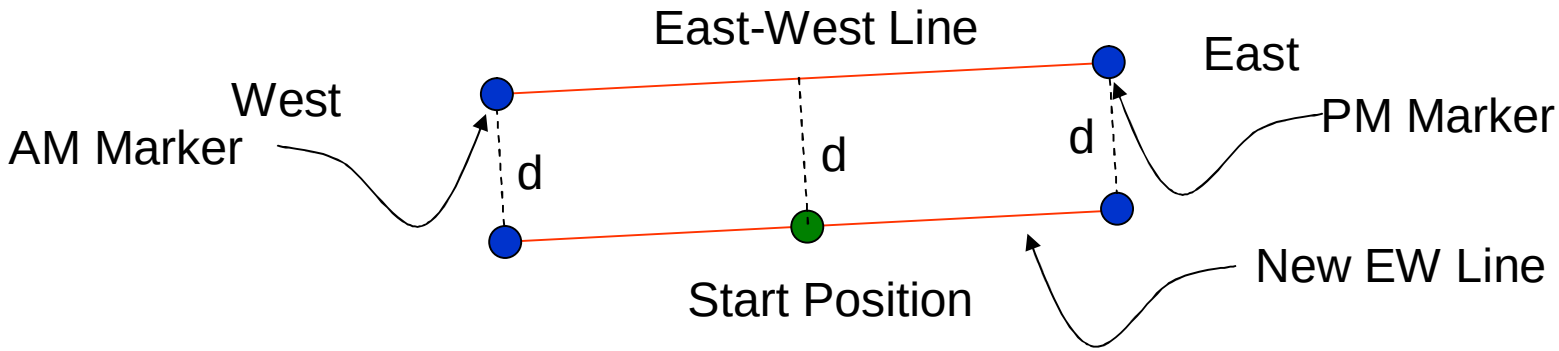


Method 3D Shadow Through the Day (Cont'd)

- **Next, take the chalk line string and connect the AM and PM Markers This chalk line string between the AM and PM Nails is now aligned East-West**

