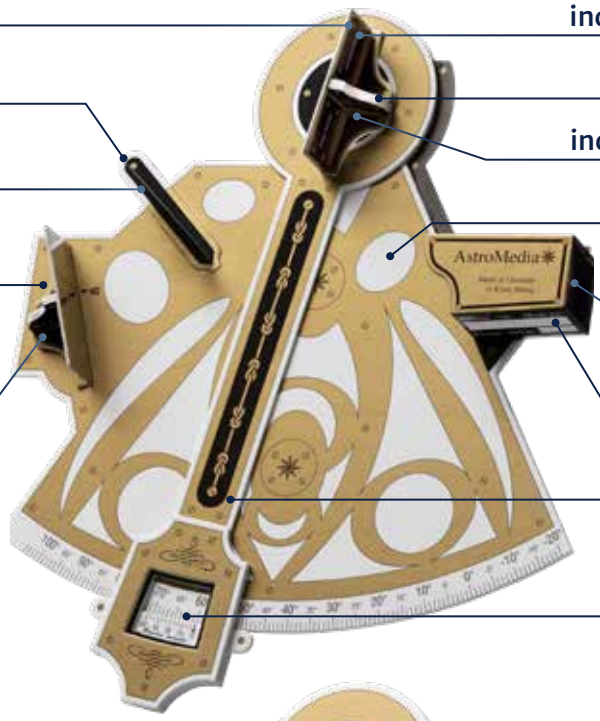
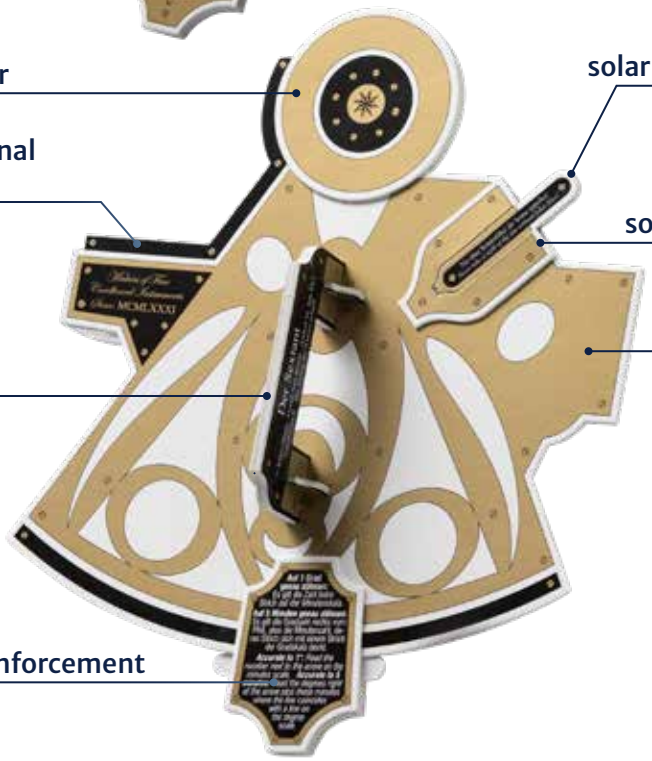
Building instructions

The Sextant





AstroMedia

Hands-on Science Series

The Sextant

Before the introduction of global positioning satellite systems (GPS), the most important method for determining your position on the high seas was to measure the height of a celestial body above the horizon or the distance between celestial bodies as precisely as possible. The quadrant and astrolabe were used for this purpose from the 9th century, even before the magnetic compass became widespread. Later, more precise measurements became possible with the Jacob's staff, invented in the 14th century, which remained the seaman's most important navigational instrument for 400 years*.

In 1731, John Hadley presented his mirror sextant in London. Independently of him, Thomas Godfrey in Philadelphia (USA) had also invented it. This instrument revolutionised navigation, because now measurements, e.g. of the Sun's height, could be made with unsurpassed accuracy and speed. In connection with the ship's chronometer invented by John Harrison, the art of navigation developed to an unprecedented level, especially in England. It can be said without exaggeration that these two inventions were the most important prerequisites for the spread of the world encompassing British Empire.

The principle is ingenious and at the same time amazingly simple: A rotatable mirror makes it possible to align an image of the point to be measured with the horizon or another reference point and to read the angle between the two on a scale (more precisely: the angle that the lines of sight to the two points form with each other). It is not surprising that the sextant was often a sailor's most valuable possession and that it is still the most well-known nautical symbol alongside the anchor and compass.

** Matching kits from AstroMedia: The Quadrant (article no 102.QUA), The Jacob's Staff (article no 106.JAK), The Magnetic Compass (article no 218.MAG), The Stardial with Sailor's Astrolabe (article no 811.ASU)*

A navigator measuring the angular distance between the moon and a star.

