How to Setup your Gard Clock Hybrid Sundial (Detailed Instructions)

These instructions are specific to the Gard Clock Hybrid sundial which uses a planetary gear system with a secondary minute dial. It also uses a curved analemma & nodus vertical plates and tilt adjustable nodus.

Figure: Planetary Geared Gard Clock Hybrid Sundial

Main Features

- The Alidade Vernier is replaced with a planetary gear system consisting of a sun gear & a planetary gear traveling around an outer ring gear on the main dial plate;
- The main dial crescent has a coarse time reading resolution of 5 minutes;
- The Alidade is coupled to a 0 to 60 secondary minute dial with a finer 1 minute reading resolution;
- The main dial crescent, along with the secondary minute dial, displays Local Mean solar time directly by computing corrections to the true, or apparent solar time. It achieves this by utilizing a visual-mechanical computer, also known as an Analemma curve;
- It converts Local Mean Time to Standard Local Time via meridian offset dial adjustments with a 5 minute resolution;
- Added a time compensation feature to the main dial to adjust for Daylight Savings Times;
- 25% larger Analemma plot on a curved vertical arm for improved reading resolution & accuracy;

- A Tilt Adjustable Nodus hole within a 25% larger curved vertical arm for Sun Elevation Compensation throughout the year. This feature enables a sharper shadow to be cast against the Analemma plate, especially at the elevation extremes;
- Improved resolution & print features on all dials;
- Time readings are accurate to < 1 minute throughout the entire solar year from any location in the northern hemisphere. In practical terms, however, the accuracy will always be determined by the quality of it's construction, assembly and precision of its final alignment;
- The time reading is "tuned-in" by turning a knob located under the main hour dial. Rotating the knob moves the entire Alidade, Nodus & Analemma assembly which enables the precise positioning of the sun's shadow against the Analemma vertical plate. The time is then read from the main hour & minute dials;
- Adjustable Latitude Scale Dial with 1 degree reading resolution;
- 4 base options are available; 3 with integrated magnetic compass and levels, and 1 without. For compass/level options, refer to these printable links:
    - Tri-leg: https://www.printables.com/model/1012539-improved-heliochronometer-sundial-base-design-with
    - Leveling base & tripod head: https://www.printables.com/model/1012575-heliochronometer-sundial-mount-for-head-leveling-b
- Assembly measures 180x200x200mm (W x L x H).

Detailed Setup Instructions

Each sundial has some inaccuracies in its component manufacturing and assembly. Fortunately, a well aligned heliochronometer can compensate for some of these inconsistencies & still be able to provide reasonably accurate time readings. If you follow these steps carefully, you should be able to obtain the best time reading accuracy possible from your sundial.

Here is a summary of the steps to follow for setting up your sundial:

1. Find a suitable place to mount your sundial;
2. Level & Align your sundial;
3. Adjust for your Latitude;
4. Adjust your sundial plate to display Standard Time;
5. Adjust your sundial plate to display Daylight Savings Time (Optional);
6. Fine Tuning.

1. Mount your Sundial

There are several different ways of mounting a sundial, depending on the base design you adopt. For this heliochronometer design, there are two available options:

Option A: Standard Tri-Leg Base Design, with or without integrated compass & level

Option B: Circular Base Design with integrated compass & circular or dual bubble levels

Option A is the simplest but the less flexible in terms of fixed placement options & adjustment capabilities; i.e.

- Mounting Location: Horizontal & flat surfaces only;
- Available Adjustments: Level only (relies on the thumb screws located on each tri-leg);
- Pros: Simple, transportable;
- Cons: Requires a relatively flat & level surface due to the base's limited adjustment range. Also, any rotation of the base during true north alignment is likely to throw it out the level resulting in re-adjustments. Easily nudged by an animal or wind which would

throw everything out of alignment. Not suitable for permanent mounting situations, unless you secure the leveling screws into a lower fixed surface, etc.

Option B can be used in a variety of mounting configurations; the most practical being mounting to a head leveling base or tripod ball which is then secured to a pedestal or post. This would be the preferred mounting method if you're looking for a more permanent installation solution; i.e.

- Mounting Location: Horizontal or inclined surfaces, pedestals, posts, tripods, etc.
- Available Adjustments: 360° Level & Azimuth (rotation);
- Pros: Greatly simplifies level & true north adjustments, independent of mounting location. More secure for permanent installations;
- Cons: Requires a separate head leveling base or tripod ball head for level adjustments.

In my installations, I use the circular base which allows me to mount my sundials on deck railing posts using a printed head leveling ball on an adapter plate. The setup is described here: [Heliochronometer Mounting Plate by 3DMason | Download free STL model | Printables.com]

