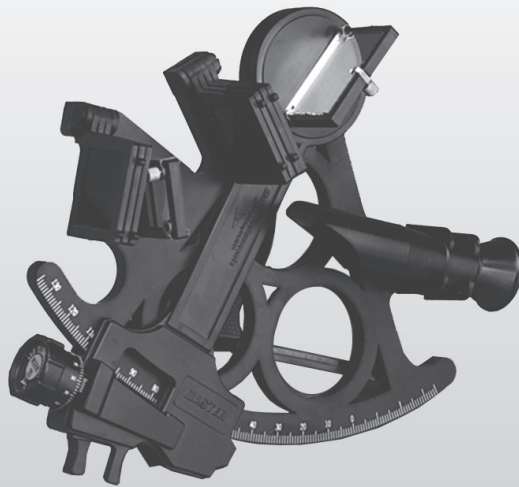

How To Use

Plastic Sextants

With Applications to Metal Sextants
and a Review of Sextant Piloting



DAVID BURCH

How To Use Plastic Sextants

With Applications to Metal Sextants and
a Review of Sextant Piloting



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Acknowledgements

Most of the basic matters of sextant use have been known for two hundred years. In fact, it has been known so long, that much of it has been forgotten. The best references on the use of sextants are usually the very old ones. In light of that, we have the Google Books project to thank for ready access to many of these classic texts. (The jury is still out on the implications of this service for modern books. All matters of reading, writing, and publishing are in a state of flux these days. We have to wait and see.)

With these known matters in hand, however, we still had to learn the practical application of these skills ourselves. And to this end, I have been very fortunate to work with the best navigators and navigation teachers one could hope for. Larry Brandt, Steve Miller, Robert Reader, and Hewitt Schlereth have all made important contributions to presentation included here.

Robert has helped shape our teaching materials and helped with analysis since the first edition of this work, 10 years ago. Hewitt has been an expert on plastic sextants for many years before we started on this project, and his recent data at sea referenced here is just more testimony to his skill. Steve Miller has also used plastic sextants in his teaching for many years, and I am especially grateful for his extensive work on mastering their use for lunar distance measurements. A few are included here. To our knowledge, Steve is the first person to adapt the Baader Solar Films to sextant telescopes. We are grateful to Bruce Stark for suggesting we extend our plastic sextant work to lunars. It was a crucial step to making other improvements in the procedures.

A special note of thanks goes to Larry Brandt. Beside his great skill as navigator and teacher are his great skills as writer and editor. His sharp eye for detail and clear expression has saved the reader many a puzzling moment.

And finally, I am once again pleased to thank Tobias Burch of Starpath Publications for his production of the book, including all of the graphics and design. There has not been a graphic we have made for any book that he has not improved conceptually in the process of rendering it. His editorial suggestions on the text are always beneficial.

Preface

This small book started out as an even smaller booklet on plastic sextants alone. It concentrated on the nuances of plastic sextants and procedures we can use to overcome their inherent limitations in accuracy. It became clear fairly quickly, however, that the methods we are forced to use in plastic sextants to obtain practicable results are the same methods we could use to enhance our accuracy with metal sextants. So after continually directing our readers and students of metal sextants to the “Plastic Sextants Book” for optimizing their sights, we simply expand the name of the book and carry on—now somewhat less incongruously.

The focus is still on plastic sextants, because they present the biggest challenges. If you master their use, you will be even better with a metal sextant in your hand. It will always be obvious how to adapt ideas and procedures described for plastic sextants to the use of metal ones.

To broaden the topic to all sextants, we have adopted parts of our celestial navigation text directly related to sextants and sight taking, and included them here as well. But this book is not intended to teach celestial navigation. We assume the reader is already knowledgeable in celestial navigation or in the process of learning it from other sources.

We have also fine-tuned some of our plastic sextant use recommendations from earlier writing with the intention of pressing their use to even higher standards. The results are encouraging.

For plastic or metal, we are concentrating on details. If you want to do your best, the answers are all in the details. On the other hand, if you want to get started right away, here are the key points: treat plastic sextants as if they cost more than metal sextants do, and handle them gently, during and after the sights. Skim through Part 1 and read the section in Part 2 on Taking Sights, then start taking sights. Be sure to record all aspects of your sight taking sessions. The more sights you take, the more you can appreciate the importance of the details. You will see your results improve as you incorporate them into your “standard procedures.”



Introduction to Sextants

1

Background

A sextant is a hand-held optical instrument used to measure angles between celestial bodies seen on the horizon or relative to the horizon. Its ingenuity lies primarily in its ability to measure these angles accurately, more or less independent of the motion of the person making the measurements. This is not a surprise, because it was invented for use at sea (in the mid 1700s), where the observer is moving about in the waves when sighting the stars. At sea or on land (with some form of artificial horizon) an observer can measure the angular heights of celestial bodies above the horizon to find their latitude and longitude on earth by means of *celestial navigation*. Measuring such an angle with a sextant is called “taking a sight.”

Sextants can also be used to measure angles between terrestrial bodies to find the observer’s position on a chart or map. This application is called *sextant piloting*. Explorers such as Lewis and Clark used both sextant applications in their famous expedition across the country, as did most of the early explorers on land and sea.

The forerunners of modern sextants were constructed of ebony wood with engraved ivory inlays for the dials. These were replaced with metal frames and gears. Measurement precision was enhanced by the invention of the vernier scale, which was then replaced in more modern times with a micrometer dial for easier reading.

