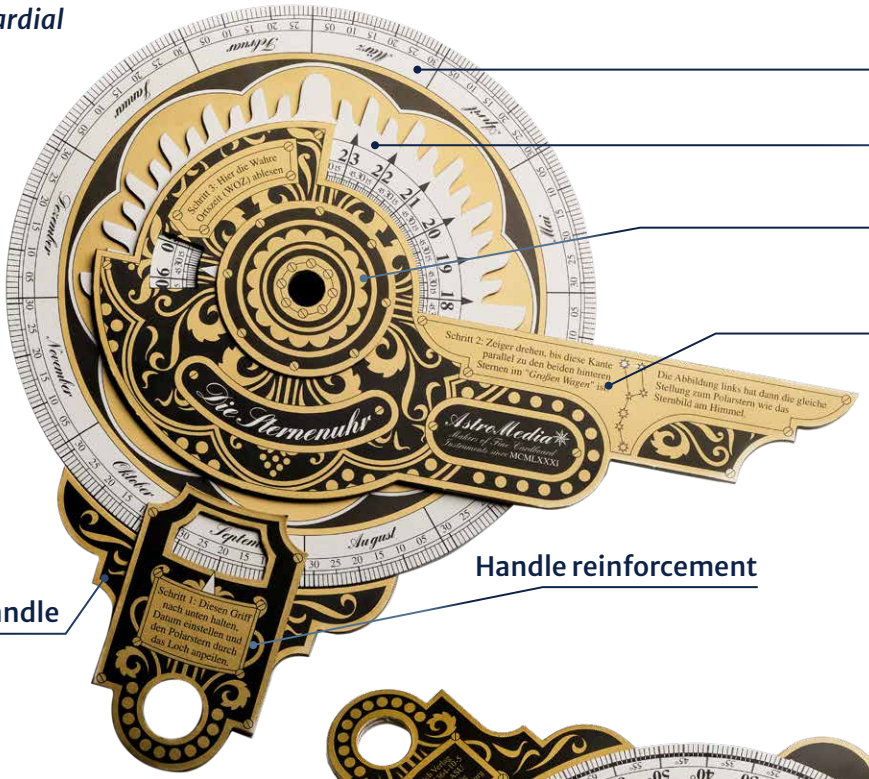
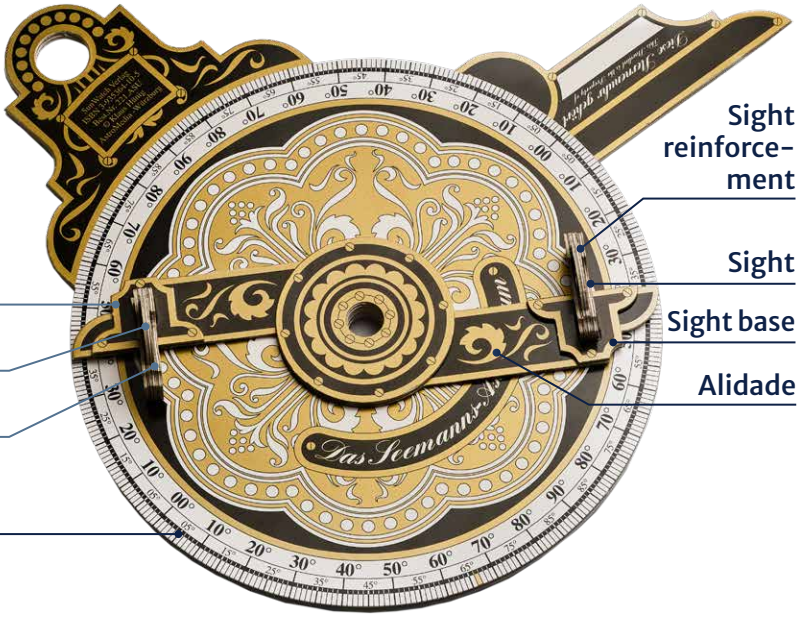
Instructions