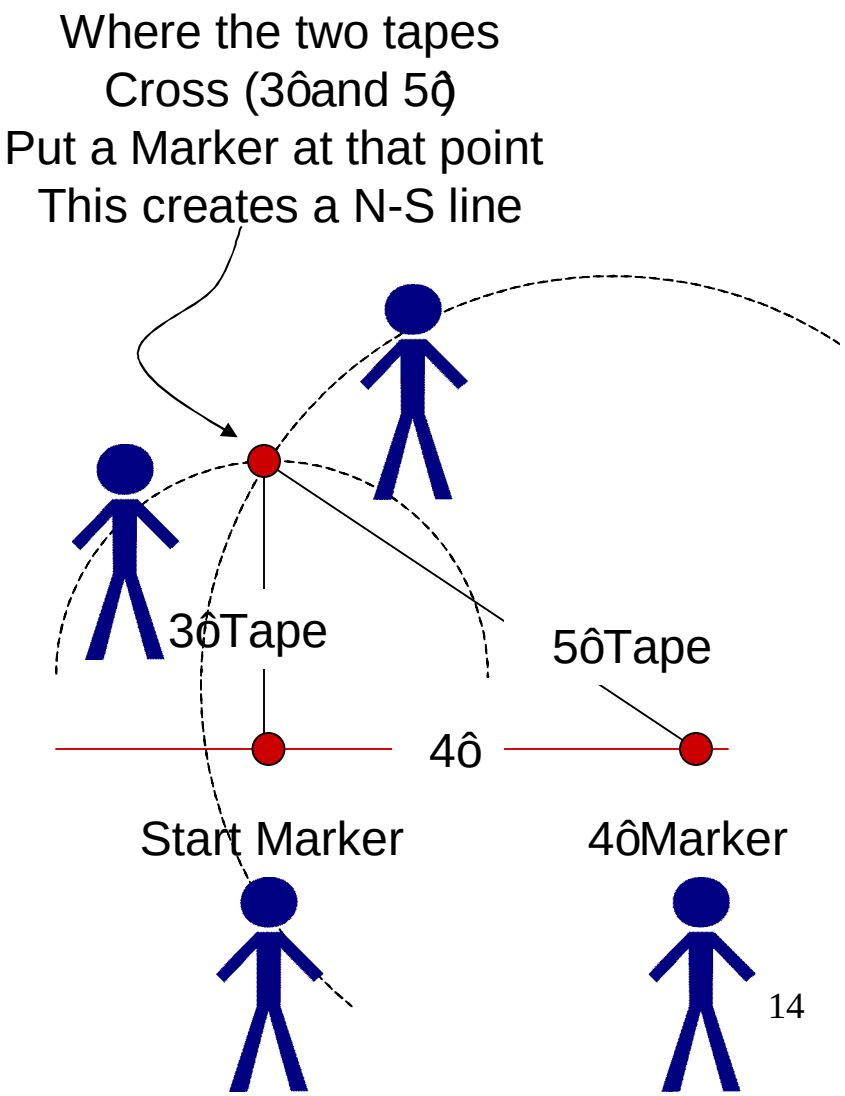


- **Measure the closest distance between the Start Marker and the E-W string. Repeat that distance from the AM and PM Marker**
- **Put in new AM and PM Markers. Move the chalk line string between these markers. The new E-W line goes through the Start Position**



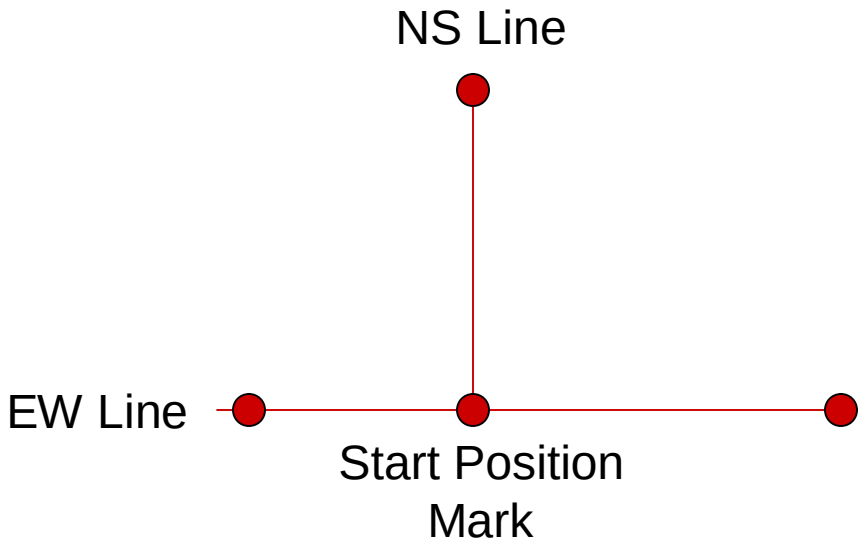
Step 4A Create N-S and E-W Lines

- **Regardless of the method, you've now established either an E-W Line or N-S Line**
- **Use the 3-4-5 right triangle to construct a right angle and complete the additional necessary line.**
- **Here we show an existing EW line and need to construct a NS line.**
- **Make sure that existing lines are extended at past the start position mark**
- **With 4 people**
  - One holds the tape measure starting at the Start marké
  - One person uses the other end of that tape and measures out to the 5-foot mark
  - One holds another tape measure starting at the 4-foot mark
  - One moves uses other end of that tape and measures out to the 3-foot mark
  - The two end people move their tapes to cross at exactly the 3 and 5 foot marks.



Step 4B Create N-S and E-W Lines

- **Now we should have EW and NS nails that go through the starting nail position**

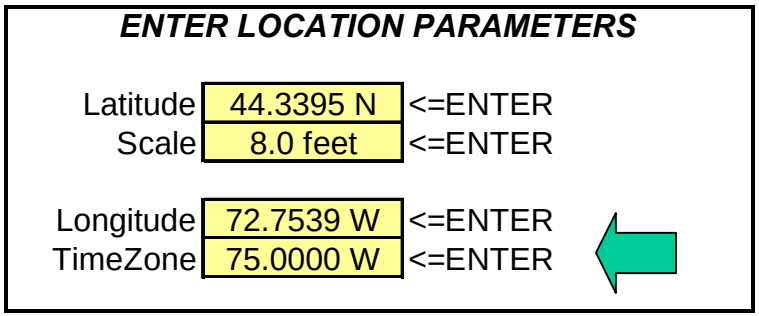


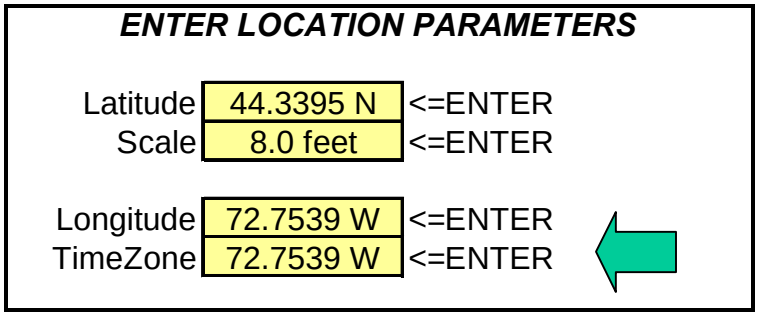
- **Out next step is to establish critical points on the NS and EW lines measured from the Start Position Mark**