Contents:

- 4 pre-punched sheets of 0.5 mm construction cardboard
- 2 stainless steel mirrors 48 x 18 mm (with protective film on mirror surface)
- 1 solar filter, 38 x 18 mm
- These instructions

You will also need for assembly:

- A firm, level work surface and a cutting board or mat, made from hardboard, plastic, or wood. Self healing cutting mats are ideal as the material re-closes after each cut.
- A sharp knife with a fine point (thin carpet knife, scalpel, AstroMedia craft knife, article no 401. MES), to cut the thin holding tabs of the pre-punched parts.
- Standard solvent based all purpose glue, e.g. UHU, Evo-Stik Impact, B&Q All Purpose Glue. **Do not use water-based glue**: it softens and warps the cardboard, and doesn't stick properly to the printed surfaces. Solvent based glues also dry much faster.
- Some methylated spirit or isopropanol to clean the stainless steel mirrors
- Some fine sandpaper or a craft file for sanding down the small holding strips and cardboard parts (e.g. AstroMedia sandpaper file, article no 400.SBF)
- A clothes-peg and a thin black permanent marker for the calibration (marking line on the horizon mirror)

Tips for successful construction Please read before commencing!

1 Every part is identified by its name and part number. The part number consists of a letter and a number in a rectangular frame: e.g. A2 . The letter denotes the part of the sextant it belongs to, the numbers denote the order of construction. The numbers are printed on the front and back of the part and sometimes also next to it. Only remove the parts as you need them.

2 Areas that are to receive glue are printed in grey. On each glueing area is a symbol that shows which part is to be glued in this place, e.g. A2 (part [A2] is glued in this place).

3 When glueing together several parts of the same size, always ensure that the edges of all parts are exactly flush, e.g. by pushing the edges onto the work surface before the glue has set.

4 Before commencing a step, remove all needed parts from the cardboard and remove all pre-cut slots and disks where required.

Note: Every part that has a part number printed on it will be needed to complete the sextant.

5 If the edges of the stainless steel mirrors are too sharp, they can easily be de-burred with some sandpaper or a craft file.

Building Instructions
Read through each step completely before commencing.

A. The Frame

The frame consists of four 0.5 mm thick layers of cardboard. This gives it a total thickness of 2 mm and, once the adhesive has completely dried, has a rigidity that compares to plywood. It is the carrier of all moving and non-moving parts of the sextant: the horizon mirror, the viewing chamber, and the handle on the back are glued to it, the index arm with the index mirror and the solar filter are (re-)movable.

Tip: *In order to achieve optimal flatness of the large parts such as the frame and the index arm, the parts should be weighed down on a flat surface, e.g. with a book, until the glue has dried.*

Tip: *Check the drawings on the back of the title page. They show all parts with their numbers and positions.*

Step 1 Remove the frame front parts [A1, sheet 1] and [A2, sheet 2] from the cardboard, open the punched slots and put the index arm axle disks aside. Glue the two parts together as indicated by the glue symbols, making sure their edges are flush.

Step 2 Do the same with the two frame back parts [A3, sheet 3] and [A4, sheet 4].

Step 3 Glue the front and back of the frame together as indicated. They are not identical along all the edges and therefore protrude beyond the other part in some places. No glue should be applied to these areas.

The black part of the back which protrudes over the front, can be used to attach the artificial horizon (see further information at the end of the instructions).

B. The Solar Filter

The height of the Sun above the horizon is the most important measurement in navigation. Please note that the Sun must never be looked at with the naked eye – this can lead to blindness. Therefore, a solar filter must be used that reduces the light of the Sun to a safe level. This is what the enclosed solar filter does. It is glued upright into the slot of the solar filter holder. The solar filter can be removed from the optical path by turning the holder around if angles between other objects are to be measured.

Step 4 Glue parts 1 and 2 of the solar filter holder [B1, sheet 1] and [B2, sheet 2] together as indicated. Use a knife to carefully clean the slot and check that the rectangular piece of solar filter can be inserted all the way in. Then glue the filter into the slot.

Step 5 Glue parts 1 and 2 of the solar filter slide [B3, sheet 3] and [B4, sheet 4] together, as well as parts 1 and 2 of the solar filter counter piece [B5, sheet 3] and [B6, sheet 4].

Step 6 Glue the solar filter holder to one side of the slide and the counter piece to the other side. After drying, make sure that the slide with its glued-on parts fits into the recess in the back of the frame. The covers of the solar filter slide [B7] and [B8] are glued on later.

Important: *Looking directly into the Sun is dangerous and can permanently damage the eye. Evidence of this is the use of imperfect solar filters on the sextants of earlier centuries, which caused many captains to become blind in one eye (their "observing eye") over the years. The solar filter in this cardboard sextant has a particularly high silver content and thus offers reliable protection. Still, it's a good rule to generally never look at the Sun any longer than necessary, even through this solar filter.*

C. The Index Arm

The index arm (also known as alidade, from Arabic "al-'iḍāda, the ruler") is attached to an axle made of 4 cardboard disks and carries the index mirror at the top. At the base there is a window in which the measured angle can be read.