The Stardial
and the Sailor's Astrolabe

Front:
Stardial



Reverse:
Sailor's Astrolabe



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Hands-on Science Series

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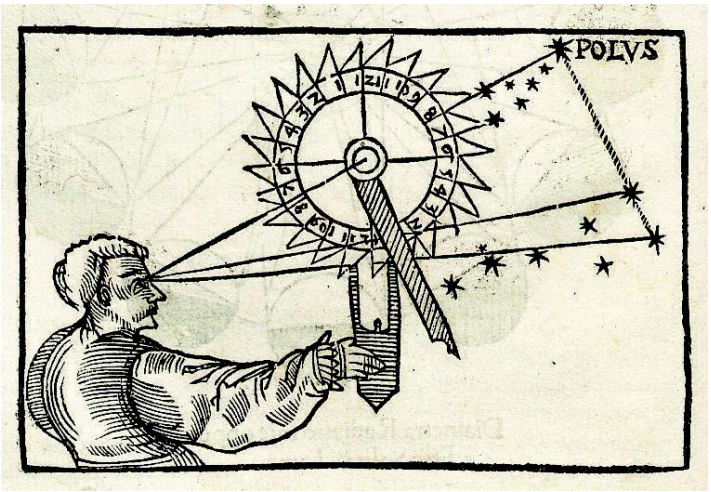
The Stardial

The Stardial and the Sailor's Astrolabe

People who worked at night, such as shepherds or hunters, have always been able to tell the time by the stars. Towards the end of the Middle Ages, resourceful astronomers and instrument makers invented the Stardial, also known as the nocturnal or nocturlabe. It was first mentioned in 1295 and was meant for the uninformed city dweller or the soldier on night watch. This clever device makes use of the fact that the constellation of the Plough / Big Dipper orbits the North Star once in 23 hours and 56 minutes, as if it were the hand on a giant clock. Because of the difference of 4 minutes compared to a whole day, the stardial needs to be set to the current date before reading. Then it shows the true local time with astonishing accuracy. You can find out how to do this at the end of these instructions.

Ancient instrument makers often combined the stardial with a second device attached to the back, such as a sundial or, as in this version, an astrolabe. The mariner's astrolabe was usually made of heavy brass to prevent it from swaying in the wind and allowed for simple measurements of the elevation angles of the Sun and stars. These measurements could then be used to draw conclusions about the current position at sea.

In the 17th century, this instrument was widespread. It was standard equipment on all ships of the Dutch East India Company, for example. Despite this, only a few examples of stardials and astrolabes have survived to this day, which is why they are nowadays found among the precious treasures of museums.



This kit contains:

- 2 die-cut cardboard sheets, 0.4 mm thick, printed
- 2 die-cut cardboard sheets, 1 mm thick, unprinted

Please read before you start:

Tips for successful assembly

1

The assembly is not difficult because all pieces are precisely pre-punched. You'll need a sharp knife to cleanly remove the parts from the cardboard, perhaps some fine sandpaper, and a good all-purpose glue. Solvent-based all-purpose glue is better than solvent-free water-based glue, as it does not warp the cardboard.

2

Each part is labeled with a part number (**[A1]**, **[A2]**, **[B1]**, **[B2]**, etc.) and its name. The letter designates the assembly section, the number the sequence within the section. Only remove the parts from the cardboard sheet that you currently need, or write the part number on the back. For each part with a part number made of thin printed cardboard, there is a corresponding part with an identical contour made of thick unprinted cardboard. These parts are referred to as "counterparts" in the assembly instructions. A few parts made of thick cardboard are not required, they are only punched out for technical reasons.

The Stardial

Step 1

Remove the date disc **[A1]** from the printed cardboard sheet and remove the axle **[A2]** from the centre. Remove and discard the small round disc in the centre of the axle to create a hole.