Plastic sextants became available sometime around World War II for use in lifeboat navigation. Plastic instruments based on these early

models were available to the public by the early 1960s, notably from Davis Instruments in the US and from East Berks Boat Company in the UK.

There is much anecdotal information about plastic sextants in magazines and online discussions, but progress with use of the instruments will go faster with a ready access to documented results, and to that end we have added throughout the text examples with all the details, with even more data in the appendix.

“The devil is in the details” is an excellent description of the plastic sextant. Without appreciating the care that must be taken, one is more likely to try it, not get the results hoped for, and abandon it—or more likely, write something derogatory about it, then abandon it.

Plastic sextants are often disparaged for lack of inherent accuracy and vulnerability to the effects of the sun. But while it is true that they are not as accurate as metal sextants and they are indeed more sensitive to the sun than metal sextants are (thermal expansion coefficients of plastic are some 10 to 30 times higher than for metals), plastic sextants can with special care still be used quite successfully for practical navigation at sea, and they provide a less-expensive alternative for new navigators to get their feet wet with sights of their own.

In some regards, plastic sextants are easier to use than metal sextants for the actual sight taking because they are so light weight, but this ease of handling is counterbalanced by the extra care required in procedures and analysis. The task at

hand here is to explain the issues and then propose a way to compensate for these limitations by presenting a systematic method for taking sights with plastic sextants.

The question of thermal effects of the sun on the instrument when not in use should not be a real issue, since we have no reason to leave them for extended periods in the sun, just as we would not leave a thousand-dollar metal sextant in the sun. Whether or not they might thermally change during a particular sight session in the bright sun is not clear, though certainly possible. We have some data that might be explained by that, but it is not at all conclusive. We will address this issue in the section on sight taking procedures. There is also a related discussion in the Appendix.

Parts of a Sextant

To understand the limitations and issues at hand we need to look briefly at how sextants work. Figures 1-2 and 1-3 show two plastic sextants with a discussion of their parts. The Mark 15 is a micrometer drum sextant; the Mark 3 is called a vernier sextant as it has no micrometer drum.

Micrometer drum sextants have a series of notches cut precisely 1° apart into the outside

Sextant Parts in Fig 1-2 and 1-3	
A	Frame
B	Index arm
C	Index mirror
D	Index shades
E	Arc
F	Horizon mirror
G	Horizon shades
H	Telescope
J	Sighting tube
K	Clamp

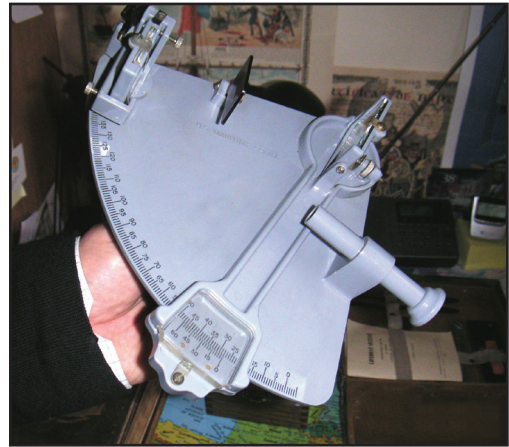
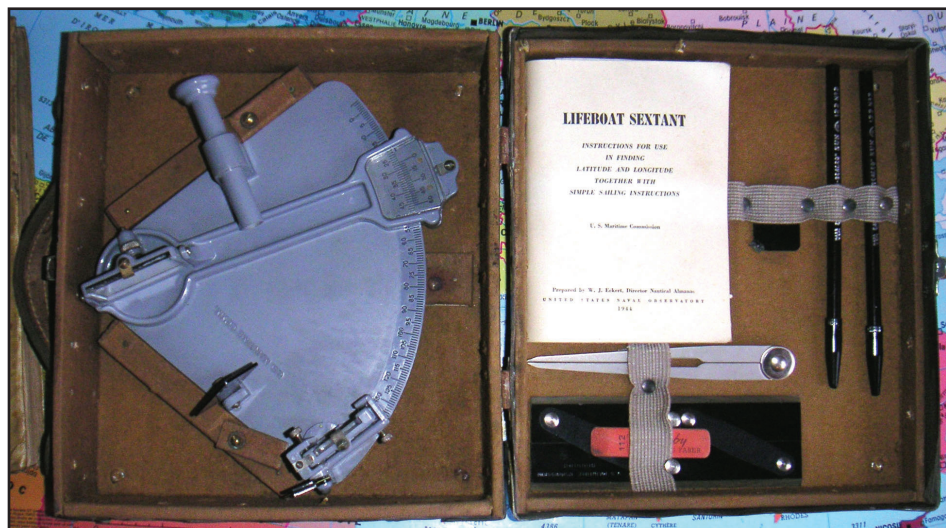


Figure 1-1. This sample of the original US Navy lifeboat sextant (Culver 1940) is part of the collection of Francois Meyrier, sailor, celestial navigation instructor, and author. It is slightly larger and of heavier plastic than its grandchild, the Davis Mark 3.