Step 7 Glue the four already removed axle disks [C1], [C2], [C3], and [C4] together as indicated, making sure that the edges are exactly flush. After drying, check that the resulting axle can be pushed into its bearing, the hole at the top of the frame, without force. If that is not the case, any protruding cardboard burrs inside the hole or on the disk must be carefully scraped off, using a knife or sandpaper.

Important: *The axle must not have any play, but must still be able to rotate in its hole. Any sluggishness will quickly disappear when it has been moved a few times.*

Step 8 Remove the punched slot and the rectangular window from the two parts of the index arm [C5, sheet 1] and [C6, sheet 2] and glue them on top of each other as indicated.

Step 9 Lay the frame back side down on a flat surface and push the axle into its bearing. Now glue the round top of the index arm centrally onto the axle disc and make sure that the round top exactly covers the round top of the frame.

Important: *Only apply the glue to the axle, not to the index arm, otherwise the top will be glued to the frame and won't be able to rotate.*

Step 10 This is how you make the index arm work after it has dried thoroughly: Press the centre of the axle and the centre of the top of the index arm firmly together with the thumb and forefinger of one hand, place the other at the base of the index arm and carefully move it a little while turning the axle at the same time. Then increase the movements slowly until the index arm can be moved across the entire frame.

Step 11 Glue the two parts of the small reinforcement [C7, sheet 1] and [C8, sheet 2] onto one another and glue the reinforcement part flush to the bottom edge on the back of the index arm. A gap to the frame of approximately 7mm should remain.

Step 12 Glue the two parts of the index arm axle cover [C11, sheet 3] and [C12, sheet 4] together, lay the frame face down on your work surface and glue the cover onto the axle.

Important: *Again, no adhesive should get onto the frame or between the frame and axle. After drying, check that the index arm can still be swivelled easily. The index arm is now firmly connected to the frame. The other parts of the index arm are only glued in place after the calibration has been carried out.*

Step 13 The slide cover for the solar filter can now also be fitted. Glue parts 1 and 2 [B7, sheet 3] and [B8, sheet 4] together and then over the slot for the solar filter slide.

Important: *The glue must not get into the slot. After drying, slide the solar filter into the resulting pocket. It might be a bit difficult to move at first, but it will get easier with time.*

D. The Viewing Chamber

The viewing chamber with its front and rear windows directs the view to the horizon mirror and past it to the horizon itself. The slots of the upper cover, which consists of 4 layers of cardboard, snap over the upper pegs of the sighting windows. The bottom and the side cover consist of only 2 layers, they are butt glued to the edges of the windows.

Tip: *The viewing chamber can optionally be set up to accommodate the AstroMedia Pocket Telescope (article no 821.WTT-E).*

Step 14 Glue parts 3 and 4 of the rear window 2 [D1] and [D2, both sheet 4], flush against each other, then parts 1 and 2 [D3] and [D4, both sheet 3] on top as indicated.

Step 15 Do the same with parts 3 and 4 of the front window [D5] and [D6, both sheet 4] and [D7] and [D8, both sheet 3].

Step 16 Glue the front window (the one with the smaller hole) with its wider peg into the slot on the front of the frame. The narrower peg points upwards. Then glue the rear window into the two slots provided for this purpose.

Step 17 Glue the viewing chamber top together as follows: first outer parts 1 and 2 [D9, sheet 1 and D10, sheet 2], then inner parts 3 and 4 [D11, sheet 1 and D12, sheet 2], and finally everything back to back. Glue the resulting four-layer part to the two windows and into the angle formed by the front of the frame with the artificial horizon holder. The pegs on the two windows snap into the slots on the underside of the cover.

Step 18 Glue parts 1 and 2 of the viewing chamber base [D13, sheet 1] and [D14, sheet 2] together, add your name and the date and glue the base under the two windows. It should be flush with the frame on the right hand side.

Step 19 Finally, glue parts 1 and 2 of the side wall [D15, sheet 1] and [D16, sheet 2] to each other and then butt onto the edges of the windows, the top, and the base. It also should be flush with the frame on the right hand side.

E. The Horizon Mirror

The horizon mirror is the fixed one of the two mirrors and directs the view coming through the viewing chamber to the centre of the movable index mirror (and, if present, also to the mirror of the artificial horizon). For all mirrors it is very important that their reflective surface is perfectly perpendicular to the surface of the frame. This is achieved with a right-angled support consisting of 6 layers.

***Tip:** The mirrors are protected on the polished side by a film that must be removed before installation. Since they are laser-cut from a stainless steel sheet, it may be necessary to remove melted edges of the foil with methylated spirit and a soft cloth.*

Step 20 Glue the two inner parts 1 and 2 of the horizon mirror support [E1] and [E2] back to back as indicated, then the inner parts 2 and 3 [E3] and [E4] on top, and finally the two outer parts 1 and 2 [E5] and [E6, all sheet 1]. Push the straight edges of this block against your work surface before drying to make sure the parts are exactly flush and at right angles to the surface.