Step 2

Remove the white counterpart of the date disc from the thick cardboard, remove the axle from the centre, and also open the hole in the axle. Now glue the date disc **[A1]** and the axle **[A2]** onto their white counterparts. Make sure the outer edges and the holes line up exactly. Then label both parts on the back with their part numbers **[A1]** and **[A2]**.

Step 3

Carefully remove the hour disc **[B1]** from the cardboard, taking care not to damage the prongs on the edge. Remove the axle **[B2]** as in Step 1 and open the hole in the centre.

Step 4

Remove the white counterparts from the thick cardboard sheet, then glue the hour disc **[B1]** and the axle **[B2]** exactly flush onto their counterparts and write the component number on the axle **[B2]**.

Step 5

Glue the serrated hour disc **[B1]** onto the date disc **[A1]**. Make sure that the prongs line up exactly with the white prongs on the glue area and that the holes in the centre of the two parts are exactly flush. When correctly aligned, the straight edge of the extended 18h prong points to the 5th June.

Step 6

Remove the punched cardboard part from the reading window of the star pointer **[C1]**, as well as the axle **[C2]** in its centre and open the hole in it. Glue the star pointer **[C1]** and the axle **[C2]** onto their thick cardboard counterparts. Write the component numbers on the backs.

Step 7

Glue the star pointer reinforcement **[C3]** onto the back of the star pointer. The counterpart made of thick white cardboard is not needed. Make sure that the edges at the end and sides of the pointer line up exactly.

Step 8

Remove the cover plate **[D1]** from the cardboard sheet and discard the small piece of cardboard from its centre. Glue it onto its counterpart made of thick cardboard and write the component number on the back.

Step 9

Remove the handle reinforcement **[E1]** from the cardboard and open the hole for the hanger. Glue the handle reinforcement onto its counterpart made of thick cardboard and write the component number on the back.

Step 10

Remove the handle **[E2]** from the cardboard, open the hole for the hanger and the window for reading the date. Glue the handle onto its counterpart made of thick cardboard. Write the part number on the back.

The Astrolabe

Step 11

Remove the astrolabe disc **[F1]** and the axle **[F2]** from the cardboard, open the hole in the axle, and glue both parts onto their counterparts made of thick cardboard. Write the component numbers on the back.

Step 12

Glue the handle reinforcement **[E1]** with its back to the back of the astrolabe disc **[F1]** so that the edges and the hole of the handle reinforcement are flush with the edges and the hole in the astrolabe disc.

Step 13

Remove the alidade **[G1]** and the axle **[G2]** from the cardboard. Remove the cardboard from the two rectangular cut-outs in the alidade and from the small hole in the axle. Glue the alidade **[G1]** and the axle **[G2]** onto their counterparts made of thick cardboard and write the component numbers on the back.

Step 14

Remove the two sight bases **[H1]** and **[H2]** from the cardboard, remove the cardboard from the rectangular cut-outs and glue both parts onto their counterparts made of thick cardboard.

Step 15

Glue the sight bases **[H1]** and **[H2]** to both ends of the alidade so that the rectangular cut-out and the curved edge at the top left line up exactly with the cut-out and curved edge of the alidade.

