Your Sextant Is Right.
Your Position Is 9 Miles Off.

The sextant: from the arc to the triangle

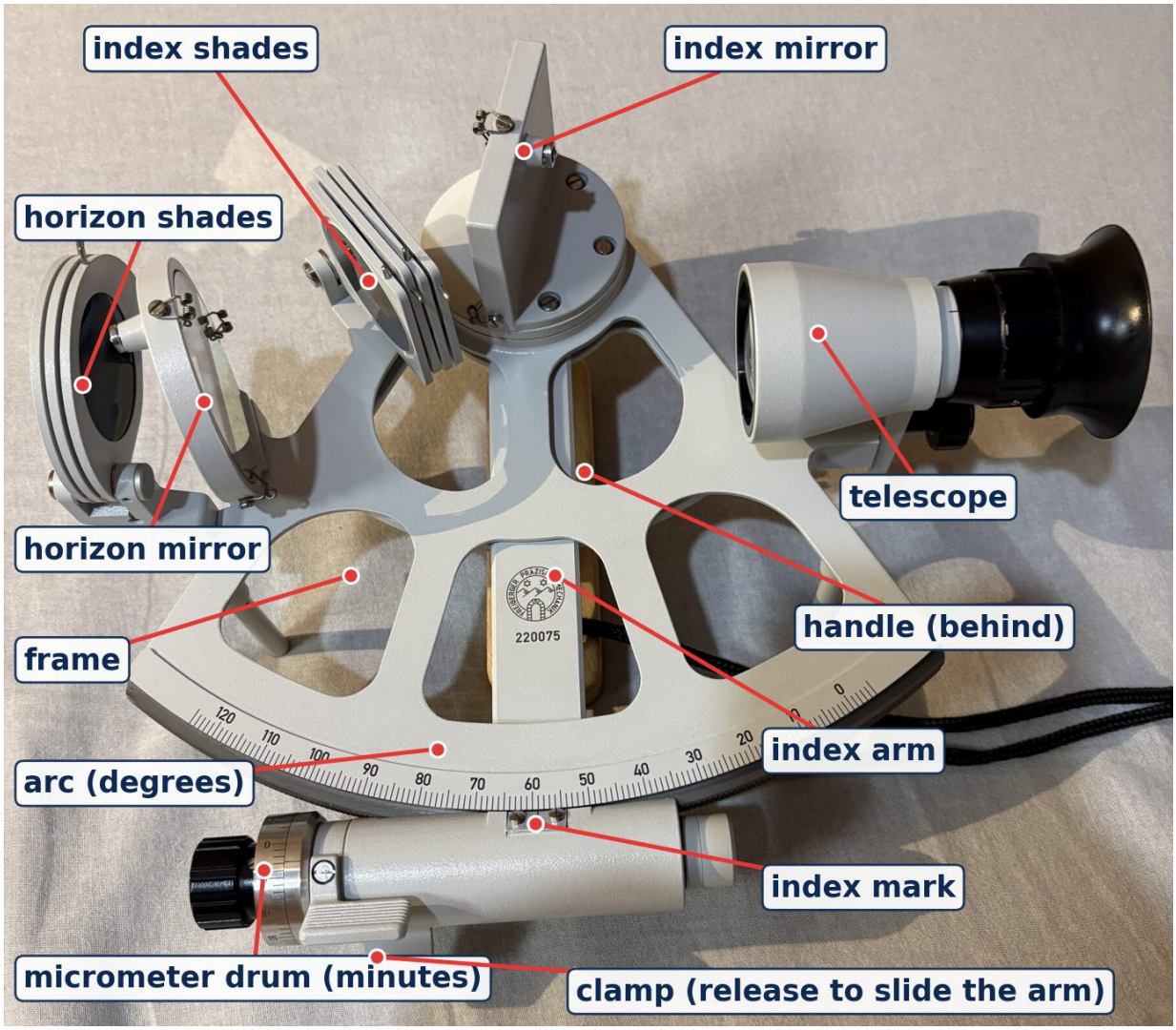
The sextant reads 35°24.0′. The triangle from Episode 6 needs 35°33.4′. This is the companion to Episode 7 — the parts of the sextant, why two mirrors double the angle (with the proof), how to take and read a sight, the five corrections in order, a dip table, and the worked example from the film.