Step 5 Enter Lat/Lon and Dial Parameters

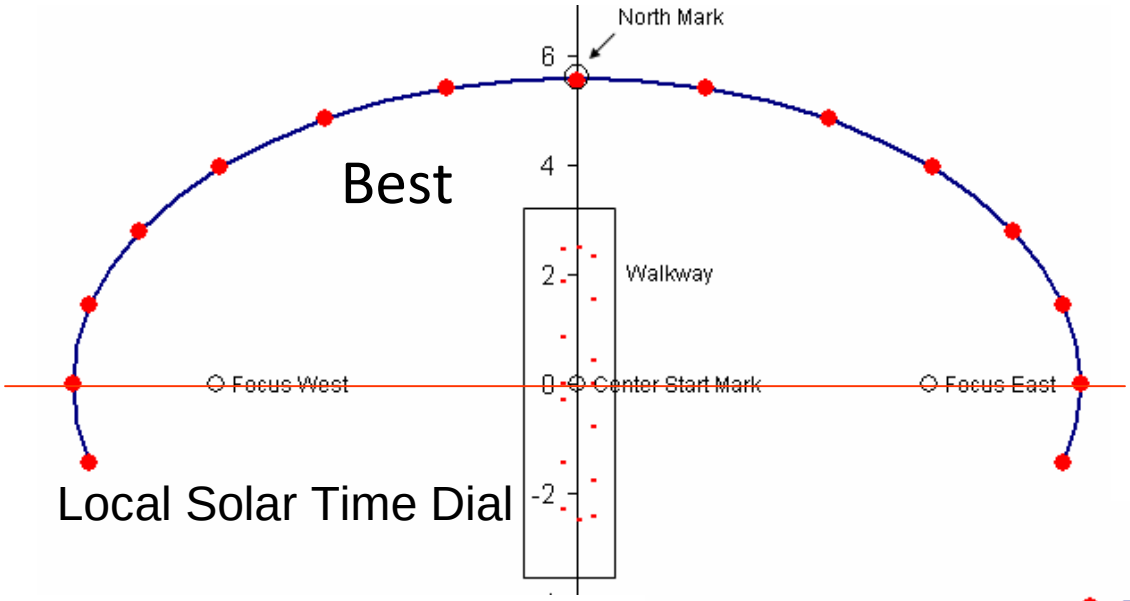
- **Use the Analemmatic Spreadsheet**
  - Enter Latitude (decimal degrees)
  - Enter Longitude (decimal degrees)
  - Enter Dial Size (suggest 8 feet)
  - Note: Just enter the numbers, the spreadsheet creates ñNö, ñWö, and ñfeetö
- **Set the Dial Construction forTime Zone or Local Solar Time**
  - If you want to use ñZone Timeöenter your time zone. Eastern Time Zone is at exactly 75.0000 degrees. This will move the Noon Mark. In the given example, the Noon Mark will be moved 9 minutes 45 sec to the east.

Best
  - **If you want to use "Local Solar Time" enter your longitude as the Time Zone. This will make the Noon Mark exactly due North**





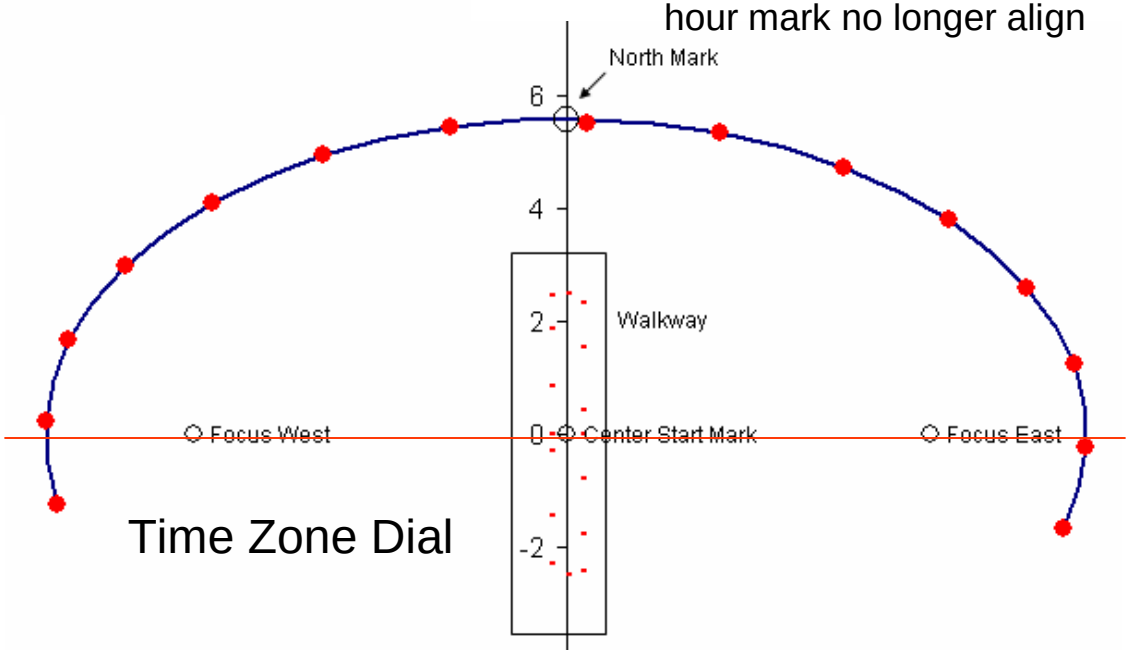
Step 5B Local Time Dial vs Time Zone Dial