Step 21 Place a mirror in the long slot on the left of the front of the frame, with the polished side facing the viewing chamber. Push the mirror support, with the edge marked by a narrow grey stripe, into the short slot that is perpendicular to the mirror. Slide the support from the back against the mirror until it is pressed firmly against the edge of its slot. Glue the mirror and support in their slots and to each other in this position.

Step 22 Make sure that the mirror is at exact right angles to the frame, e.g. by using one of the square corners of a sheet of cardboard or by looking across the frame at a small angle at the mirror: the surface of the frame should continue in the mirror image without a bend. If necessary, make corrections before the glue is completely dry.

Step 23 Glue the base covers of the horizon mirror 1 and 2 [E7, sheet 1] and [E8, sheet 2] as well as 3 and 4 [E9, sheet 1] and [E10, sheet 2] first on top of each other and then onto the designated spots behind the horizon mirror. This covers the still visible part of the slot.

Step 24 Glue the two horizon mirror back covers [E11, sheet 1] and [E12, sheet 2] onto the back of the mirror.

The horizon mirror is now fully assembled.

F. The Index Mirror

The index mirror is installed in the same way as the horizon mirror.

Step 25 Glue the 6 parts of the index mirror support [F1], [F2], [F3], [F4], [F5], and [F6, all sheet 2] together as indicated.

Step 26 Glue the mirror and support into their slots in the top of the index arm.

***Important:** In the slot for the mirror you can see the axle in the middle and the frame at its two ends. Make sure that the mirror is only glued to the axle, not to the frame – otherwise the index arm cannot move.*

Step 27 Look in the mirror and make sure it is at right angles: the index arm's top and its reflection must complement each other to form a perfectly round disc.

Step 28 Glue the base covers of the index mirror 1 and 2 [F7, sheet 1] and [F8, sheet 2] and 3 and 4 [F9, sheet 1] and [F10, sheet 2] first on top of each other and then behind the index mirror.

Step 29 Finally glue the back covers 1 and 2 [F11, sheet 3] and [F12, sheet 4] behind the mirror.

G. The Handle

The handle consists of 8 layers of cardboard and is therefore very sturdy. With two 4-layer supports it is securely anchored to the back of the frame.

Step 30 Glue the inner parts 1 and 2 of the handle [G1] and [G2, both sheet 4] back to back. Now add the inner parts 3, 4, 5, and 6 [G3], [G4, both sheet 4], [G5] and [G6, both sheet 3] and finally the two outer parts 1 and 2 [G7] and [G8, both sheet 3]. Again, make sure that the edges are flush by pushing the block of 8 layers of cardboard onto the work surface on all sides before the glue sets.

Step 31 Glue the inner parts 1 and 2 of the first support [G9] and [G10] back to back and then the outer parts 1 and 2 [G11] and [G12], all on sheet 3] on top. Again, make sure that the edges are flush. Then glue the inner and outer parts of the second support [G13], [G14], [G15] and [G16, all on sheet 4] together in the same way.

Step 32 Check their fit by inserting the supports into the slots in the handle. They must be flush with the bottom of the handle so that the handle can snap into the cross-shaped slots on the back of the frame. Glue the supports to the handle first, then glue the handle with the supports to the frame.

H. The Calibration of the Minute Scale

The degree scale at the bottom edge of the frame provides an accuracy of approx 1°, which is increased to up to 5 arc minutes (1/12 arc degree) with the minute scale (vernier scale). For this, however, the sextant must first be calibrated: the index mirror is aligned exactly parallel to the horizon mirror by moving the index arm and then the minute scale is glued on accordingly.

Step 33 There is a small printed arrow on the frame near the horizon mirror. Use a thin felt-tip pen to make a small, clearly visible marking on the upper, long edge of the horizon mirror, exactly at the level of this arrow.

Tip: *Use a set square or the corner of a piece of cardboard as a right-angled ruler. This is how you check whether the line is in the right place. Remove the solar filter and push the index arm past the 100° mark until it touches the horizon mirror. If you now look through the viewing chamber at the horizon mirror, you will see the index mirror as a compressed rectangle in its upper part. The marker line on the horizon mirror must be exactly in the middle of this collapsed rectangle. If this is not the case, you can remove the line with methylated spirit and redraw it.*

Step 34 Move the index arm until horizon and index mirror are approximately parallel and the 5° mark appears in the middle of the read out window. Hold the sextant vertically and aim through the two sighting windows at a distant horizontal line, e.g. the horizon or the roof ridge of a large building. The distance should be at least one kilometre, better still further away. On the left side of your field of vision, the un-mirrored view goes straight ahead past the horizon mirror. On the right side, it falls on the horizon mirror, which directs it to the index mirror, from where it continues straight ahead again. Now carefully move the index arm a little bit back and forth until the targeted horizontal line on the left goes from the non-reflected image to the right without a break, exactly where you have made the marking line on the horizon mirror. If both mirrors are correctly aligned, the un-mirrored and mirrored image form an unbroken straight line. In this position, the index arm is provisionally fixed at the top, e.g. with a clothes-peg.