Never look at the Sun through a sextant without the shades.

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1. The parts of the sextant



A drum sextant, seen from the side you look at when you read it. The telescope looks at the horizon mirror; the index arm swings along the arc and carries the index mirror at its pivot.

The frame and the arc. The arc is one sixth of a circle — the sextant's name — and is engraved in whole degrees, from a little below 0° ("off the arc") to about 120°.

The index arm pivots at the top of the frame and sweeps along the arc. At its foot is the **index mark**, which shows the whole degrees, and the **micrometer drum**, which shows the minutes. Squeeze the **clamp** to slide the arm quickly; let go and the drum turns it finely.

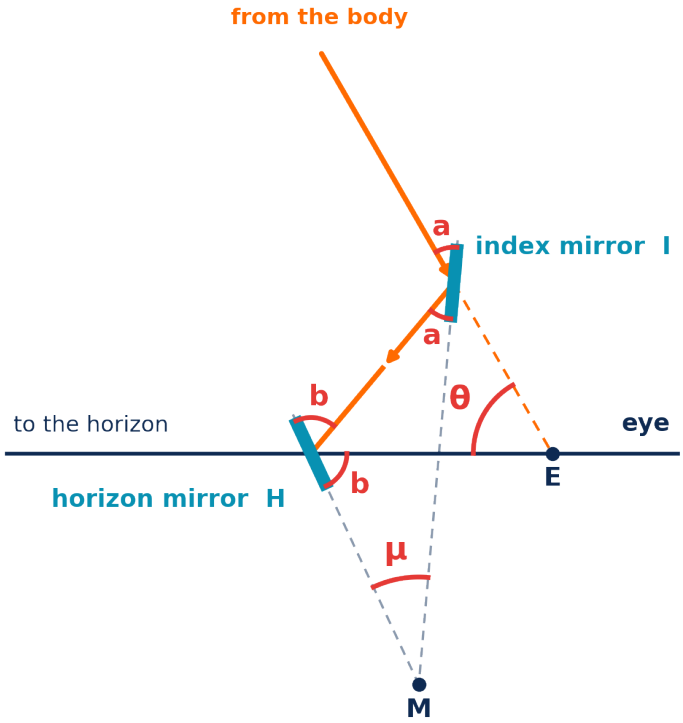
The index mirror sits on the arm, at the pivot, and turns with it.

The horizon mirror is fixed to the frame. On a traditional sextant one half is clear glass, through which you see the horizon directly, and the other half is silvered, showing the reflection from the index mirror. A "whole-horizon" mirror does both across its full width with a partly silvered coating.

The shades are coloured filters: the **index shades** between the two mirrors dim the body, the **horizon shades** dim the glare on the sea. The **telescope** brings both images to your eye.

2. Two mirrors, double the angle

Light from the body reaches the index mirror, bounces to the horizon mirror and from there into the telescope — next to the horizon seen directly. When the reflected body sits on the horizon, the sextant reads the angle between them: the altitude.



Drawn to scale for an altitude $\theta = 60°$: the mirrors are $\mu = 30°$ apart. I and H: index and horizon mirror. E: where the ray from the body, produced beyond I, crosses your line of sight. M: where the two mirror planes meet.

The law of reflection. A ray leaves a mirror at the same angle to its surface as it arrived. Call that angle a at the index mirror and b at the horizon mirror.

One fact from school geometry. The exterior angle of a triangle equals the sum of the two interior angles opposite it.

Triangle I H E. At I the ray turns away from its old line (I to E) by $2a$; at H it turns back by $2b$. The exterior angle at H, between the ray arriving from I and your line of sight, is $2b$:

$$2b = 2a + \theta.$$

Triangle I H M. The sides are the ray from I to H and the two mirror planes. The exterior angle at H is the glancing angle b:

$$b = a + \mu.$$

So $\theta = 2(b-a)$ and $\mu = b-a$:

$$\boxed{\theta = 2\mu}$$ the angle measured is twice the angle between the mirrors.