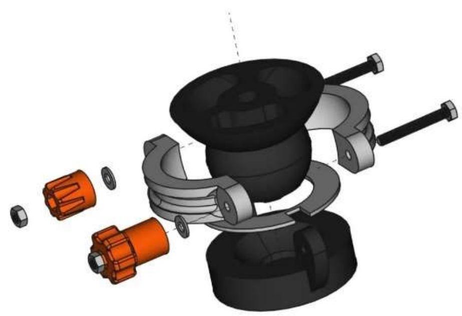


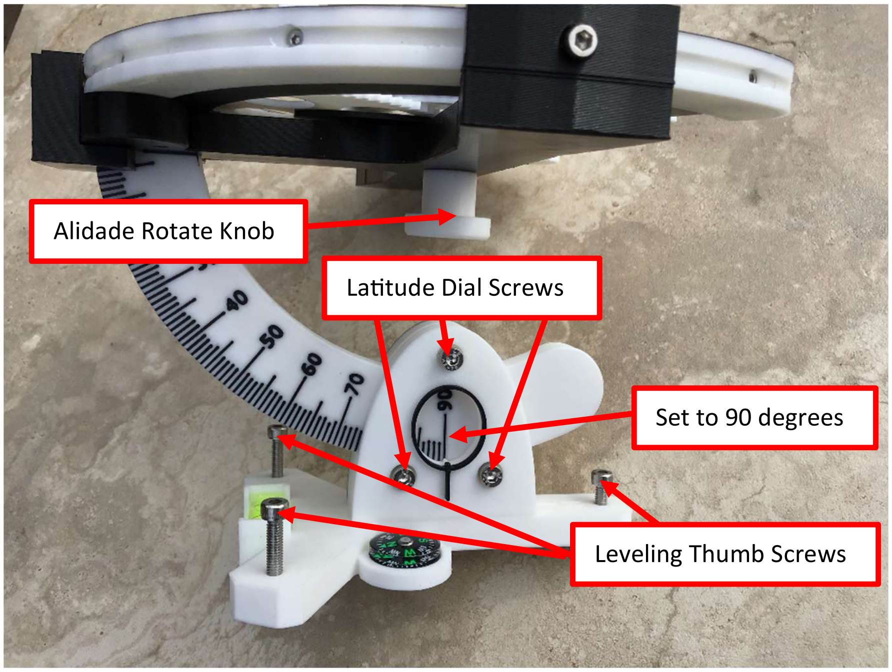
Figure: Circular Sundial Base on a Head-Leveling Ball Mounted on a Railing Post

For convenience, I will be referring to both Options A & B in the adjustment descriptions provided below.

2. Level & Align your Sundial

➔ **These Instructions Apply to Both Options A & B Base Mounts:**

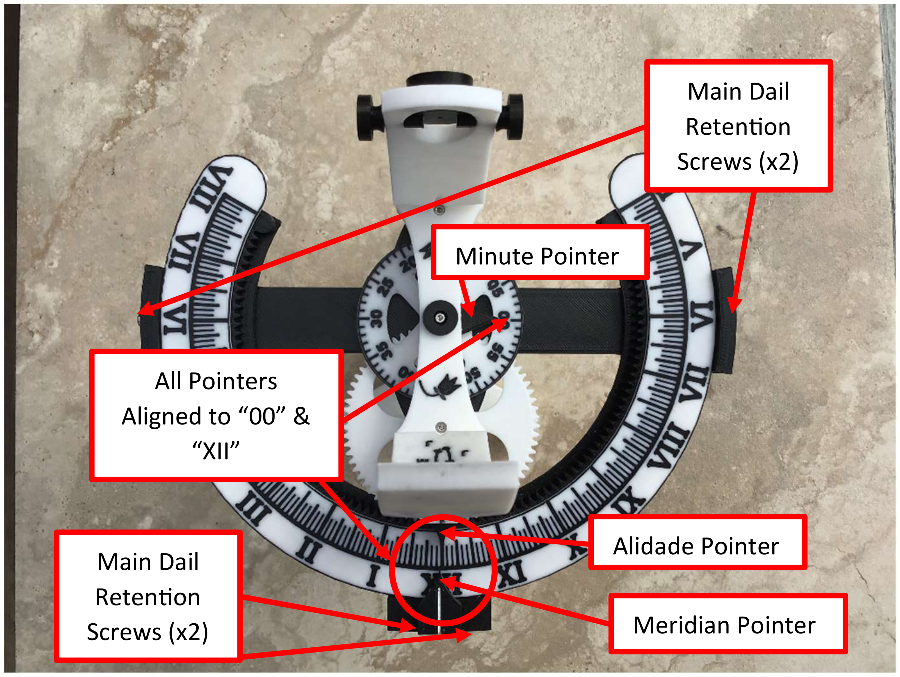
Loosen the 3 screws which secures the latitude dial and adjust the tilt angle for 90 degrees; i.e. horizontal. Re-tighten the screws once set.



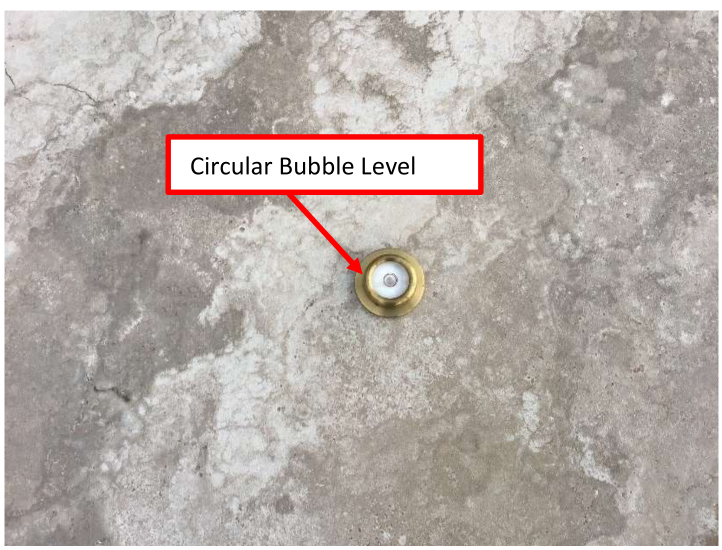
➔ **<u>These Instructions Only Apply to *Option A* Base Mounts:</u>**

1. Unscrew the leveling screws at each tri-leg so that the bottoms are not protruding pass the sundial base mount;
2. Partially unscrew the 4 screws holding the main dial located at the left, right & bottom of the crescent support. Rotate the dial plate & align the meridian offset pointer to “XII”;
3. Rotate the sundial alidade from the knob located below the main dial plate so that it is aligned with;
    a. the meridian offset pointer;
    b. pointing at “XII” standard meridian mark;
    c. secondary minute dial at “00” minutes;