Step 35 Glue parts [C9, sheet 1] and [C10, sheet 2] of the minute scale on top of each other. Place the minute scale in the gap at the foot of the index arm, between the small foot reinforcement and the base plate, so that the small arrow on the minute scale is pointing exactly at the 0° mark of the frame scale. Glue it in this position and before final drying, check again that the sighting still shows a uniform, continuous image without a break when the minute scale arrow is pointing at 0°.

Step 36 Now glue parts 1 and 2 of the large reinforcement [C13, sheet 1] and [C14, sheet 2] on top of each other and then from behind onto the minute scale and small reinforcement.

Step 37 Glue parts 1 and 2 of the read out window [C15, sheet 3] and [C16, sheet 4] on top of each other and then to the front of the foot of the index arm with the edges flush.

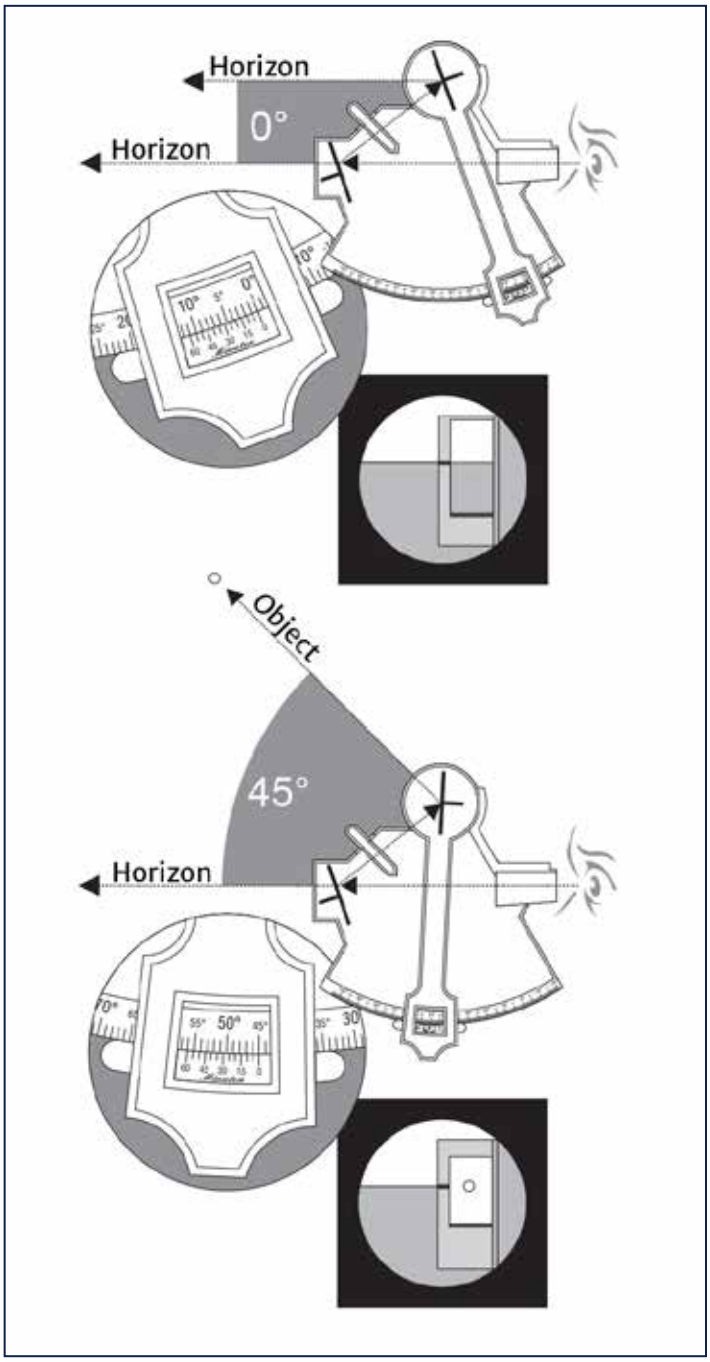
Step 38 Finally, glue parts 1 and 2 of the back of the index arm [C17, sheet 1] and [C18, sheet 2] onto each other and then flush onto the back of the index arm foot. The back of the index arm now overlaps the back of the frame from below, giving the index arm a firm hold on the frame. Check that it can still be rotated easily.

Tip: *If you want to improve the calibration after the minute scale has already been glued in place, you can move the black marking line on the horizon mirror. It can be removed with methylated spirit and redrawn as often as needed until the result is satisfactory.*

Congratulations!

Your sextant is now complete. You can say with justifiable pride that you have built this fully functional device for celestial navigation with your own hands. We hope you enjoy working with your sextant.

How the sextant works



Measurements with the sextant

With your finished sextant you now have a versatile instrument. You can determine positions and courses, measure angles, distances, and altitudes. Below are some examples.