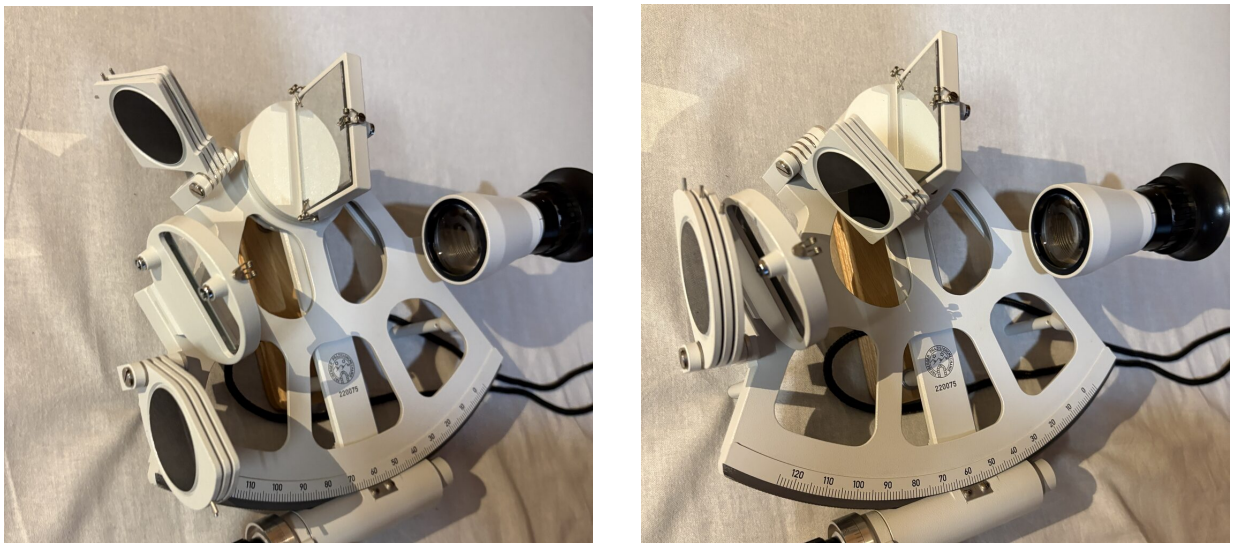
Nothing in the proof depends on how the sextant is held in its own plane. Roll, pitch or a shaking hand turn both mirrors together: μ stays the same, so the body stays on the horizon in the eyepiece. That is why the instrument works on a moving deck.

Why a sixth of a circle measures a third of one. At 0° the two mirrors are parallel, $\mu = 0$. The index mirror sits on the arm, so when the arm turns by an angle α the mirror turns by α too, and $\mu = \alpha$. The altitude is then $\theta = 2\alpha$. That is why the arc is engraved with double values: one degree of real arc is marked as two. A real arc of 60° — one sixth of a circle — reads up to 120°, one third of a circle.

3. Safety first: the Sun

Never look at the Sun through a sextant without the shades. The telescope gathers the light; damage to the eye is painless, instant and permanent.

- Swing the index shades in *before* you point the sextant anywhere near the Sun. Start with the darkest and lighten one at a time only if the image is too faint.
- Use horizon shades as well when the sea is bright with glare.
- Do not sweep the telescope across the sky with the shades out: the Sun can enter the mirrors on the way.
- A phone or camera held to the eyepiece needs the same shades.
- A cracked or loose shade is a missing shade. Check them before the sight.



Left: shades swung out, for stars and the horizon. Right: index shades swung in, in front of the index mirror, and the horizon shades in front of the horizon mirror — the way to start any Sun sight.

4. Taking a sight

Bringing the body down. With the Sun: shades in, arm at zero, look at the Sun, then move the arm forward slowly while you tilt the sextant down, bringing the Sun's reflection with you, until it sits on the horizon. With a star: set the arm to the altitude you expect, look at the horizon below the star, and the star will be waiting in the mirror. Or hold the sextant upside down, look at the star through the clear glass and move the arm until the horizon comes up to meet it; then turn the sextant the right way up and finish as usual.