Best

Local Solar Time Dial

Notice that the hour lines are slightly shifted. Solar noon North Mark and 12pm hour mark no longer align



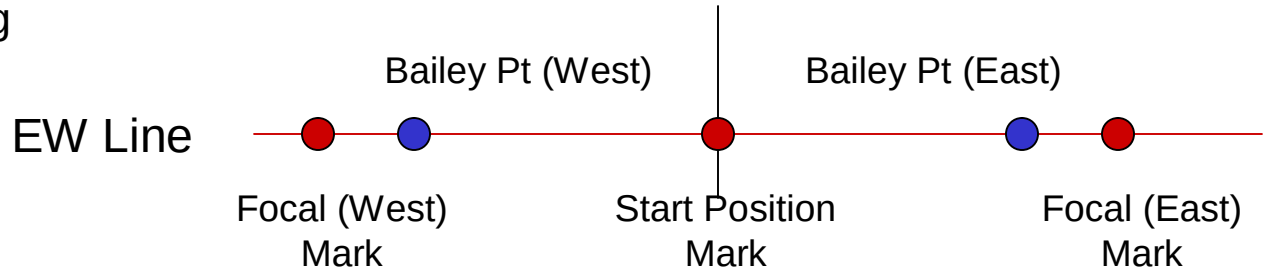
Time Zone Dial

Step 6A Mark East and West Focal Points

- **Use the Analemmatic Spreadsheet**
  - Read the focal East and focal West distances
- **Mark focal points on E-W line**
  - From the start location nail, measure East (+) along the E-W Line and mark the East focal point with a nail that has a ribbon or flag
  - Our example is 5 foot 8½ inches
  - From the start location nail, measure West (-) along the E-W Line and mark the West focal point with a nail that has a ribbon or flag

Ellipse Axes and Focal Points				
	Ellipse		feet	inches
x	a		**8**	**--**
y	b		**5**	**7**
x	Focus East		**5**	**8 1/2**
x	Focus West		**-5**	**8 1/2**
y	North Mark		**5**	**7**
x	Scale		**8**	**--**

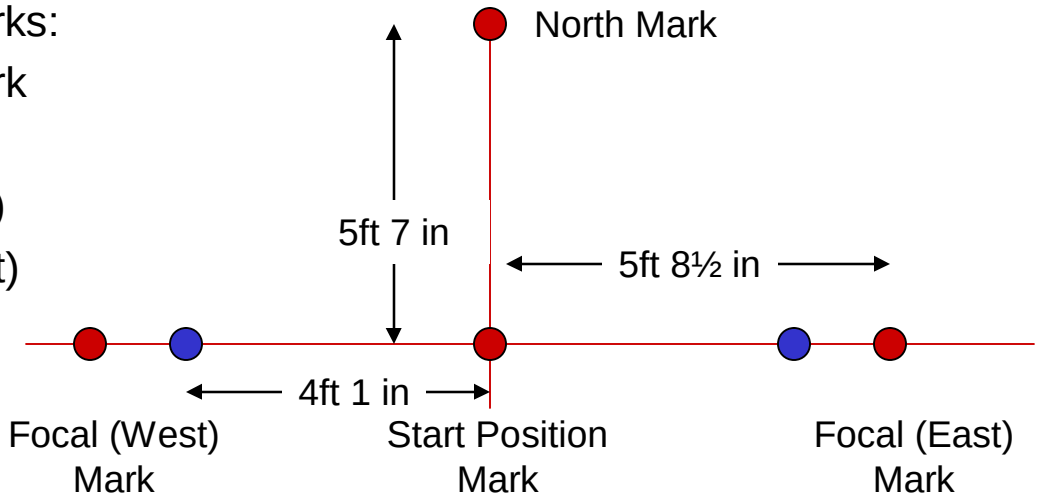
Bailey Sunrise/Sunset Points				
On EW axis			feet	inches
E	Bailey Point		**4**	**1**
W	Bailey Point		**-4**	**1**