Determining your latitude with the height of the Sun

1. Insert the solar filter so that it is between the mirrors.

2. Set the index arm to 0°.

3. Point the sextant at the Sun so that it appears in the mirrored image through the filter.

Caution: *aim at the Sun only through the filter, never look at it directly! It is safest if you do not initially hold the sextant by the handle but by the cardboard projection behind the horizon mirror so that your hand blocks your direct view of the Sun.*

4. Slowly lower the sextant while moving the index arm forward so that the reflected image of the Sun remains visible.

5. Read off the angle when the reflected image of the Sun is exactly on top of the horizon at the height of the marking line.

Your latitude can be determined from the height of the Sun above the horizon, measured at true noon (i.e. when the Sun is due south and thus at its highest point). To do this, the declination of the Sun (i.e. its distance from the celestial equator) must be known for the time of the measurement (see adjacent table).

I. Altitude of celestial equator = measured altitude minus solar declination

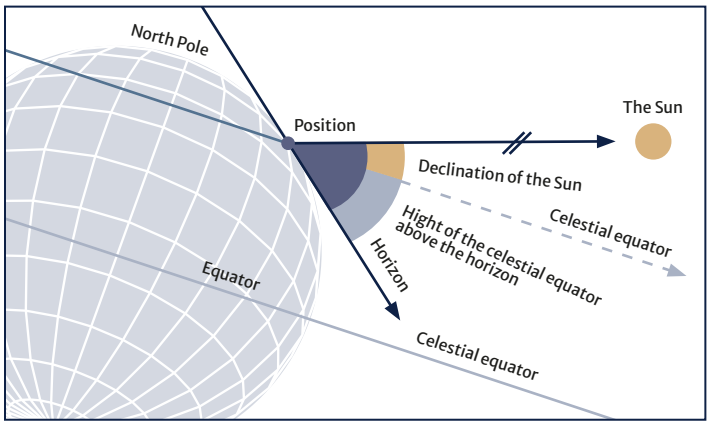
II. Latitude = 90° minus the altitude of the celestial equator

Example: *On the 1st August at 12:00 noon you measure the height of the Sun as 58°. In the annual table you will find a Sun declination of 18° for 1st August. You calculate:*

I. Altitude of the celestial equator = 58° – 18° = 40°

II. Latitude = 90° – 40° = 50°

You are therefore exactly on the 50th degree of latitude. ***Caution:*** *In the winter months, the declination of the Sun, which is subtracted from the measured value, is negative. If a negative number is subtracted from another, the result is positive: A – (–B) = A + B.*



Determination of the angle between any two points

To determine the angle between two objects, e.g. the peaks of a coastal mountain range or two church towers, hold the sextant horizontally and move the index arm until the un-mirrored image of one object coincides with the mirrored image of the other one.

The distance to the coast can be determined from several such angular distances between various points using a chart and a protractor. Similarly, if the distance is known, you can determine the height of a building graphically by measuring the angle between the horizontal and the top

of the building (α) and between the horizontal and the bottom edge (β) and entering it in a sketch. For measurements of this kind, the scale of the sextant goes down to −5° below the zero mark.

However, you have to keep in mind that the result becomes less accurate with shorter distances and larger angles. The reason: the upper line of sight intersects with the nonmirrored line of sight at a slightly different point, depending on the position of the index arm, because it does not reach the eye directly but via the two mirrors. The resulting shift is called parallax. However, it can be disregarded as long as the angles are small and the observed objects are distant, such as stars.