Step 16

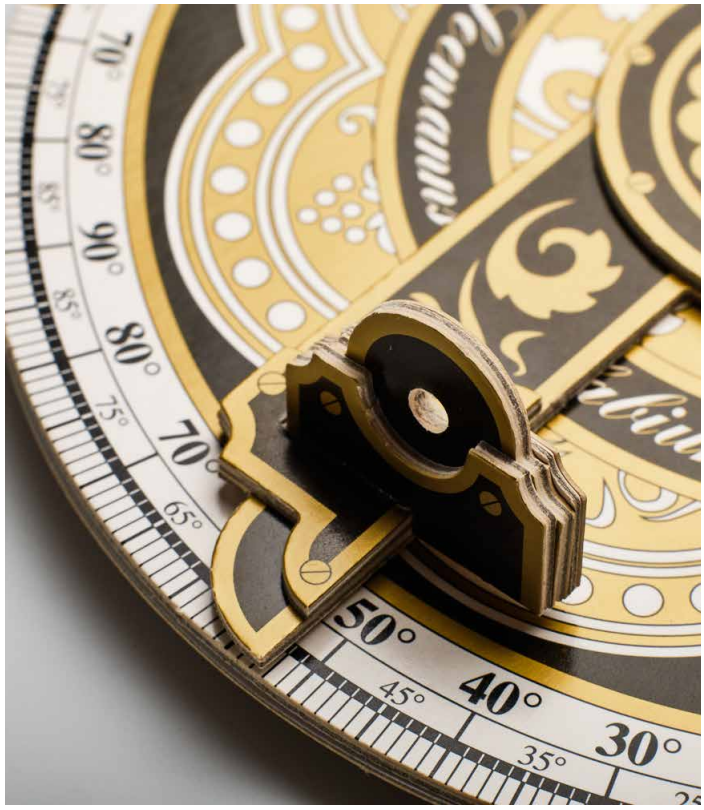
Remove the two sight parts **[J1]** and **[J2]** from the cardboard and open the small hole. Remove one of the two counterparts from the thick cardboard and glue the sight parts onto both sides. Make sure that the cut-outs at the bottom edge line up exactly. The other counterpart is not needed.

Step 17

Remove the sight reinforcements **[J3]** and **[J4]** from the cardboard and glue them onto their counterparts made of thick cardboard. Then glue one of the two sight reinforcements onto each side of the sight **[J1/J2]**. Make sure that the cut-outs at the bottom edges of the three parts are completely flush.

Step 18

Proceed with the other two sight halves **[J5]** and **[J6]** as in Step 16. The counterpart is not required here either.



Step 19

Proceed with the two sight reinforcements **[J7]** and **[J8]** as in Step 17 and glue them to both sides of the sight **[J5/J6]**.

Step 20

Remove the cover plate **[L3]** from the cardboard and open the hole in the centre. Glue it onto its counterpart made of thick cardboard and write the component number on the back.

Assembling the stardial and astrolabe

Step 21

Glue all five axles **[A2]**, **[B2]**, **[C2]**, **[F2]**, and **[G2]** together to form a cylindrical axle block. Then remove the axle **[K2]**, which is located inside the sliding disc **[K1]**, from the thin cardboard and glue it onto the block as well. The counterpart made of thick cardboard is not needed. Make sure that the outer edges and holes of all discs are exactly aligned. Check that the axle block can be inserted into the star pointer, date disc, astrolabe disc, and alidade and that it can be rotated. If necessary, carefully sand down any protruding edges with sandpaper. The axle block is now exactly the height of all the parts that are to rotate around it.

Step 22

Glue the axle block onto the unprinted side of the cover plate **[D1]** and make sure that the holes in the middle are exactly aligned.

Step 23

Place the axle block with the cover plate facing down on your work surface and, without using any glue, slide all the parts you have prepared so far onto the axle block in this order:

a) Star pointer **[C1]**: printed side down, glued-on reinforcement facing up

b) Sliding disc **[K1]**: only the thin cardboard disc, printed side down. The thick counterpart is not needed

c) Date disc **[A1]**: glued hour disc side down, white side facing up

d) Astrolabe disc **[F1]**: glued-on handle reinforcement side down, printed astrolabe disc facing up

e) Alidade **[G1]**: white side down, glued-on sight feet facing up

Step 24

When all parts are pushed tightly together, the end of the axle block should be flush with the surface of the alidade. Check that all parts can be rotated independently of each other around the axle. A slight stiffness will disappear with use. If necessary, the axle or axle hole of a part can be carefully adjusted with sandpaper.