Rocking the sextant. A tilted sextant measures too large an angle. Swing it gently left and right about the line of sight: the body traces a small arc, like a pendulum. At the bottom of that arc the sextant is vertical

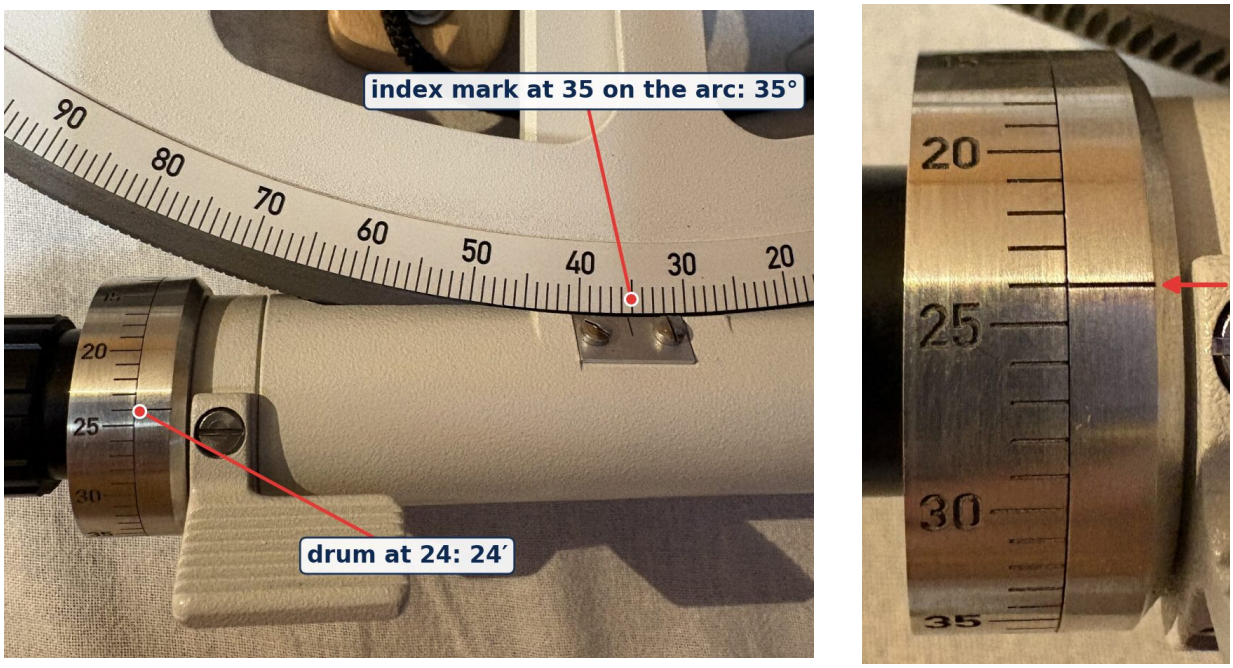
— that is where the body must just touch the horizon. With the Sun, the lower edge (lower limb) touches.

The mark. At the moment of contact call "mark" and note the time, to the second. The Earth turns $15'$ of arc in one minute of time, so

$$4\text{ s} = 1' \text{ of longitude} \qquad (= 1 \text{ NM at the equator}).$$

5. Reading the sextant

Whole degrees on the arc, at the index mark. Minutes on the micrometer drum. Tenths of a minute from the drum as well — on the vernier, if your sextant has one, or by eye.



The sight from the film, set on a real sextant. Left: the index mark at 35 on the arc, the drum at 24. Right: the drum close up — the index line on the fixed ring (arrow) is exactly on the 24 mark. Reading: 35° and 24.0′.

$\boxed{\text{Hs} = 35°24.0'}$ the sextant altitude

No vernier? Estimate the tenths between the drum marks. The sextant in these photos has no vernier. Its drum is marked every $1'$, and the tenths are judged by eye: where between two marks does the index line sit? Exactly on a mark is .0, half way is .5, a third of the way about .3. With practice you are good to a couple of tenths — finer than a rolling deck usually lets you measure anyway.

Many sextants have a small **vernier** beside the drum instead (the one in the film does): a short scale of ten divisions. The vernier line that lines up exactly with a drum mark gives the tenth.