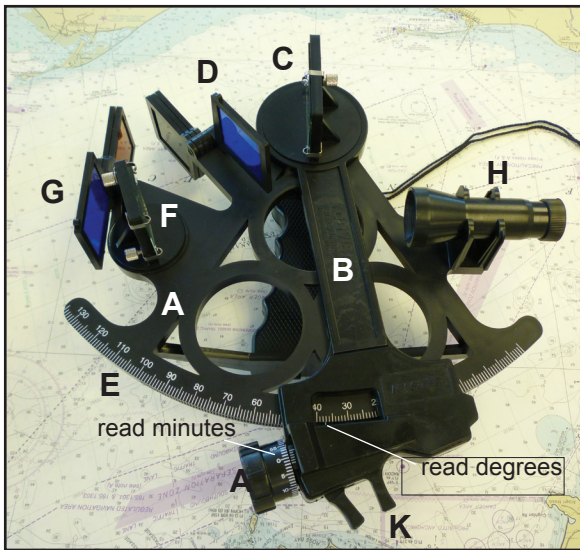


Figure 1-2 A Davis Mark 15 sextant. It has a 7" frame radius, with a 3 x 27 telescope (magnification of 3, diameter of lens 27mm). The arc reads from -5° to 120° .

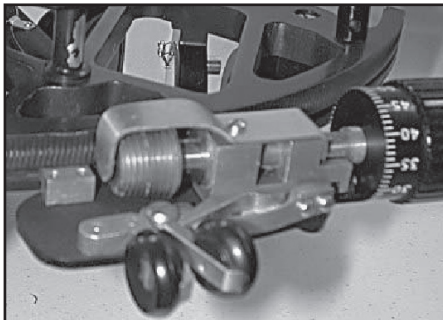


Figure 1-4 Top Close up of the worm gear on a metal sextant. A similar mechanism is encased in plastic in the Mark 15. When the clamp is compressed it pulls the worm gear out of the notches in the arc.

Figure 1-5 bottom Close up of the arc and gear rack on a Mark 15.

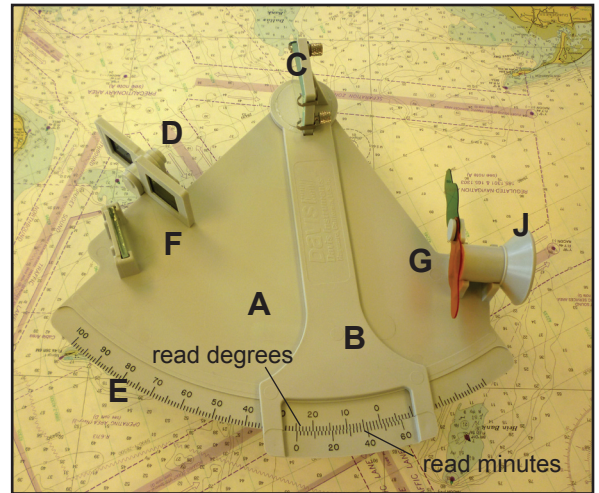


Figure 1-3. A Davis Mark 3 sextant. First models date from about 1963. There is "sighting tube" in place of a telescope.

edge of the arc of the instrument. The notches are labeled in degrees along the side of the arc. A worm gear at the base of the index arm presses into these notches as it moves along the arc. This gear is encased in the plastic of the Mark 15. A similar design on a metal sextant is shown in Figure 1-4. Large changes in sextant angle are made by squeezing two levers that disengage the worm gear and allow the index arm to slide along the arc. Releasing the levers engages the worm gear once again, but sometimes a slight twist of the micrometer drum is needed to seat the gear properly. The degrees part of the new sextant angle is read from a reference mark on the index arm against the degrees scale printed or engraved into the side of the arc. Angle changes with the vernier model are made by sliding the index arm manually along the arc.

The Mark 15 comes in a functional plastic case. A "sighting tube", included in the case, is sometimes used with sextant piloting. There is also a string tied to the sextant which is intended as a neck strap, but this will certainly cause more trouble than good and should be removed. If a neck strap is called for then a large piece of soft webbing as used for sail ties would be better.

The eye piece of the telescope also comes with a small plastic cup. This cup, too, can be completely removed and not used, but if it is to be left on then it should be trimmed by a couple mm because it is slightly too long. As is, it can inhibit the telescope adjustment tube from being pushed all the way in, which in turn prevents getting the best focus from the telescope. As discussed later, we do not want to touch the scope to our forehead (or glasses) so there is no need for this cup.

The Ebbco sextant is an intermediate design style. It has a solid arc similar to the Davis Mark 3, but then includes a micrometer drum for the minutes, which is more similar to the Davis Mark 15. A sample is shown in Figure 1-6, along with another US Navy forerunner of plastic sextants in Figure 1-7. Ebbco sextants have been cherished by their users for many decades.

The Davis Mark 25 is essentially identical to the Mark 15, but is fitted with what is most often called a “full-view mirror,” or “whole-hori-

zon mirror,” although neither is what Davis calls them, and Davis is the company that invented this alternative horizon mirror for sextants. It is now offered as an option by most sextant manufacturers. The original Davis patent for the design is available online.

There are pros and cons to the full-view mirrors; there is not a simple answer—again, the devil is in the details.

If you have never taken a sight before and are presented with a sun in midday with a dark blue sea and light blue sky, and you were asked to compare the two types of sextants, you would almost certainly choose the full-view style. It will at this first use of a sextant in these ideal conditions seem easier. And indeed it is this reaction that has led many new users to choose this option.