Step 6B Make North Mark

- **Use the Analemmatic Spreadsheet**
  - Read the North Mark distance
- **Create North Mark on N-S Line**
  - From the start location nail, measure North and mark the North Mark with a nail that has a ribbon or flag
  - Our example is 5 foot 7 inches
- **Remove all other extraneous Markers**
  - We'll use the following marks:
  - Start (Center Position) Mark
  - North Mark
  - Focal Marks (East & West)
  - Bailey Points (East & West)

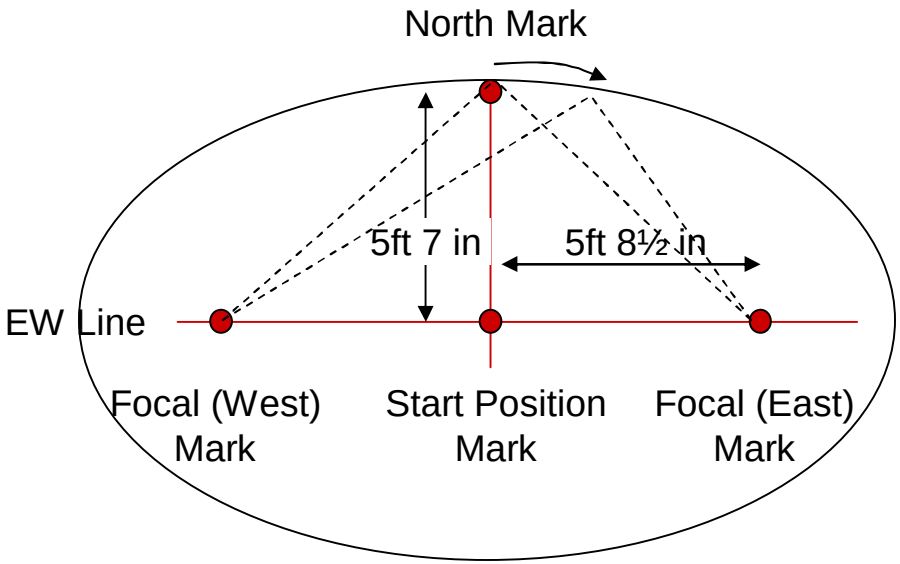
Ellipse Axes and Focal Points				
	Ellipse		feet	inches
x	a		**8**	**--**
y	b		**5**	**7**
x	Focus East		**5**	**8 1/2**
x	Focus West		**-5**	**8 1/2**
y	North Mark		**5**	**7**
x	Scale		**8**	**--**



Step 7 Draw Ellipse

- **Use the two focal marks and north mark**
- **Use a chalk line from focal west to north mark to focal east**
- **Use a piece of chalk to mark the ellipse keeping the line taught**

	Ellipse Axes and Focal Points		
	Ellipse	feet	inches
x	a	8	--
y	b	5	7
x	focus East	5	8 1/2
x	focus West	-5	8 1/2
y	North Mark	5	7



Step 8A Mark Morning Hours

- **Use the Analemmatic Spreadsheet**
  - Use the Morning Hour Table
  - Measure from the Start (Center) Marker and North Marker