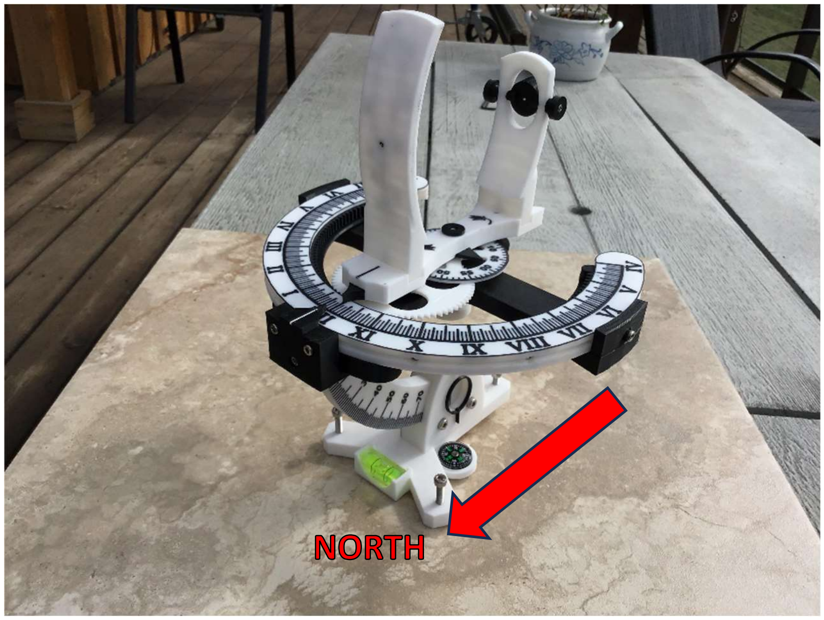
    When rotating the alidade, always do so from the bottom knob, never from the analemma or nodus vertical arms, or the alidade horizontal arm or you may damage the planetary gear system. Retighten the dial plate retention screws once adjusted but do not overtighten. Tighten just enough to keep the main dial from rotating;
4. Keep the alidade aligned with the meridian offset marker at “XII” & the minutes dial at “00” for the remainder of the adjustments. See photo below;



5. Find a flat & level surface to place your sundial. The flatter & more level the better for reasons that will be explained later. A standalone plate or tile with the ability to prop up the bottom for levelness works best. Make coarse level adjustments from the bottom of the plate using shims or similar;

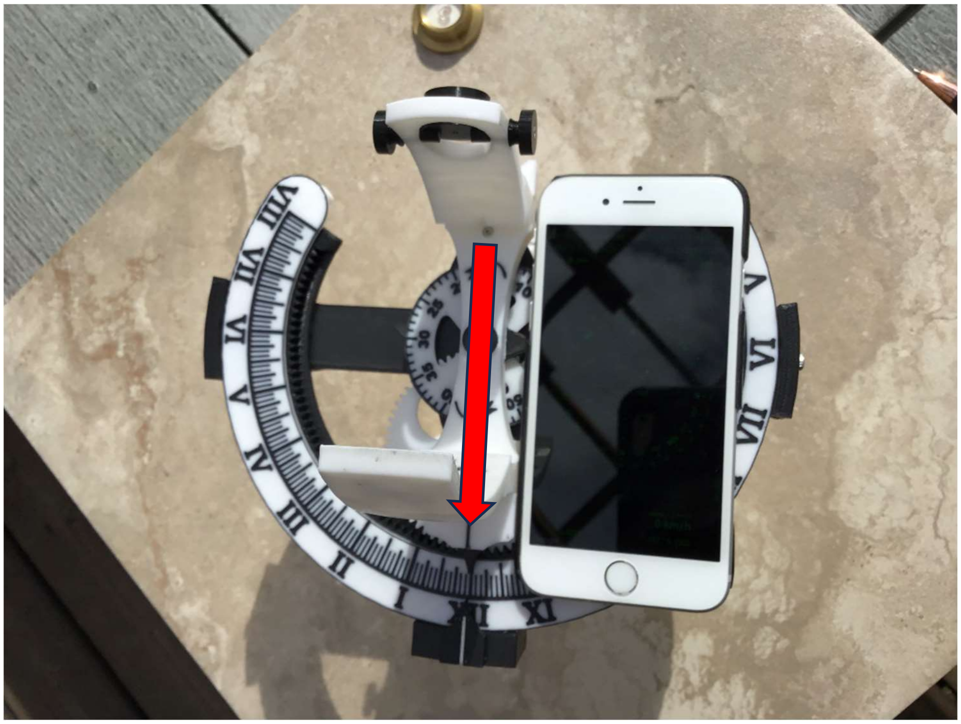


6. Place the sundial on your level surface & orientate it so that it is pointing in a general northernly direction. If you are using the base design with the integrated magnetic compass, use that for a rough setting. It doesn’t need to point to true north yet;



7. Using a bubble level; (a large circular bubble level works best), or a smartphone leveling app, place the level horizontally on top of the alidade (between the two vertical arms), or on top of the dial plate. If you are using the base design with the integrated levels, use that for the initial setup. It is worth mentioning that you will notice some differences if you level from the sundial base vs. dial plate or alidade. This is due to the inherent construction & assembly inaccuracies present in your sundial which are difficult to control from 3D printed parts vs. machined parts. Therefore, for any final adjustments, it is always best to level from the dial plate, or the top of the alidade horizontal arm (better). You can now perform finer adjustments using the 3 leveling screws situated on the sundial base to achieve a perfect level;