What you soon will learn, however, is that this is indeed a very easy sight, and regardless of what sextant you have in your hand, you will in a few minutes of practice be doing it just fine

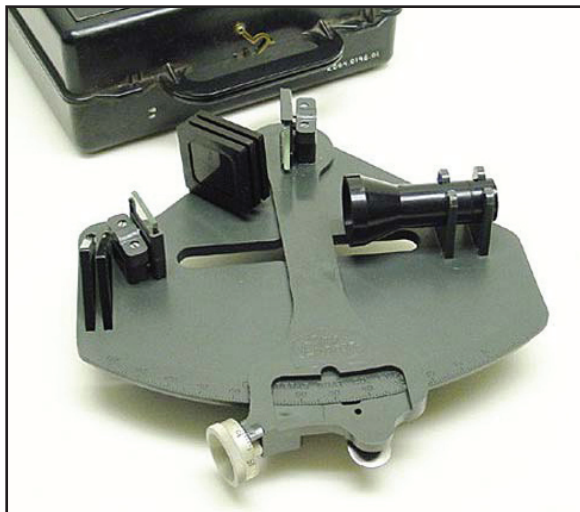


Figure 1-6. An Ebbco sextant. Once available in the US, but now only in Europe. We have had one for 20 years, which still works well, but a couple of the shades have gone opaque with age. The telescope (2.5 x 28) is about the same as the one on a Mark 15. Further notes on the Ebbco are in the Appendix.

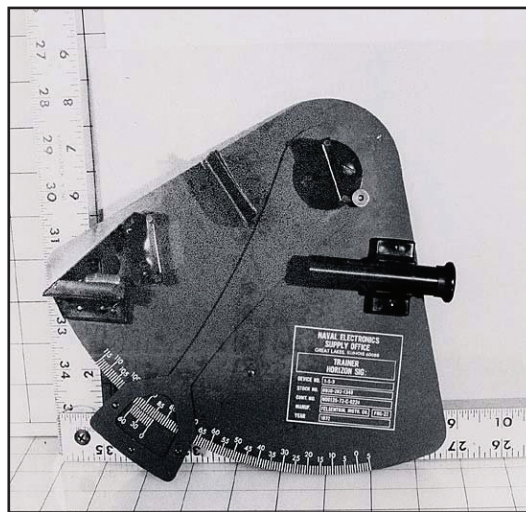


Figure 1-7. A US Navy grandparent of plastic sextants made by Felsenthal Plastic Company in Chicago, the origin of the 2102-D Star Finder. During WW II this company produced 90% of the Navy’s plastic navigation tools. From the Smithsonian Museum, with bubble attachment for aircraft use.

with a traditional horizon mirror, which is half silver and half glass. With this standard type of sextant horizon mirror (used since 1750's) you do have to coordinate keeping the sextant pointed toward the object as you move around some and rotate (rock) the instrument. With the full-view model, you have broader leeway here and this is easier. We cover details of the sight taking section of Part 2.

On the other hand, for other sights, things are completely different. The full-view mirror works by splitting the light spectrum in half according to color, by means of special optical coatings on the glass. This special surface reflects the bluish half and transmits the yellowish half, as shown in the Appendix. The net effect is you see at the same time light passing through it and light reflected from it—but only roughly half of the light intensity in each case. Hence the problem. For faint stars, you are losing half the light so the stars are more difficult to see.

But that is not the main problem. The main problem comes in when viewing anything that is about the same color as the sky. A daytime moon in a “white” sky, for example, can sometimes not be taken at all with that style of mirror. Also when the sea and sky are nearly the same color—which is fairly often—then it is very difficult with this model to check the index correction using the horizon.

Another drawback shows up when you use the sextant for coastal piloting, either with vertical sextant angles or horizontal angles, such as the famous three-body fix, which is such an accurate means of piloting it is usually called sextant surveying. In these sights you are looking at land overlapping land images where they often differ only in the shade of color. These sights are significantly more difficult with the full-view type of mirror.

In a nutshell, “full-view” mirrors make the easy sights easier and the hard sights harder. We generally do not recommend them unless the primary intended function is sun sights at sea as a back-up to electronic navigation. If you will be using the sextant for its full range of functions, the traditional mirror is a better choice. On the other hand, Davis sells the mirrors separately, so one could in principle replace the full view mirror on a Mark 25 with a traditional mirror from a Mark 15. Such a change, however, would be more or less permanent. It is not feasible to change them at will for different applications. The change is easy, but tedious, because the clamping springs are very tight.

For completeness we should mention this exception. Very high sights (angles above some 85°) are difficult because with the sun essentially overhead it is difficult to keep the sextant pointed toward the sun's direction—it is very

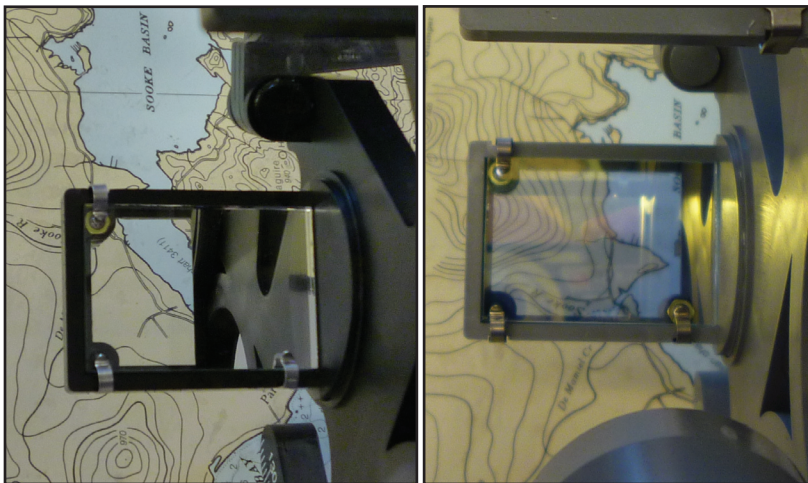


Figure 1-8. *Horizon mirror options. Left is the traditional half-split mirror used on a Mark 15, with clear glass on the left side and mirror on the right side, here reflecting another part of the sextant. On the right is a Davis Mark 25 “full-view” mirror that has the same optical coating over the full horizon glass. Davis called the coating a “beam converger,” but the name never caught on, and even Davis now describes it as “full horizon.” More details are presented in the Appendix.*