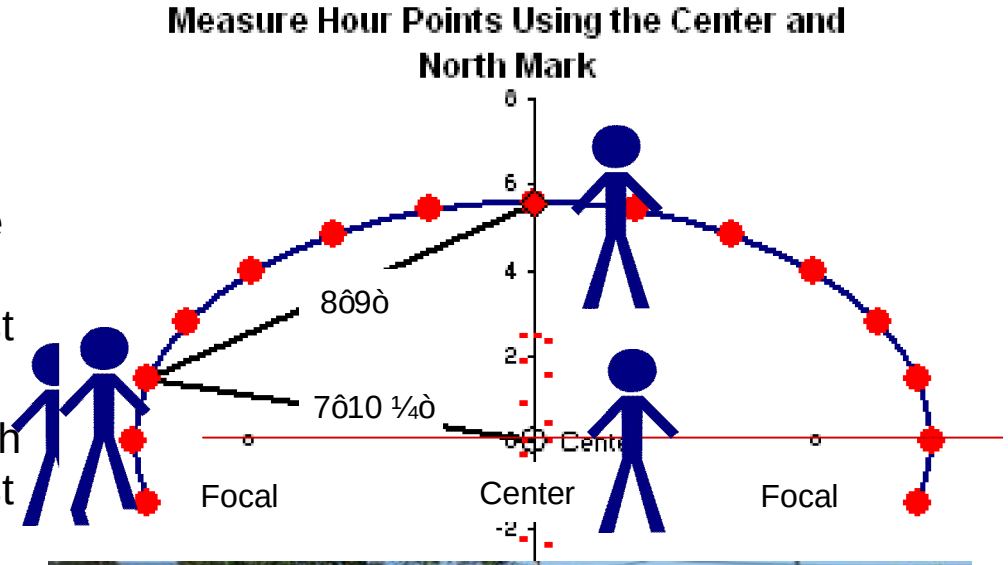
Standard Tim		E-W x	N-S y	Distance use W focus (-)		Distance use E focus (+)		Distance use Center		Distance use N Mark		Standard Time	
Hour	Minute	feet	feet	feet	inches	feet	inches	feet	inches	feet	inches	Hour	Minute
5	**0**	**-7.73**	**-1.45**					**7**	**10 1/4**	**10**	**5 1/4**	**5**	**0**
5	30	-7.93	-0.73					7	11 1/2	10	1 1/2	5	30
6	**0**	**-8.00**	**0.00**					**8**	**--**	**9**	**9**	**6**	**0**
6	30	-7.93	0.73	**Use Center and Noon Mark ==>**				7	11 1/2	9	3 1/2	6	30
7	**0**	**-7.73**	**1.45**					**7**	**10 1/4**	**8**	**9**	**7**	**0**
7	30	-7.39	2.14					7	8 1/4	8	1 3/4	7	30
8	**0**	**-6.93**	**2.80**					**7**	**5 1/2**	**7**	**5 1/2**	**8**	**0**
8	30	-6.35	3.40					7	2 1/4	6	8 1/2	8	30

- Suggest that you use only the hour distances. Ignore the half-hour values (at least until you get the dial laid out and decide to add the additional markers)

- This will take 5 volunteers !!

Step 8B Mark Morning Hours

- **Measure from the Start Point and from the North Mark**
  - One person holds the tape measure on the start point (center) A second person runs the tape out to the West
  - One person holds their tape measure on the north mark. A fourth person runs the tape out to the West
  - Use the table distances and cross the tapes until they match at those distances. It helps to have a fifth person with clip board reminding the tape ñrunnersòof the distance they need to use.



- **Example: 7am Marker**
  - From Center 7ft 10¼ in
  - From North Mark 8 ft 9 in

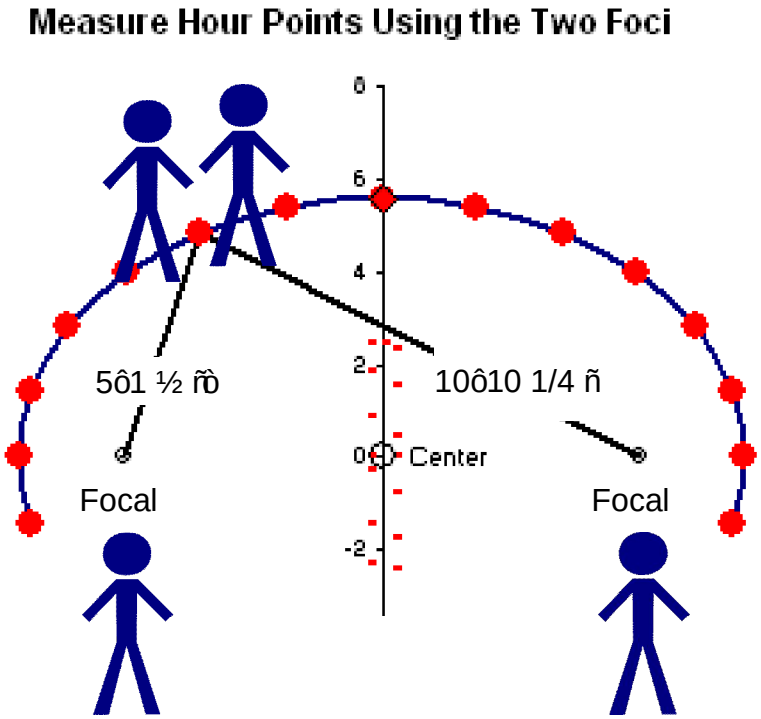
Step 8C Mark Mid Day Hours

- **Use the Analemmatic Spreadsheet**
  - Use the Mid Day (9am-3pm) Table
  - Measure from **Two Foci Markers** instead of the Center Mark and North Mark