Step 25

Glue the cover plate **[L3]** onto the axle block where it protrudes from the alidade. Be careful not to get any adhesive between the cover plate and the alidade or between the alidade and the axle.

Step 26

Turn the astrolabe over so that the stardial is facing upwards. Glue the handle **[E2]** onto the white glue area of the handle reinforcement so that the curved edges and the hole for hanging are exactly aligned. The handle will then extend over the date disc and the date will appear in its reading window.

Step 27

Turn the stardial over again so that the astrolabe is facing upwards. Glue one of the reinforced sights to each end of the alidade so that the bevelled peg on the underside fits into the rectangular cut-out of the alidade. The hole in the sight will then be directly above the reading edge of the alidade.

Five simple steps to tell the time from the stars at night:

1

Turn the date disc until the current date is above the arrow mark in the reading window on the handle.

2

Find the constellation of the Plough/Big Dipper and the North Star. You will find the North Star by extending the distance between the two stars of the plough blade opposite the handle (the two white stars in the illustration on the star pointer) 5½ times in the direction of the wider part of the blade (on the stardial, this corresponds to the direction of the axis).

3

Hold the stardial by the handle so that the handle points vertically downwards, and with your arm bent at a right angle, aim at the North Star through the hole in the axis.

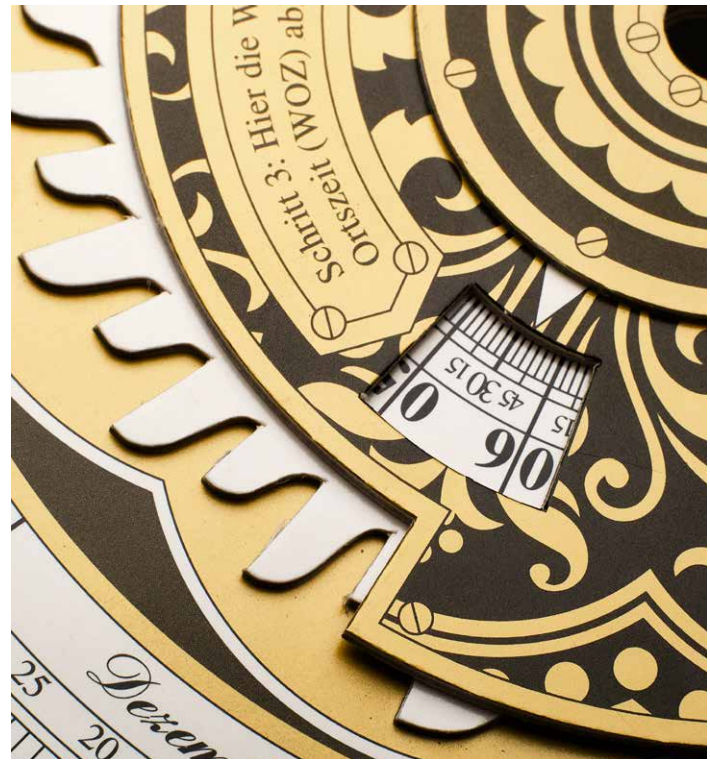
4

Turn the star pointer until its straight edge is parallel to the two stars of the Plough opposite the handle. The Plough on the stardial now has the same angle as the one in the sky.

5

You can now read off the true local time in the reading window of the star pointer. As with old stardials, whose users rarely had access to a light source at night, you can also read the time by touch, using the long and short points on the hour disc. The slightly longer points represent the full hours, the shorter ones half hours of the time shown below the point. Therefore, the point whose time currently appears in the reading window of the stardial is the one to use, and the outer edge of the stardial just reveals the correct point. To make reading off the time easier, the points for 6 p.m., 12 a.m., and 6 a.m. are longer and wider than those for the other full hours. You can therefore start by feeling the 6 p.m. or 12 a.m. point and then count the hours that have passed since 6 p.m. or 12 a.m. on the exposed points.