figuratively like deciding which way is south at the North Pole. These high sights are definitely doable, but it takes special techniques in both the sight taking and of course in the analysis. You cannot use conventional sight reduction methods for near-overhead sights. For these rare sights, a full-view type of mirror makes them a bit easier than a split-view mirror. That said, we still do not change our recommendation.

Full view and traditional horizon mirrors are shown in Figure 1-8.

Sextant Principles

A sextant measures the angle between two objects using a double reflection principle shown in Figure 1-9. To measure the height of a star above the horizon, we look at a light ray from the star in the horizon mirror after it has been reflected from the index mirror alongside a direct view of the horizon through the horizon glass. The measurement is made by moving the index arm until the star is precisely even with the sea horizon.

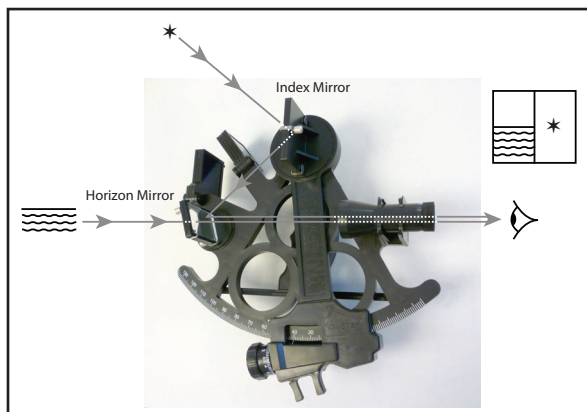


Figure 1-9. Light from a star reflects from the index mirror, then from the mirror side of the horizon mirror, and then into the telescope. The horizon can be viewed directly through the clear-glass side of the horizon mirror. The angle of the star above the horizon is read from the arc when the reflected image of the star aligns with the direct view of the horizon, as shown in the insert.

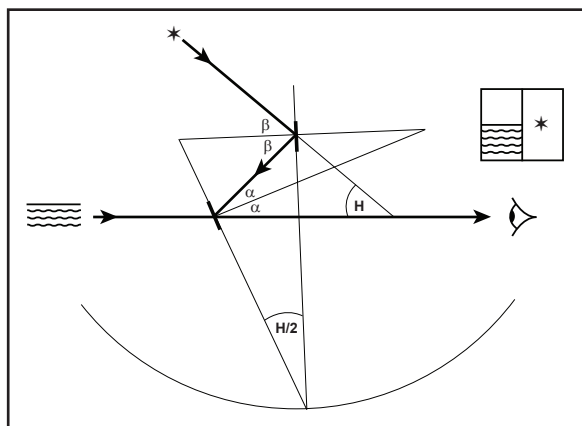


Figure 1-10. When light reflects from a mirror, the angle of reflection equals the angle of incidence, from which geometry can prove that the height of the star above the horizon (H) is equal to twice the angle between the mirrors. This way a sextant with a frame arc of one-sixth of a circle (60°) can be used to measure angles of up to 120° .

Though at first it might not be apparent, the index arm of the sextant only moves half as much as the angle being measured, as shown in Figure 1-10. For those who like such things, it is a nice geometry exercise to prove this.

The angular height read from the arc and micrometer drum presumes that the two mirrors are precisely parallel to each other when the dial

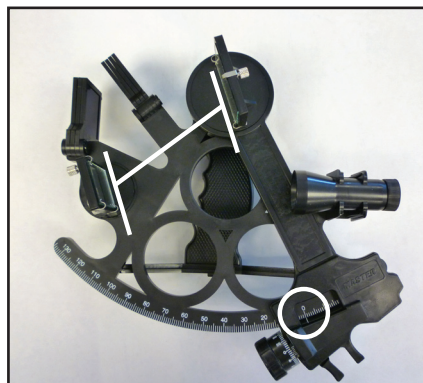


Figure 1-11. The index correction is how much the two mirrors differ from exactly parallel when the dial is set to $0^\circ 0'$. There are several ways to measure this.

reads $0^{\circ} 0'.0'$ as shown in Figure 1-11. If they are not parallel, the instrument has an Index Error, and this must be accounted for with an Index Correction. Procedures for measuring and adjusting the index correction are covered later.