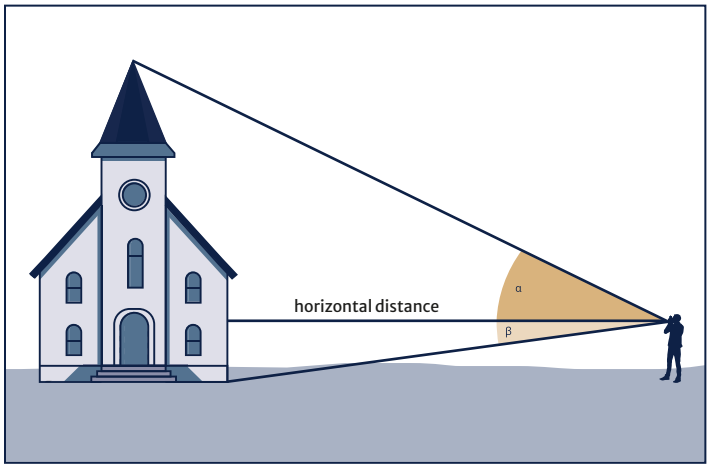


Table of the Sun's declination during a year

01.01. −23°01′	**07.02.** −15°21′	**16.03.** −1°48′	**22.04.** 12°09′	**29.05.** 21°36′	**05.07.** 22°48′	**11.08.** 15°18′	**17.09.** 2°18′	**24.10.** −11°42′	**30.11.** −21°37′
02.01. −22°56′	**08.02.** −15°02′	**17.03.** −1°24′	**23.04.** 12°29′	**30.05.** 21°45′	**06.07.** 22°42′	**12.08.** 15°01′	**18.09.** 1°55′	**25.10.** −12°03′	**01.12.** −21°47′
03.01. −22°50′	**09.02.** −14°43′	**18.03.** −1°00′	**24.04.** 12°49′	**31.05.** 21°54′	**07.07.** 22°36′	**13.08.** 14°42′	**19.09.** 1°32′	**26.10.** −12°24′	**02.12.** −21°56′
04.01. −22°44′	**10.02.** −14°24′	**19.03.** 0°37′	**25.04.** 13°09′	**01.06.** 22°02′	**08.07.** 22°29′	**14.08.** 14°24′	**20.09.** 0°45′	**27.10.** −12°44′	**03.12.** −22°05′
05.01. −22°38′	**11.02.** −14°04′	**20.03.** 0°13′	**26.04.** 13°28′	**02.06.** 22°10′	**09.07.** 22°22′	**15.08.** 14°05′	**21.09.** 0°45′	**28.10.** −13°04′	**04.12.** −22°13′
06.01. −22°31′	**12.02.** −13°44′	**21.03.** 0°11′	**27.04.** 13°47′	**03.06.** 22°18′	**10.07.** 22°15′	**16.08.** 13°47′	**22.09.** 0°22′	**29.10.** −13°24′	**05.12.** −22°21′
07.01. −22°23′	**13.02.** −13°24′	**22.03.** 0°34′	**28.04.** 14°06′	**04.06.** 22°25′	**11.07.** 22°07′	**17.08.** 13°28′	**23.09.** 0°01′	**30.10.** −13°44′	**06.12.** −22°29′
08.01. −22°16′	**14.02.** −13°04′	**23.03.** 0°58′	**29.04.** 14°25′	**05.06.** 22°32′	**12.07.** 21°59′	**18.08.** 13°08′	**24.09.** 0°25′	**31.10.** −14°04′	**07.12.** −22°36′
09.01. −22°07′	**15.02.** −12°43′	**24.03.** 1°22′	**30.04.** 14°44′	**06.06.** 22°38′	**13.07.** 21°51′	**19.08.** 12°49′	**25.09.** 0°48′	**01.11.** −14°23′	**08.12.** −22°42′
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13.01. −21°30′	**19.02.** −11°20′	**28.03.** 2°56′	**04.05.** 15°56′	**10.06.** 23°00′	**17.07.** 21°13′	**23.08.** 11°29′	**29.09.** −2°22′	**05.11.** −15°38′	**12.12.** −23°04′
14.01. −21°20′	**20.02.** −10°58′	**29.03.** 3°19′	**05.05.** 16°13′	**11.06.** 23°04′	**18.07.** 21°03′	**24.08.** 11°09′	**30.09.** −2°45′	**06.11.** −15°56′	**13.12.** −23°08′
15.01. −21°09′	**21.02.** −10°37′	**30.03.** 3°43′	**06.05.** 16°30′	**12.06.** 23°09′	**19.07.** 20°52′	**25.08.** 10°48′	**01.10.** −3°08′	**07.11.** −16°14′	**14.12.** −23°12′
16.01. −20°58′	**22.02.** −10°15′	**31.03.** 4°06′	**07.05.** 16°47′	**13.06.** 23°12′	**20.07.** 20°41′	**26.08.** 10°27′	**02.10.** −3°31′	**08.11.** −16°32′	**15.12.** −23°16′
17.01. −20°46′	**23.02.** −9°53′	**01.04.** 4°29′	**08.05.** 17°03′	**14.06.** 23°15′	**21.07.** 20°30′	**27.08.** 10°07′	**03.10.** −3°55′	**09.11.** −16°49′	**16.12.** −23°19′
18.01. −20°34′	**24.02.** −9°31′	**02.04.** 4°52′	**09.05.** 17°19′	**15.06.** 23°18′	**22.07.** 20°18′	**28.08.** 9°45′	**04.10.** −4°18′	**10.11.** −17°06′	**17.12.** −23°21′
19.01. −20°22′	**25.02.** −9°09′	**03.04.** 5°15′	**10.05.** 17°35′	**16.06.** 23°21′	**23.07.** 20°06′	**29.08.** 9°24′	**05.10.** −4°41′	**11.11.** −17°23′	**18.12.** −23°23′
20.01. −20°22′	**26.02.** −8°46′	**04.04.** 5°38′	**11.05.** 17°51′	**17.06.** 23°23′	**24.07.** 19°54′	**30.08.** 9°03′	**06.10.** −5°04′	**12.11.** −17°39′	**19.12.** −23°25′