8. You will now need to fine tune your sundial's azimuth adjustment for true north. Download a GPS compass app on your smartphone, or use a good magnetic compass. You will need to determine true-north and not magnetic north. Therefore, if you are using a magnetic compass, you will need to look-up & adjust/compensate for the magnetic declination offset in your region;
9. Place your phone (or compass) flat on the dial plate <u>and keep it against the alidade</u>. <u>Make sure that the alidade has not moved & is still aligned with the meridian marker set at "XII" & that the secondary minute dial is at "00"</u>. Also confirm that the alidade pivot screw or dial clips aren't affecting your compass readings. If you notice any magnetic interference, find a better location on (or above) the dial plate to minimize the effect. While monitoring your smartphone app (or magnetic compass), rotate the entire sundial from it's base; (not the dial plate or alidade) until the alidade is aligned to true north. It is possible that the level adjustment is off after you rotated your sundial. This is where the importance of having a flat & level plate was highlighted in step 5. Now do final level adjustments using the sundial base screws, making sure that the sundial remains lined-up for true-north.



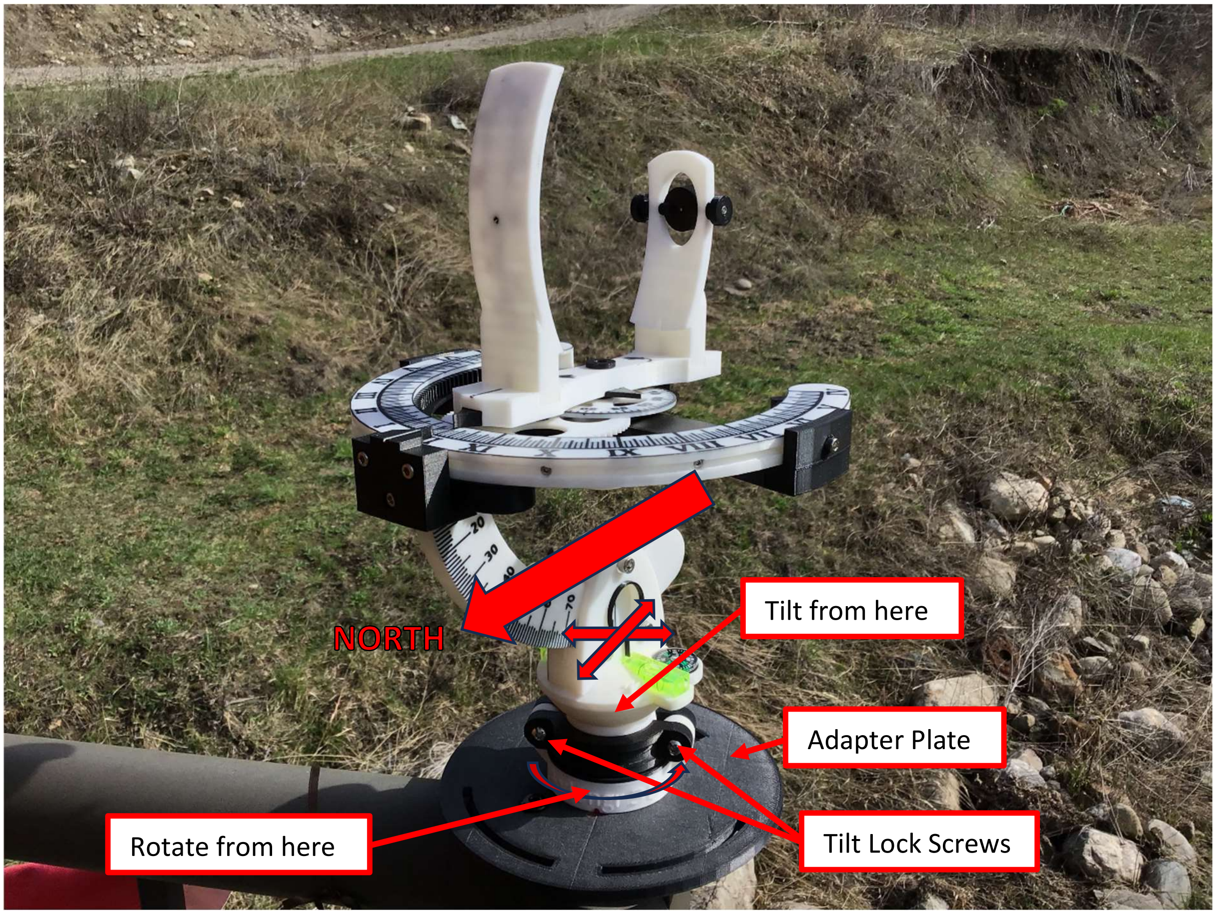
10. Secure both the sundial base & the plate it is sitting on so that they can no longer move. You will need to decide on the best option for this, depending on your situation. As long as nothing moves since the next adjustment steps could cause the sundial to get knocked-out of alignment & level. One option is hot glueing the sundial base screws against the plate surface then clamping down the plate on the fixed surface it is sitting on. Option B base mounts eliminate this problem & is the reason why it is preferred over this option A base mount solution.