6. Five corrections, in order

The sextant altitude Hs is not yet the altitude in the triangle. Five corrections turn it into the **observed altitude** Ho, always in this order:

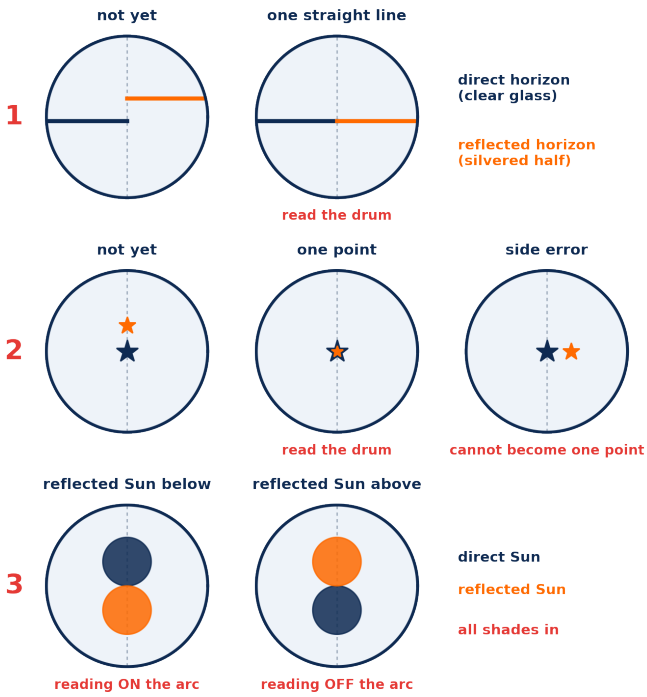
	whose error	sign	the example
IE	the instrument: index error	on the arc −, off the arc +	−2.0′
dip	you: the height of your eye	always −	−3.5′
= *apparent altitude Ha*			35°18.5′
SD	the body: semi-diameter	lower limb +, upper limb −, stars 0	+16.2′
R	the air: refraction	always −	−1.4′
PA	the triangle: parallax	always +	+0.1′
= *observed altitude Ho*			35°33.4′

1. Index error (IE). If the two mirrors are not exactly parallel at zero, every reading is out by the same small amount: the index error. Find it before every round of sights — one of the three ways below — and apply it with the right sign:

On the arc (the zero point is above zero): subtract. **Off the arc** (below zero): add.

If it's on, take it off; if it's off, put it on.

Reading off the arc. Below zero the drum counts backwards: the index mark is just below the 0 on the arc, and the drum shows 60 minus the error. Read the drum and take it from 60: a drum at 57.5′ means 60′ − 57.5′ = 2.5′ off the arc. On a drum marked every 1′, like the one in the photos, 57.5′ is the index line half way between the 57 and 58 marks.



What the telescope shows. Navy: the direct image, through the clear glass. Orange: the reflected image, from the index mirror.

Method 1 — on the horizon. Use it by day, with a sharp horizon.

1. Set the arm at 0° and the drum near 0.
2. Hold the sextant vertical and look at the horizon.
3. Turn the drum until the direct and the reflected horizon make one straight line (row 1).
4. Read: on the arc (for example 2.0′, the example in this PDF) subtract; off the arc (drum 57.5′ ⇒ 2.5′) add.
5. Do it two or three times, coming from above and from below, and take the mean.

Method 2 — on a star. More precise at night, when the horizon is poor.

1. Arm at 0°, drum near 0; look at a bright star.
2. Turn the drum until the reflected star sits exactly on the direct one: one point (row 2). Read and apply as on the horizon.
3. *Side error.* The drum moves the reflected star only up and down. If it passes beside the direct star instead of through it (row 2, right), the horizon mirror is not square to the frame: side error. It is removed by adjustment, not arithmetic — see *Adjusting the sextant* below.

Method 3 — on the Sun, two discs. The most precise, and it checks itself.

All shades in, index and horizon, before you point the sextant at the Sun. You are looking straight at it.

Before you start: look up the Sun's semi-diameter for the day in the nautical tables (for 28 November 2026: 16.2′). You need it to check the measurement.

1. Arm at 0°; look at the Sun. You see two discs, direct and reflected.
2. Turn the drum until the reflected Sun sits just **below** the direct one, the two edges touching (row 3, left). Read: this is **on** the arc.
3. Turn the drum back past zero until the reflected Sun sits just **above**, edges touching (row 3, right). Read: **off** the arc, as 60 minus the drum.
4. Index correction and check:

$$\boxed{\text{IC} = \frac{\text{off} - \text{on}}{2}} \qquad \boxed{\frac{\text{on} + \text{off}}{4} = \text{SD of the Sun}}$$

   IC is the correction itself: negative means the error is on the arc (subtract), positive off the arc (add).
5. If $(\text{on} + \text{off})/4$ differs from the day's semi-diameter by more than about 0.2′, repeat the measurement.