Note: *The stardial does not show civil time, e.g. Greenwich Mean Time (GMT) or Central European Time (CET) or Summer Time (BST/CEST). Instead it shows Mean Solar Time, which is determined by the course of the Sun. According to solar time, it is 12 noon when the Sun is exactly in the south and midnight when it has reached its lowest point below the horizon. This occurs earlier in places further east and later in places further west, even if the people in these places live in the same time zone. For example, in Warsaw the Sun stands 1 hour and 16 minutes earlier due south than in Barcelona, even though both places are in the Central European Timezone. A detailed explanation of the differences between Solar Time and Zone Time – as well as instructions on how to calculate Solar Time – can be found in the PDF file entitled "Explanation of Time Terms" on our website under the "Instructions" tab in the article "The Stardial."*



Four simple steps to measure solar and celestial altitudes with the mariner's astrolabe:

1 In order for the astrolabe to measure elevation angles, it must be suspended vertically by a string threaded through the hole in the handle. To do this, you must first balance the asymmetrically shaped star pointer by aligning its reading edge with the small golden mark located at the bottom left of the astrolabe scale between 66° and 67°. You can check whether the astrolabe is really hanging vertically by holding a simple plumb line, consisting of a piece of thread and a small weight, in front of the suspended astrolabe. The thread must run across both 90° marks and the centre of the axle.

2 To measure the angle between the horizontal and the top of a mountain or building, or a star, hold the astrolabe by the cord at eye level and move the alidade until you can see the target through both sighting holes at the same time.

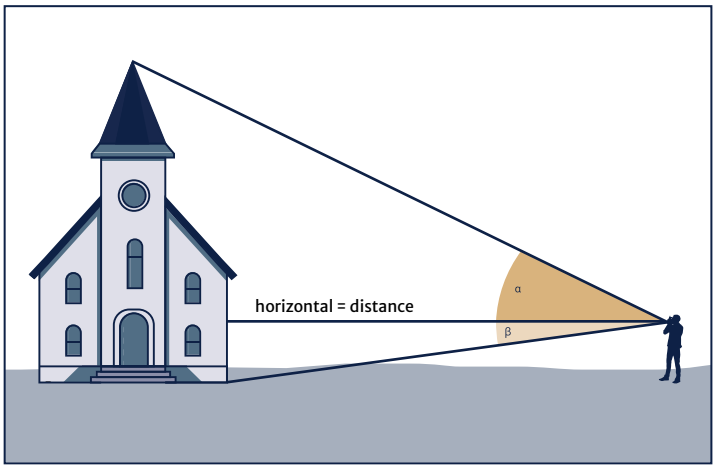
3 To measure the height of the Sun, let the astrolabe hang lower and adjust the alidade until sunlight passes through both holes at the same time, e.g. onto the palm of your hand held behind it. ***Important: Never look directly at the Sun, as this can cause permanent damage to your eyes!***

4 Read off the angle on the scale at the ends of the alidade.

Some examples of what you can find out with a measured elevation angle:

1 If you know the distance to a building and the angle between the horizontal and the line of sight to the top of the building, you can find out the height of the building by calculation or through a drawing.

2 If you measure the altitude of the North Star, you can find out your geographical latitude, because they are closely related. Their difference depends on the date. At the time of an equinox they are equal, at the time of summer or winter solstice they differ by plus or minus 11.75 degrees. This measurement was of utmost importance to sailors in the past.



3 When the Sun is at its highest point, it is true noon. In the past, this measurement was used not only to adjust the hourglasses on board a ship, but also to determine the geographical latitude (similar to using the North Star): one simply had to look up the angular distance between the Sun and the celestial equator on that day in a table and from this you could easily determine the geographical latitude. These measurements were perfected with the invention of the mirror sextant a few hundred years later.

4 A more detailed description of how to navigate using the Sun's altitude at noon can be found on our website in the PDF with the construction instructions for the article 'The Sextant' on pages 7 and 8.

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