➔ **These Instructions Only Apply to *Option B* Base Mounts:**

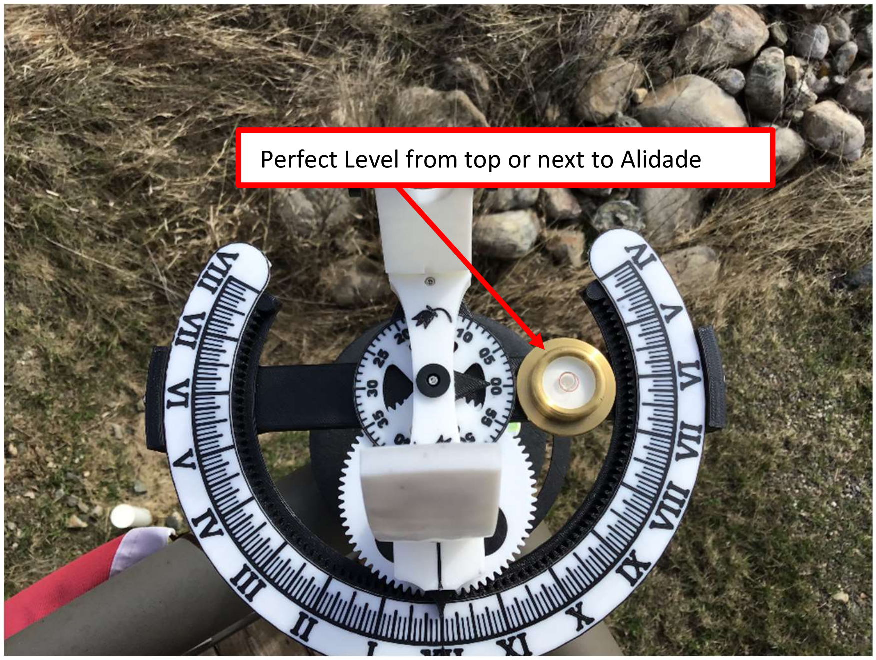
The following description assumes that a circular base will be mounted on a railing post using a levelling ball head with the adapter plate described here: [Heliochronometer Mounting Plate by 3DMason | Download free STL model | Printables.com]

As with option A, make sure that the latitude adjustment dial is set to 90 degrees before proceeding with these option B adjustments.

1. (see Option A step 2)
2. (see Option A step 3)
3. With your sundial attached to a railing post, loosen the tilt lock screws on the ball head just enough to allow the sundial to tilt freely with a bit of resistance;



4. Using the integrated magnetic compass on your sundial base, rotate the entire sundial from the base of the levelling head (not from the ball head but between the base & adapter plate) so that it is pointing in a general northernly direction. It doesn't need to point to true north yet since it is just a rough adjustment. If the Nylock nut which attaches the mounting plate to the levelling head is not overly tighten, it should allow the base to freely rotate on top of the adapter plate with just a bit of resistance;
5. NOTE: Rotation of the sundial in azimuth is always achieved from the bottom of the levelling head. The tilt or level adjustments are always done from the leveling ball head;
6. Using a bubble level; (a large circular bubble level works best), or a smartphone leveling app, place the level horizontally on top of the alidade (between the two vertical arms), or on top of the dial plate. If you are using the base design with the integrated levels, use that for the initial setup. It is worth mentioning that you will notice some differences if you level from the sundial base vs. dial plate or alidade. This is due to the inherent construction & assembly inaccuracies present in your sundial which are difficult to control from 3D printed parts vs. machined parts. Therefore, for any final adjustments, it is always best to level from the dial plate, or the top of the alidade horizontal arm (better). Tilt the sundial until you achieve perfect level;



7. Once you are satisfied with the leveling of your sundial, re-tighten the tilt lock screws on the leveling head to secure the sundial in place;
8. You can now fine tune your sundial's azimuth adjustments for true north. Download a GPS compass app on your smartphone, or use a good magnetic compass. You will need to determine true-north and not magnetic north. Therefore, if you use a magnetic compass, you will need to look-up & adjust/compensate for the magnetic declination offset in your region;
9. Place your phone (or compass) flat on the dial plate <u>and keep it against the alidade</u>. <u>Make sure that the alidade has not moved & is still aligned with the meridian marker set at "XII" and that the secondary minute dial is at "00".</u> Also confirm that the alidade pivot screw or dial clips aren't affecting your compass readings. If you notice any magnetic interference, find a better location on (or above) the dial plate to minimize the effect. While monitoring your smartphone app (or magnetic compass), rotate the entire sundial from the base of the levelling head (not from the ball head but between the lower portion of the leveling base & adapter plate, as before) until the alidade is aligned to true north. It is possible that the level adjustment might be slightly off after you rotated the sundial. Therefore, do one last check for levelness & make any fine adjustments while still making sure the sundial remains pointing to true-north;

3. Adjust for your Latitude:

➔ **These Instructions Apply to Both Option A & B Base Options:**

Unloosen the 3 screws which secures the latitude dial and carefully tilt the dial plate in elevation until it matches your latitude. During this adjustment, grab the latitude dial crescent & slide it back & forth within the pedestal to adjust the tilt angle vs. trying to move it from the dial plate. Re-tighten the screws;

4. Standard Time Adjustment:

➔ **These Instructions Apply to Both Option A & B Base Options:**

The relationship between the time your sundial reads & your actual clock time is as follows:

True Solar Time + EOT → Local Mean Time + Longitudinal Time Correction → Standard Time

Therefore, you will likely need to adjust the Local Mean Time (LMT); normally displayed by a corrected analemmatic sundial like this heliochronometer, to display actual Standard (clock) Time. The reason for this is that sundial readings without longitudinal correction are only accurate if the sundial is located on the central meridian for the time zone it is in. Most time zones are 15 degrees in longitude apart for every hour; i.e. 1 earth rotation every 24 hours, or 360°/24 hrs = 15°/hr, or 4 minutes for every degree of longitude. In an ideal world, every whole-hour offset from UTC (Coordinated Universal Time with reference to Greenwich), would lie exactly on a multiple of 15° of longitude. However, due to politically or historically motivated choices, some countries do not align perfectly on the "ideal" 15° intervals. Some regions use half-hour or even 45-minute offsets, resulting in "standard meridians" at multiples of 7.5° or 11.25°.