Example. On the arc: arm at 0, drum 34.4′ (the line four tenths of the way from 34 to 35). Off the arc: drum 29.6′, so off $= 60' - 29.6' = 30.4'$.

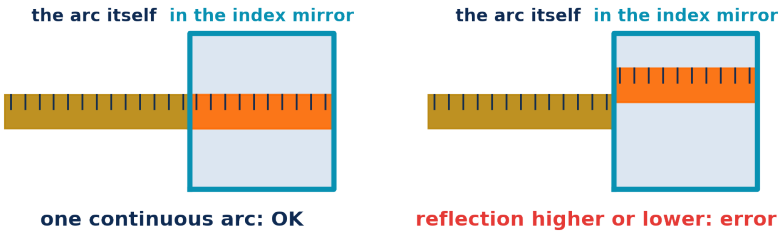
$$\text{IC} = \frac{30.4' - 34.4'}{2} = -2.0' \qquad \frac{34.4' + 30.4'}{4} = 16.2' = \text{SD} \checkmark$$

The index error is 2.0′ on the arc: subtract 2.0′ — the value used in the worked example.

Adjusting the sextant. Three adjustments, always in this order, because each one upsets the next. On most sextants the index mirror has one adjusting screw at the back and the horizon mirror has two.

(a) Perpendicularity: the index mirror square to the frame.

1. Set the index arm to about the middle of the arc.
2. Hold the sextant flat, arc away from you, and look into the index mirror obliquely, from beside it, so that you see the arc directly and its reflection in the mirror at the same time.
3. One continuous arc: the mirror is square to the frame. Reflection higher or lower than the arc itself: perpendicularity error.
4. Remove it with the adjusting screw at the back of the index mirror.

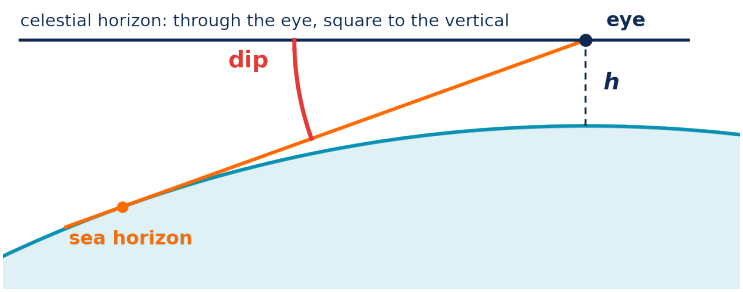


(b) Side error (also called tilting error): the horizon mirror square to the frame. Check it on a star (method 2 above, row 2 right) or on the horizon with the sextant held at about 45°: the direct and reflected images must not stand side by side. Remove it with the adjusting screw at the back of the horizon mirror, behind its clear (unsilvered) half — on most sextants the one *farther from* the frame.

(c) Index error: the two mirrors parallel at zero. Measure it as above, and if you remove it, use the horizon mirror's other adjusting screw — on most sextants the one *nearer to* the frame. A small index error, a few minutes, is usually not removed: it is simply applied as a correction, as in the worked example.

Adjustments (b) and (c) affect each other. Make them in turn, a little at a time, and repeat until both are gone; then measure the index error once more.

2. Dip. The celestial horizon is a plane through your eye, square to the vertical (Episode 5). Your eye is above the sea, so the sea horizon you actually see lies a little below that plane. Every altitude measured from the sea horizon is too large by that angle, the **dip**, so it is always subtracted. Taking off IE and dip gives the **apparent altitude** Ha.





Left: the dip, with the height of the eye greatly exaggerated. Right: from the deck of a tall ship the eye is some metres above the water — the higher you stand, the larger the dip.