Standard Tim		E-W x	N-S y	Distance use W focus (-)		Distance use E focus (+)		Distance use Center		Distance use N Mark		Standard Time	
Hour	Minute	feet	feet	feet	inches	feet	inches	feet	inches	feet	inches	Hour	Minute
9	**0**	**-5.66**	**3.95**	**3**	**11 1/4**	**12**	**1/2**	**6**	**10 3/4**	**5**	**10 1/2**	**9**	**0**
9	30	-4.87	4.44	4	6	11	5 3/4					9	30
10	**0**	**-4.00**	**4.84**	**5**	**1 1/2**	**10**	**10 1/4**					**10**	**0**
10	30	-3.06	5.17	5	9 1/2	10	2 1/4					10	30
11	**0**	**-2.07**	**5.40**	**6**	**6**	**9**	**5 3/4**					**11**	**0**
11	30	-1.04	5.54	7	3	8	8 3/4					11	30
12	**0**	**0.00**	**5.59**	**8**	**--**	**8**	**--**	**<== Measure from Two Foci**				**12**	**0**
12	30	1.04	5.54	8	8 3/4	7	3					12	30
1	**0**	**2.07**	**5.40**	**9**	**5 3/4**	**6**	**6**					**1**	**0**
1	30	3.06	5.17	10	2 1/4	5	9 1/2					1	30
2	**0**	**4.00**	**4.84**	**10**	**10 1/4**	**5**	**1 1/2**					**2**	**0**
2	30	4.87	4.44	11	5 3/4	4	6					2	30
3	**0**	**5.66**	**3.95**	**12**	**1/2**	**3**	**11 1/4**	**6**	**10 3/4**	**5**	**10 1/2**	**3**	**0**

Step 8D Mark Mid Day Hours

- **For Mid-Day Hour Marks, use the same measuring technique, but the measuring references are from the two focal points.**
  - Example is for 10AM
  - Note: Make Sure you Donôt confuse the East and West Focal Point Distances



Step 8E Mark Afternoon Hours

- **Use the Analemmatic Spreadsheet**
  - Use the Afternoon Table
  - Measure from the **Start (Center) Marker and North Marker**

Standard Tim		E-W x	N-S y	Distance use W focus (-)		Distance use E focus (+)		Distance use Center		Distance use N Mark		Standard Time	
Hour	Minute	feet	feet	feet	inches	feet	inches	feet	inches	feet	inches	Hour	Minute
3	**0**	**5.66**	**3.95**	**12**	**1/2**	**3**	**11 1/4**	**6**	**10 3/4**	**5**	**10 1/2**	**3**	**0**
3	30	6.35	3.40					7	2 1/4	6	8 1/2	3	30
4	**0**	**6.93**	**2.80**					**7**	**5 1/2**	**7**	**5 1/2**	**4**	**0**
4	30	7.39	2.14					7	8 1/4	8	1 3/4	4	30
5	**0**	**7.73**	**1.45**					**7**	**10 1/4**	**8**	**9**	**5**	**0**
5	30	7.93	0.73	**Use Center and Noon Mark ==>**				7	11 1/2	9	3 1/2	5	30
6	**0**	**8.00**	**0.00**					**8**	**--**	**9**	**9**	**6**	**0**
6	30	7.93	-0.73					7	11 1/2	10	1 1/2	6	30
7	**0**	**7.73**	**-1.45**					**7**	**10 1/4**	**10**	**5 1/4**	**7**	**0**

- **Hint: The two tape measure marks should ALWAYS cross on the ellipse**

Step 9A Create Hour Circles

- **Use Plastic Lids**
  - Center on each hour mark
  - Draw Circle with Chalk
- **Paint Hour Circles**
  - Use white or a light color background
  - Use a dark color for numbers
  - Can put one number in circle for standard time, another number outside circle for daylight saving time

Step 9B Create Hour Circles

- **You can make the hour marks of any design.**
  - Circular with standard time hours (that is, 12pm near or at the North Mark)
  - If the dial is only used during summer weather, daylight savings time can be used. In that case the 1pm is near or at the North Mark
  - Maybe you want to show both standard and daylight savings time. Use two different colors.
  - Make the hour markers 6-8 inches in diameter with a plastic lid to guide your chalk marks

Step 10A Lay Out the Walkway

- **All Measurements are made from the North Mark.**
  - If you've selected Local Solar Time, then the North Mark and the 12 noon Marker are the same
  - If you've selected the Time Zone option, BE CAREFUL. The North Mark and the 12 noon Marker will be close to each other, but they are not the same. Only the North Mark lays on the N-S line running through the dial center start point
- **Marks are made for the first of each month, plus special marks for the solstices and equinoxes**