A reasonably complete listing of "central", or sometimes called "reference" or "standard" meridians which correspond to the official UTC-based offsets used around the world are provided at the end of this document.

<u>For 15° time zones which are centered on a standard meridian; i.e. -7.5° ← (Meridian) → +7.5°</u>
Sundials situated at the extreme eastern portion of a 15° time zone could read as much as 7.5° x 4min/deg = 30 minutes fast, as compared to a regular clock. Conversely, sundials at the extreme western portion would read as much as 30 minutes slow. This highlights the importance of having the ability to compensate for central meridian offsets if you want your sundial to accurately display actual standard clock time.

Here is simple example of how to make the longitude adjustments for a sundial situated in Vancouver, BC, Canada. The steps would be similar for your location if you know your longitude & that of your time zone meridian. Note also that this adjustment only needs to be made once if you keep your sundial at a fixed location.

<u>Example for Vancouver, BC:</u>

- Longitude: -123° 07m, or -123.1167° in decimal degree;
    - which is 3° 7m West of the Pacific Standard Time (PST) zone meridian at 120°;
- Therefore, the time correction (TC) would be:
    - TC = (3 + 7/60) x 4m/deg of longitude = 12.467m or 12m 28s.

Since Vancouver is west of the PST time zone meridian: LMT = PST - TC

or conversely: PST = LMT + TC

In this example, sundials in Vancouver would be running behind sundials situated on the pacific standard meridian because Vancouver is west of the meridian. Therefore, the dial plate would need to be rotated counter-clockwise; i.e. ahead from it's meridian mark by 12-1/2 minutes to properly display PST. Note that every minor tick mark on the main dial is 5 minutes, so the rotation would be 2-½ minor ticks *ahead* on the dial. The adjustments for this example are highlighted in the figure below:

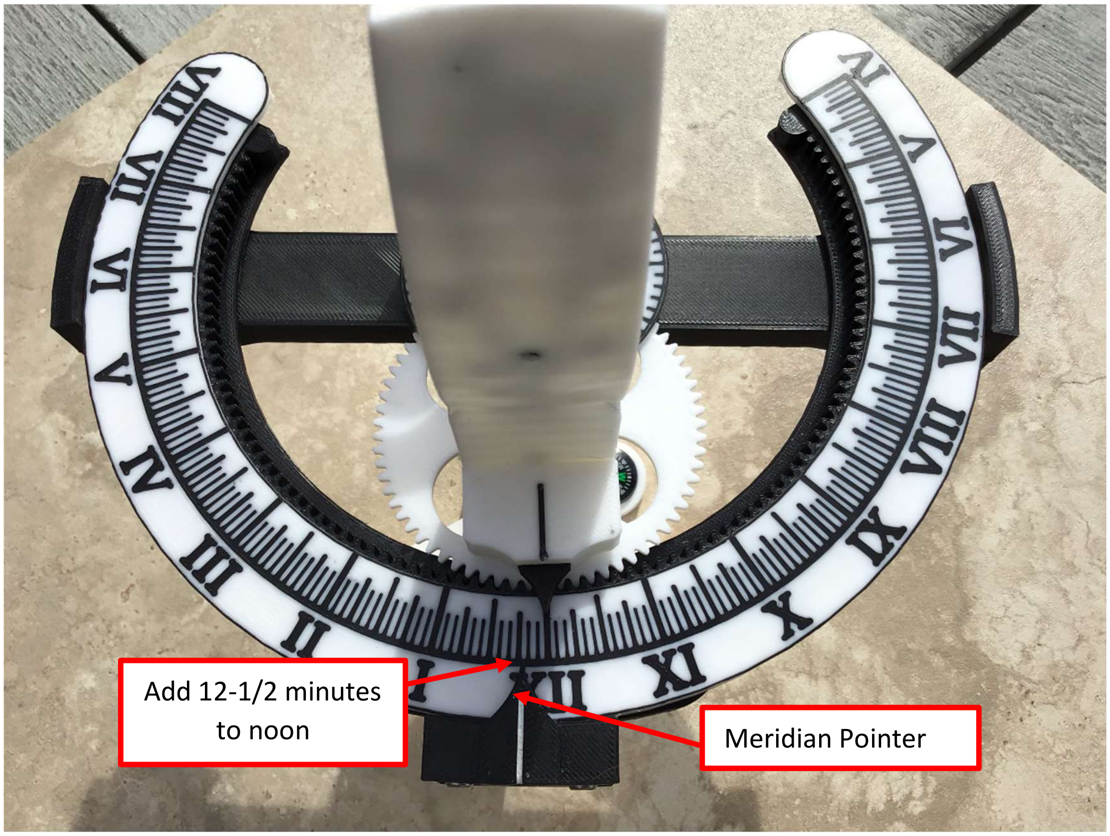


Figure: Dial adjusted for PST in Vancouver; i.e. LMT + 12-1/2 minutes.

Note that you will need to un-tighten the (4x) main dial plate retention screws again. The main dial is rotated so that the meridian marker points to the meridian offset you calculated above. Note that the alidade pointer should be kept aligned to “XII” & the secondary minute dial to “00” when rotating the main dial. The main dial plate & Alidade need to rotate together.

If your location is East of your standard time zone, your dial plate would need to be rotated clockwise instead of counter-clockwise since your local time would be ahead of your meridian; i.e. Your Standard Time = LMT – TC.