Without the air, the dip would be $\sqrt{2h/R}$, or $1.93'\sqrt{h}$ with h in metres. The air bends the line of sight to the horizon slightly back down, and the value used in practice (it is the one in the nautical tables) is

$$\boxed{\text{dip} = 1.76'\sqrt{h}} \qquad h \text{ in metres} \qquad (0.97'\sqrt{h} \text{ with } h \text{ in feet}).$$

eye, m	ft	dip	eye, m	ft	dip
1.5	4.9	2.2′	8	26.2	5.0′
2	6.6	2.5′	10	32.8	5.6′
2.5	8.2	2.8′	12	39.4	6.1′
3	9.8	3.0′	15	49.2	6.8′
4	13.1	**3.5′**	20	65.6	7.9′
5	16.4	3.9′	25	82.0	8.8′
6	19.7	4.3′	30	98.4	9.6′

Height of eye above the sea, not above the deck. The example uses $h = 4$ m: dip 3.5′. A yacht's cockpit is typically 2–3 m.

3. Semi-diameter (SD). A star is a point; the Sun and the Moon are discs, and you put an edge on the horizon, not the centre. The triangle wants the centre: add the semi-diameter for the lower limb, subtract it for the upper. The Sun's semi-diameter changes over the year with its distance, from about 15.8′ in early July to 16.3′ in early January; the nautical tables give it for each day. At the end of November it is 16.2′.

4. Refraction (R). Light from the body bends as it comes down through the air, always the same way: the body looks higher than it is. Subtract.

apparent altitude	0°	5°	10°	15°	20°	30°	45°	60°	90°
refraction	34′	9.9′	5.4′	3.6′	2.7′	1.7′	1.0′	0.6′	0′

Mean refraction at 10°C and 1010 hPa. Right on the horizon it is more than half a degree — larger than the Sun's whole diameter, so when the Sun's disc touches the sea it is in fact already below the horizon.

It is largest near the horizon and shrinks fast as the body climbs. Low down it also depends on the temperature and pressure of the day, which is why navigators avoid bodies below about 10° (the nautical tables have a small extra correction for non-standard air). In the example, at 35°18.5′: −1.4′.

5. Parallax (PA). The tables give every body's position as seen from the centre of the Earth; you stand on its surface, some 6 400 km away from that centre. A nearby body therefore looks a little lower. Add. For the stars it is nothing, for the Sun 0.1′ at most, for the planets a few tenths, and for the Moon up to about a degree (61′ on the horizon) — which is why Moon sights have their own large correction table.

7. Worked example: nine miles

Hs sextant altitude, Sun, lower limb	$35°24.0'$	
IE, $2.0'$ on the arc	$-2.0'$	
dip, eye 4 m	$-3.5'$	
Ha apparent altitude	$35°18.5'$	
SD, end of November	$+16.2'$	$35°34.7'$
R, at $35°18.5'$	$-1.4'$	$35°33.3'$
PA	$+0.1'$	
Ho observed altitude	**35°33.4′**	

Ho − Hs = $+9.4'$. On the Earth one minute of arc is one nautical mile (Episode 5): put the sextant reading straight into the triangle, and the position is **9.4 nautical miles** out.

What the tables do. In practice you don't work out SD, R and PA one by one. The nautical publications have altitude correction tables — one for the Sun, one for stars and planets, a larger one for the Moon. You enter with the apparent altitude Ha and read a single number. For the example:

$$\mathrm{SD} + \mathrm{R} + \mathrm{PA} = +16.2' - 1.4' + 0.1' = +14.9'.$$

The printed Sun table uses one mean semi-diameter for each half of the year, so for a given day its number can differ from this by about $0.1'$. IE and dip are always yours to apply.

No correction is the same for every sight: each depends on the instrument, on you, on the body, on the air, or on how high the body stands.

Try it. If you have a sextant, check its index error on the horizon tonight and tell us in the comments how big it was. If you don't, tell us the height of your eye on your own boat — and what the dip is from there.

Every number in this document has been computed rather than copied: dip and refraction from the formulas used for the nautical tables ($1.76'\sqrt{h}$; $R = 0.0167°/\tan(H + 7.32/(H + 4.32))$), the Sun's semi-diameter and parallax from its distance on 28 November 2026. The proof of the double reflection has been checked numerically on the geometry of the figure. The photos show a real drum sextant. Educational material: it does not replace official nautical publications, charts or almanacs.

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