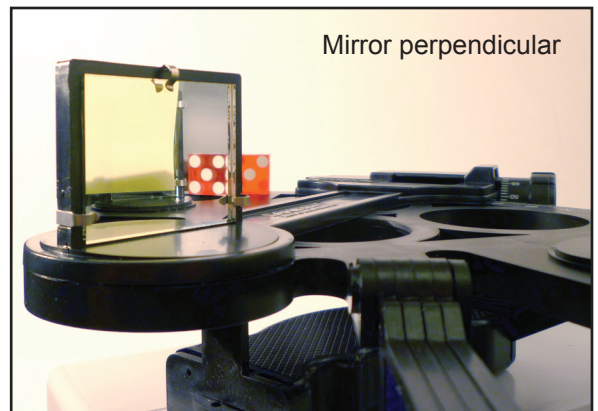
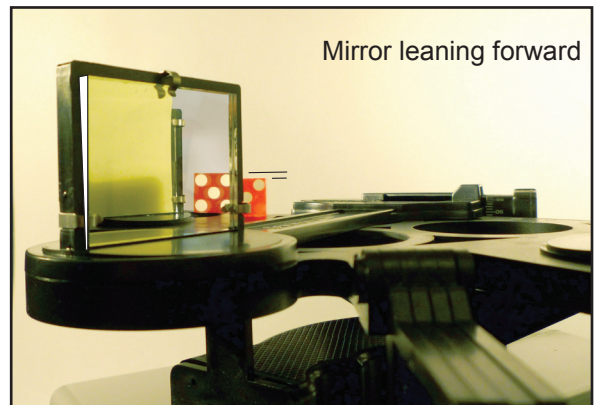
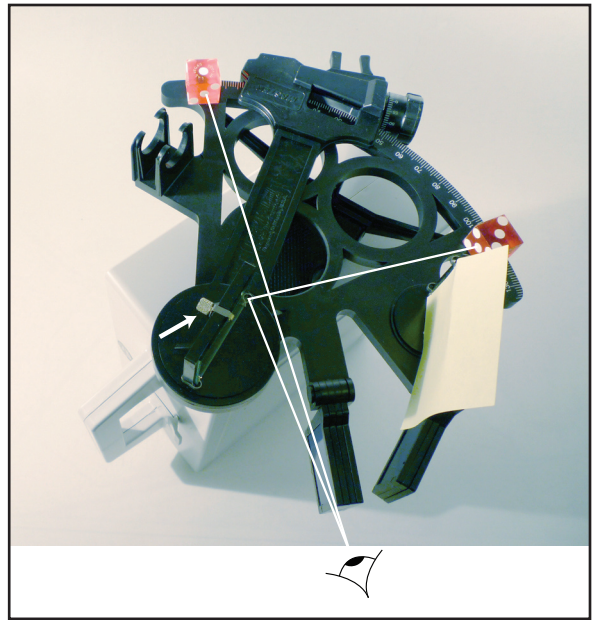
Side Error Adjustment

Another adjustment that is crucial for accurate work in both sight taking and in measuring the index correction is aligning the two mirrors to be precisely perpendicular to the frame of the sextant. When the mirrors are not perpendicular to the frame, the instrument is said to have a *side error*.

The adjustment proceeds in two steps, first adjust the index mirror using a view of the arc as shown in Figure 1-12. You can do this with the arc alone (without the dice), but it is easier and more accurate with something like the casino dice shown. Used casino dice (3/4 inch cube) are just a dollar or so online or at a casino and perfect for the job.

Once the index mirror is plumb, we need to go outside to view a distant landmark or horizon to make the horizon mirror parallel to the index mirror. One easy way is to view a star. Set the index arm to $0^{\circ} 0'$ and view a star through the telescope, and adjust the telescope tube for optimum focus, as discussed in Figure 1-13. You will most likely see two stars, one in the direct

Figure 1-12. Procedure for setting the index mirror perpendicular to the sextant frame. Top shows the setup. Place a dice cube at each end, then move the index arm till you can see both as shown below. We have put a Post-it over the horizon mirror to stress that it does not enter the process. We are viewing reflections from index mirror alone. It can be easier to remove the telescope, but if so, do it carefully (see Fig 1-13). Elevate the sextant on a table so you can sight the dice parallel to the arc and adjust the indicated screw until the dice tops are level. Then gently flick the mirror housing to be sure the mirror and springs are set, and double check the alignment. When this is right, the reveal of the mirror usually will be symmetric on all sides. If this is not the case, try setting it so ahead of time and start again.



view and one in the reflected view. They should be relatively close, but will not overlap. The vertical separation between the two is the index error, which we address later, and the horizontal separation is a result of the side error, meaning the lack of parallelism between index and horizon mirrors. See Figure 1-14.

The next step is to adjust the tilt of the index horizon mirror to move the two stars together horizontally. This is done with the horizon mirror screw that is farthest from the plane of the arc. Laying flat, it is the top one, but this adjustment must be done as you hold the sextant to your eye viewing the star, so it will then be the outside one, on the left, which is the easiest one to reach.

The challenge, however, is that at this stage the index error and side error are interrelated to some extent. When you turn the adjustment

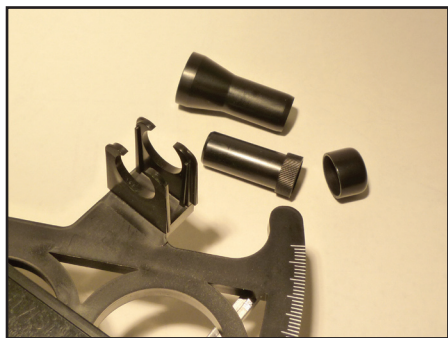


Figure 1-13. *The telescopes on the Mark 15 and Mark 25 are identical (but for color). The front lens is 27 mm in diameter and the power of the scope is nominally 3x. The main body of the scope can be carefully slid out of the holding brackets as needed. These brackets are fragile, but if one breaks you can hold the scope in place with a post office rubber band. The eyepiece tube slides in and out of the main tube for focusing. The tolerances are just off on some units and it might help to file off the main tube a mm to allow for better distance focusing. Likewise the eyepiece cup can prevent the tube from moving in far enough, so trimming it a mm or so can help—or leave it off completely as it is not needed. If the fit is so tight that pressure pushes the tube back out, then drill a small hole in the large tube to prevent that.*