21.01. −19°56′	**27.02.** −8°24′	**05.04.** 6°01′	**12.05.** 18°06′	**18.06.** 23°24′	**25.07.** 19°41′	**31.08.** 8°41′	**07.10.** −5°27′	**13.11.** −17°56′	**20.12.** −23°26′
22.01. −19°42′	**28.02.** −8°01′	**06.04.** 6°24′	**13.05.** 18°21′	**19.06.** 23°25′	**26.07.** 19°28′	**01.09.** 8°20′	**08.10.** −5°50′	**14.11.** −18°11′	**21.12.** −23°26′
23.01. −19°29′	**01.03.** −7°38′	**07.04.** 6°47′	**14.05.** 18°36′	**20.06.** 23°26′	**27.07.** 19°14′	**02.09.** 7°58′	**09.10.** −6°13′	**15.11.** −18°27′	**22.12.** −23°27′
24.01. −19°14′	**02.03.** −7°15′	**08.04.** 7°09′	**15.05.** 18°50′	**21.06.** 23°26′	**28.07.** 19°01′	**03.09.** 7°36′	**10.10.** −6°36′	**16.11.** −18°42′	**23.12.** −23°26′
25.01. −19°00′	**03.03.** −6°53′	**09.04.** 7°32′	**16.05.** 19°04′	**22.06.** 23°26′	**29.07.** 18°47′	**04.09.** 7°14′	**11.10.** −6°58′	**17.11.** −18°57′	**24.12.** −23°25′
26.01. −18°45′	**04.03.** −6°29′	**10.04.** 7°54′	**17.05.** 19°18′	**23.06.** 23°26′	**30.07.** 18°32′	**05.09.** 6°52′	**12.10.** −7°21′	**18.11.** −19°12′	**25.12.** −23°24′
27.01. −18°30′	**05.03.** −6°06′	**11.04.** 8°16′	**18.05.** 19°31′	**24.06.** 23°25′	**31.07.** 18°18′	**06.09.** 6°29′	**13.10.** −7°43′	**19.11.** −19°26′	**26.12.** −23°22′
28.01. −18°14′	**06.03.** −5°43′	**12.04.** 8°38′	**19.05.** 19°44′	**25.06.** 23°24′	**01.08.** 18°03′	**07.09.** 6°07′	**14.10.** −8°06′	**20.11.** −19°40′	**27.12.** −23°20′
29.01. −17°58′	**07.03.** −5°20′	**13.04.** 9°00′	**20.05.** 19°57′	**26.06.** 23°22′	**02.08.** 17°48′	**08.09.** 5°44′	**15.10.** −8°28′	**21.11.** −19°53′	**28.12.** −23°18′
30.01. −17°42′	**08.03.** −4°56′	**14.04.** 9°22′	**21.05.** 20°09′	**27.06.** 23°20′	**03.08.** 17°32′	**09.09.** 5°22′	**16.10.** −8°50′	**22.11.** −20°06′	**29.12.** −23°14′
31.01. −17°25′	**09.03.** −4°33′	**15.04.** 9°43′	**22.05.** 20°21′	**28.06.** 23°17′	**04.08.** 17°16′	**10.09.** 4°59′	**17.10.** −9°12′	**23.11.** −20°19′	**30.12.** −23°11′
01.02. −17°08′	**10.03.** −4°10′	**16.04.** 10°04′	**23.05.** 20°33′	**29.06.** 23°14′	**05.08.** 17°00′	**11.09.** 4°36′	**18.10.** −9°34′	**24.11.** −20°31′	**31.12.** −23°07′
02.02. −16°51′	**11.03.** −3°46′	**17.04. 10°26′**	**24.05.** 20°44′	**30.06.** 23°11′	**06.08.** 16°44′	**12.09.** 4°14′	**19.10.** −9°56′	**25.11.** −20°43′	
03.02. −16°34′	**12.03.** −3°22′	**18.04.** 10°47′	**25.05.** 20°55′	**01.07.** 23°07′	**07.08.** 16°27′	**13.09.** 3°51′	**20.10.** −10°17′	**26.11.** −20°55′	
04.02. −16°16′	**13.03.** −2°59′	**19.04.** 11°08′	**26.05.** 21°06′	**02.07.** 23°03′	**08.08.** 16°11′	**14.09.** 3°28′	**21.10.** −10°39′	**27.11.** −21°06′	
05.02. −15°58′	**14.03.** −2°35′	**20.04.** 11°28′	**27.05.** 21°16′	**03.07.** 22°58′	**09.08.** 15°53′	**15.09.** 3°05′	**22.10.** −11°00′	**28.11.** −21°17′	
06.02. −15°40′	**15.03.** −2°11′	**21.04.** 11°49′	**28.05.** 21°26′	**04.07.** 22°53′	**10.08.** 15°36′	**16.09.** 2°42′	**23.10.** −11°21′	**29.11.** −21°27′	

These are average values, valid for 12:00 noon true local time. They vary very slightly from year to year due to the fact that the Earth takes 365 and a quarter days to circle the Sun, which is also the reason for leap years. Negative values mean that the Sun is below the celestial equator.