Walkway Place to Stand					
Sun			**Measure South From N-Mark**		
Month	Day	(deg)	feet	inches	E/W mark
Solstice	356	-23.44	8	3/4	0
Jan 1	1	-23.03	8	1/4	0.25
Feb 1	32	-17.22	7	4 1/4	0.25
Mar 1	60	-7.74	6	4 1/4	0.25
Equinox	80	0.00	5	7	0.25
Apr 1	91	4.38	5	1 3/4	0.25
May 1	121	14.96	4	1/2	0.25
Jun 1	152	22.00	3	3 1/4	0.25
Solstice	173	23.44	3	1 1/4	0
Jul 1	182	23.13	3	1 3/4	-0.25
Aug 1	213	18.12	3	8 1/2	-0.25
Sep 1	244	8.43	4	8 3/4	-0.25
Equinox	266	0.00	5	7	-0.25
Oct 1	274	-3.02	5	10 1/2	-0.25
Nov 1	305	-14.30	7	1/2	-0.25
Dec 1	335	-21.74	7	10 1/4	-0.25
Solstice	356	-23.44	8	3/4	0

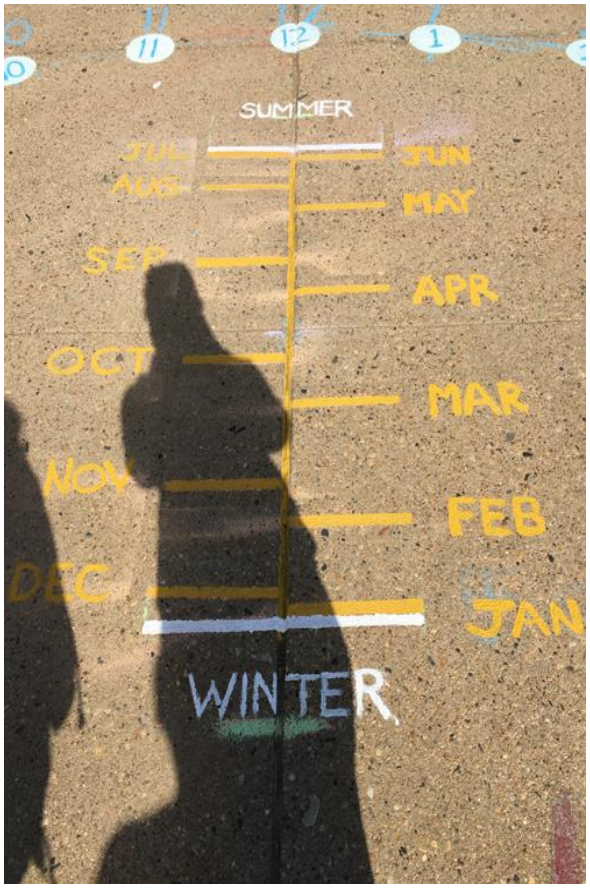
Step 10B Lay Out the Walkway

Step 10C Lay Out the Walkway

- **After marking walkway, use blue painter tape to outline monthly lines**
- **Here a white line is painted for the summer and winter solstice**

Step 10D Lay Out the Walkway

- **Plain or Fancy**
  - Notice the Central Line. You put one foot on each side and stand on the date.
  - Notice that June and December are very squashed, so you may have to use thin month separator lines.
  - If this is a paver walkway, extend it north beyond the summer solstice mark and south beyond the winter solstice mark so that you have a place to stand.



Step 11 Include the Bailey Points

- **Use the Analemmatic Spreadsheet**
  - On the East-West Axis add two more points. These are the Bailey Points
  - From where you stand on the walkway to tell the time, looking past the East Bailey Point is the direction of sunrise
  - Looking past the West Bailey Point is the direction of sunset

Ellipse Axes and Focal Points				
	Ellipse		feet	inches
x	a		**8**	**--**
y	b		**5**	**7**
x	Focus East		**5**	**8 1/2**
x	Focus West		**-5**	**8 1/2**
y	North Mark		**5**	**7**
x	Scale		**8**	**--**

Bailey Sunrise/Sunset Points				
On EW axis			feet	inches
E	Bailey Point		**4**	**1**
W	Bailey Point		**-4**	**1**

Bailey Point

Hint: Use a small lid to outline the point with a circle

Some Analemmatic Dials

More Analemmatic Dials

Big Plastic Template Done Inside First

It’s so easy to lay out the analemmatic dial directly on the ground, doing a big plastic template isn’t necessary

More Analemmatic Dials

Even More Analemmatic Dials