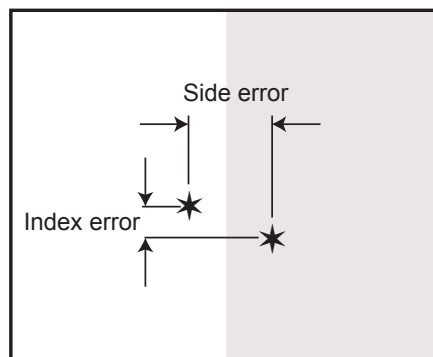


Figure 1-14. *Looking toward a star or planet with the arc set to 0° 0' showing side error and index error.*

screw to tilt the top of the mirror toward or away from the telescope to adjust its perpendicularity, you will also shift the side of the mirror somewhat, which will change the index error.

So it is an iterative process. Remove the side error, then use the other screw on the horizon mirror to remove the index error. This is the screw that is difficult to reach without blocking your view of the star. You must reach up and over the view to the star.

Then go back and forth as needed to get them both as small as possible. Try tapping or flicking the mirror housing periodically to insure the mirror and springs are set properly. (Don't flick it any harder than you would flick your own nose!) These errors do not need to be totally removed by adjustment, however, because we must in any event measure the residual index correction very carefully, as explained in a later section. It is valuable, however, to remove the side error as best you can at this stage.

This can also be done with the sun (Figure 1-15) or the moon (Figure 1-16). With the sun, and sometimes the moon, you will see the reflected image of the sun on the horizon glass as well. This is just the sunlight reflecting from the surface of the horizon glass. It is a gift that makes the sun and bright moon measurements easier. It does not work for the stars, but might for a bright planet. Thus if you get stuck one day

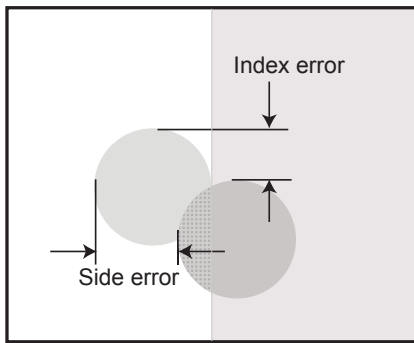


Figure 1-15. Looking toward the sun with the arc set to $0^{\circ} 0'$ showing side error and index error. **CAUTION:** you must use proper filters on both the horizon and index mirrors when doing this. See Index Correction section for a good custom filter solution and important safety discussion. This is dangerous when done wrong. If in doubt, use a star or a landmark.

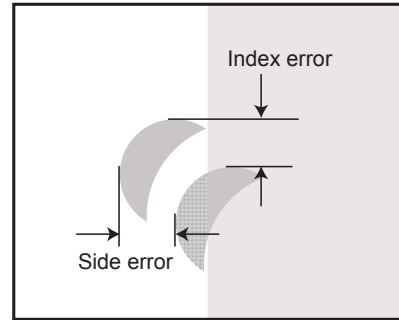


Figure 1-17. Looking toward the moon with the arc set to $0^{\circ} 0'$ showing side error and index error. Sometimes you must rotate the sextant to see the moon orientation properly in the mirrors, especially when measuring the index correction. For zeroing both errors as a starting point, this is not so crucial.

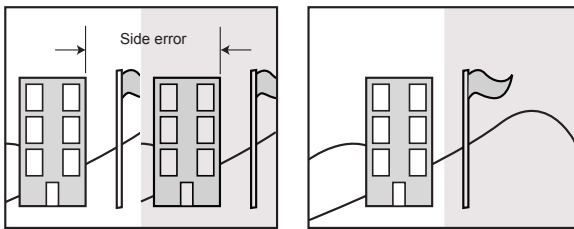


Figure 1-16. Using a distant vertical landmark to gauge and remove the side error. The left is with mirrors not plumb; the right is corrected. At sea during daylight hours you can turn the sextant sideways and use the horizon as your “vertical” line.

without any horizon mirror, even a plain piece of glass will serve as a “whole-horizon” mirror for sun sights.

The side error can also be adjusted using a distant tower or building edge, at least a couple miles away. Or even the sloping side of a distant hill can be used. At sea you can turn the sextant sideways and actually use the horizon for this side error adjustment. The moon can also be used, and in the index correction section we also discuss using special filters to use the sun, but a star or planet is an easy way to get it set about right.

We have found that painting the screws with fingernail polish once adjusted has helped preserve the alignment of the mirrors, but we do not have enough evidence to suggest this might universally work. It is something to try. We have had very good luck with fingernail polish on a Mark 3, but it has a different arrangement of the adjustment screws. All is done with two screws on the index mirror.

We have spent a lot of time on the side error removal even though it does not really enter into the actual sighting error in many cases. In the end, it is the correction for the index error that is most crucial to accurate results. However, later we look at ways to accurately measure the index correction and these methods require that the side error be gone, or nearly gone, for best results. We will come back to the topic in the section on Index Correction. At this stage, just set them both as near zero as possible.