5. Daylight Savings Time (DST) Adjustment (Optional)

If you live in an area that is affected by Daylight Savings Time, further adjustments can be made to the sundial to have it display DST directly. The adjustment is relatively simple. Just rotate the dial forward in time by an additional 1 hour, as indicated in the example below. Note that the longer graduations on the dial marks the hours, second longest is ½ hours, third longest ¼ hours

& the shortest marks 5-minute intervals. Don't forget to move the dial back to its original position once DST is ended.

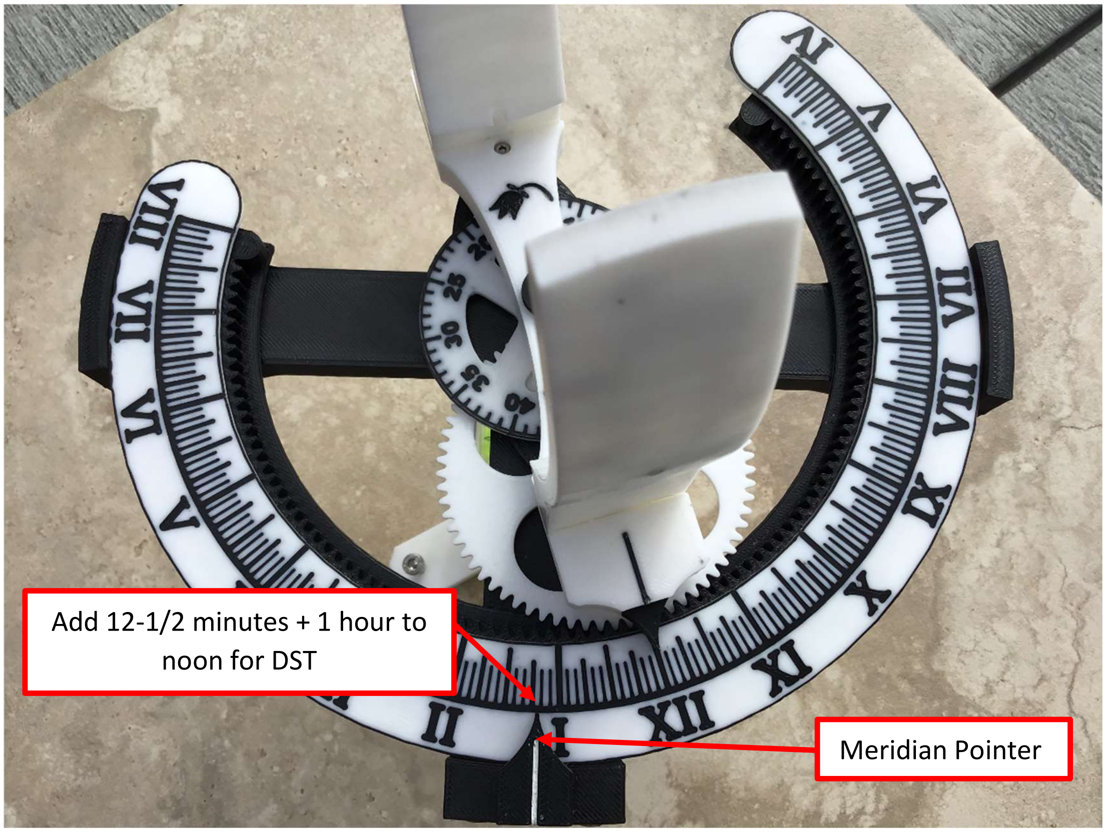


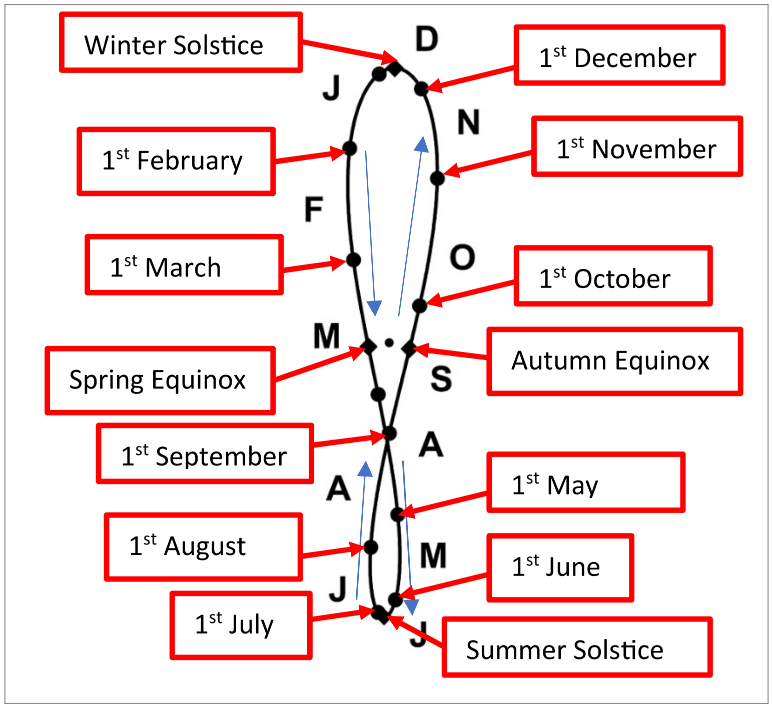
Figure: Dial rotated an additional 1 hour ahead to display daylight savings time directly from your sundial.

Retighten the dial plate retention screws once the meridian & DST adjustments are made but do not overtighten. Tighten just enough to keep the main dial from rotating.

6. Fine Tunning

➔ **<u>These Instructions Apply to Both Option A & B:</u>**

1. Choose a day which has an identifying marker on the analemma plate; like the 1st day of the month (indicated by circles), or on an equinox or solstice (indicated by diamonds); i.e.



2. To give yourself enough time for any fine tunning, choose an arbitrary time which is ahead of your actual clock time by a least 15 minutes. The time you choose should preferably be on-the-hour such that you have a clear indication on the dial plate. 12 o'clock noon works best. Rotate the alidade knob so that it points to the time you have chosen;
3. Keep the alidade position fixed throughout the remainder of the adjustments;
4. Once your clock time catches up with the time you set on your sundial & without touching the alidade or sundial plate, rotate (in azimuth) the entire sundial from its base; i.e. clockwise or counter-clockwise following the horizon, such that the sunlight spot passing through the nodus sighting hole is aligned on top of the analemma curve. Make sure that you are on the right half of the analemma curve which corresponds to the month you are in;
5. If the light spot is not on the identifying marker you chose in step 1, then unloosen the screws to the latitude dial & try to align. You might need to go back & forth between the azimuth adjustments & the elevation adjustments until the light spot from the nodus is exactly aligned on top of the analemma marker. Make sure that your sundial time & clock time still corresponds when you are making these adjustments;
6. Re-tighten the latitude screws;
7. Your sundial is now fully aligned & tuned to provide the best readings possible.

Meridian Offset Notes :

1. Integer offsets from UTC (+n or −n hours) correspond to 15n degrees from Greenwich.
2. Half-hour offsets (n:30) correspond to 15n+7.5 degrees.
3. 45-minute offsets (n:45) correspond to 15n+11.25 degrees.

4. For negative UTC offsets, we typically express the meridian in degrees *west* of Greenwich; for positive offsets, in degrees *east* of Greenwich. In reality, a longitude like 195° E is the same as 165° W, and 210° E is the same as 150° W, etc.

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1. Integer Hour Offsets (UTC−12 to UTC+14)

UTC Offset	Meridian	Common Example(s)
UTC−12	180° W	(Uninhabited areas, Baker Island)
UTC−11	165° W	American Samoa, Niue
UTC−10	150° W	Hawaii (HST), French Polynesia
UTC−9	135° W	Alaska Time (AKST)
UTC−8	120° W	Pacific Time (PST)
UTC−7	105° W	Mountain Time (MST)
UTC−6	90° W	Central Time (CST)
UTC−5	75° W	Eastern Time (EST), Colombia
UTC−4	60° W	Atlantic Time (AST), Chile (part)
UTC−3	45° W	Argentina, Brazil (eastern)
UTC−2	30° W	(Some Atlantic islands)
UTC−1	15° W	Azores
UTC±0	0°	Greenwich Mean Time (UK, Iceland)
UTC+1	15° E	Central Europe (CET)
UTC+2	30° E	Eastern Europe (EET), S. Africa
UTC+3	45° E	East Africa, Arabia, W. Russia
UTC+4	60° E	UAE, Oman, Azerbaijan
UTC+5	75° E	Pakistan, Uzbekistan
UTC+6	90° E	Bangladesh, Bhutan
UTC+7	105° E	Thailand, Vietnam, W. Indonesia
UTC+8	120° E	China, Malaysia, W. Australia
UTC+9	135° E	Japan, Korea (KST), E. Indonesia
UTC+10	150° E	Eastern Australia (AEST), Vladivostok
UTC+11	165° E	Solomon Islands, New Caledonia
UTC+12	180° E	New Zealand (NZST), Fiji
UTC+13	195° E (≡165° W)	Samoa, Tonga (in Southern Summer)

UTC Offset	Meridian	Common Example(s)
UTC+14	210° E (≡150° W)	Line Islands (Kiribati)

2. Half-Hour & Forty-Five-Minute Offsets

Below are the most commonly used “non-integer” time zones and their corresponding standard meridians. (Not all are used year-round or by all countries consistently.)

UTC Offset	Meridian	Used By / Example
UTC−3:30	52.5° W	Newfoundland (NST)
UTC−2:30	37.5° W (historic)	St. John’s (rarely used in past)
UTC−4:30	67.5° W (historic)	Venezuela (pre-2016), Myanmar (1942–
UTC+3:30	52.5° E	Iran Standard Time (IRST)
UTC+4:30	67.5° E	Afghanistan
UTC+5:30	82.5° E	India (IST), Sri Lanka
UTC+5:45	86.25° E	Nepal
UTC+6:30	97.5° E	Myanmar (MMT)
UTC+8:30	127.5° E	North Korea (KST, since 2018)
UTC+8:45	131.25° E	Southeastern Western Australia (unofficial)
UTC+9:30	142.5° E	Central Australia (ACST)
UTC+9:45	146.25° E (rare)	(Unofficial use in some parts of Oz)
UTC+10:30	157.5° E	Lord Howe Island (LHST, part-year)
UTC+11:30	172.5° E	Norfolk Island (NFT, part-year)
UTC+12:45	191.25° E (≡168.75° W)	Chatham Islands (CHAST)

Caveats

1. **Some meridians exceed 180° E**
   For large positive UTC offsets (e.g. UTC+13 or UTC+14), the “east” longitude can be written as 195°E or 210° E; these are equivalent to 165°W or 150°W, respectively.
2. **Historic or rarely used offsets**
   A few half-hour or 45-minute offsets have been used historically or unofficially (e.g. UTC−2:30 in parts of Newfoundland before standardization, UTC−4:30 in Venezuela before 2016, etc.). Modern adoption may differ.

3. **Daylight Saving Time (DST)**
   Some regions jump an additional hour (or half-hour) forward during part of the year. Their “standard meridian” remains the same, but the local clock time shifts seasonally.
4. **The 15° rule is a guideline, not always the practice**
   Politically or historically motivated choices mean many countries do not align perfectly on the “ideal” 15° intervals from Greenwich.