Reading the Dials

Before we get into taking sextant sights of various kinds, we take a look at how to read the dials once the angle has been set.

On a micrometer drum sextant, angle settings between whole degrees are made by rotating the micrometer drum. This rotation changes the angle continuously from one degree to the next. The drum settings can typically be read to a precision of $0.1'$ of arc making use of a vernier scale printed along the edge of the drum. Hence if a sextant were set to an angle of $32^\circ 21.8'$, we would read the 32° from the scale on the arc, the $21'$ from the micrometer drum, and the $0.8'$ from the vernier scale.

On a Mark 3 vernier sextant, the degrees part is read from the arc and all of the minutes part is read from the vernier. They are nominally precise to $2'$, but you can estimate $1'$ readings with care. Good lighting and a magnifying glass are often helpful, especially for the vernier dial reading, which requires careful judgment of alignment.

Below are instructions on reading the dials of a sextant and discussion of the nuances that might arise.

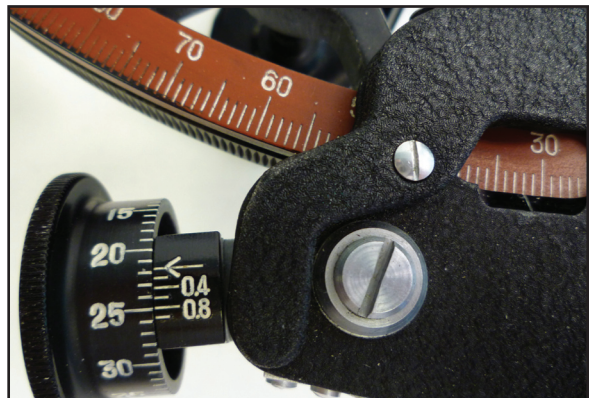
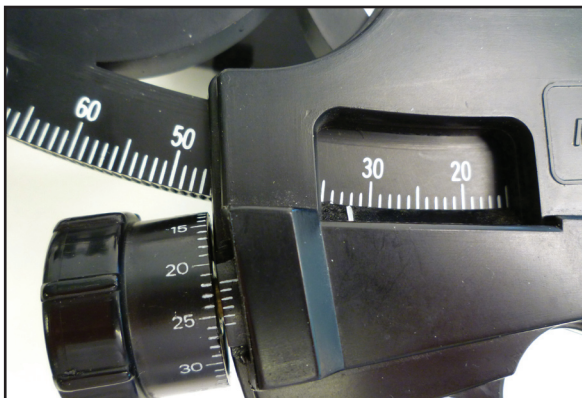
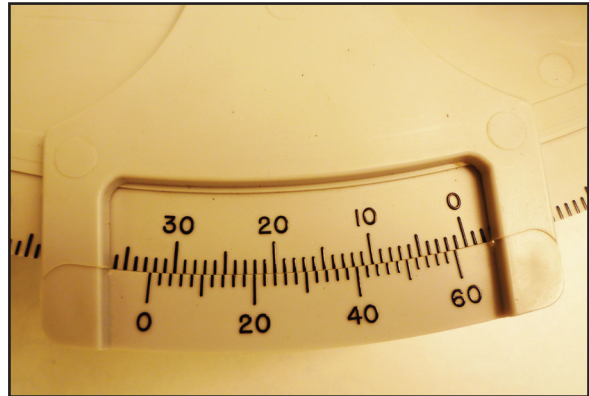
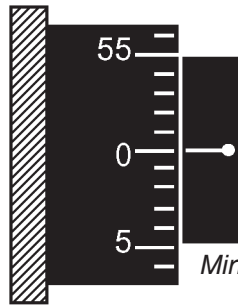


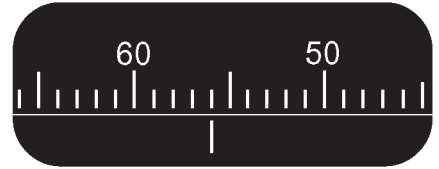
Figure 1-18. Micrometer drum and vernier scale reading $32^\circ 21.8'$ on a Mark 15 (left) and Ebbco (middle right) plastic sextants, and also on a metal sextant (bottom right). The Davis Mark 3 (top right) reads $32^\circ 22'$ which is the closest it can be read—periodically the vernier alignment will be equally off on two numbers and then we can estimate an odd arc minute reading, as discussed on the following pages.

Step 1

Notice that the index marks align exactly with the numbers. The degrees increase when you move the index arm to the left, out away from you. The minutes increase as you "unscrew" the micrometer drum, counterclockwise.



Degrees read from the arc = 56



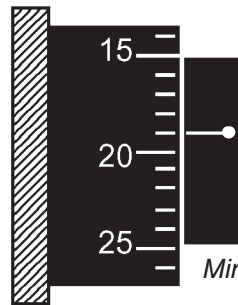
This sextant reads 56° 00.0'

Minutes read from the drum = 00.0

Step 2

Notice that index mark on the arc is past the 56, about one third of the way to the 57. We can't tell that it is one third exactly, but we can tell that it is less than half. The minutes must be less than 30, as they are. The minutes align exactly with 19.0.

Caution: A possible mistake is to read the scales the wrong way and interpret this as 21'. Always check which direction is increasing before reading the dial. This type of error could be 2' (ie 19 vs 21) or as large as 8' (ie 16 vs 24). The smaller ones might be hard to detect later on.



Degrees read from the arc = 56

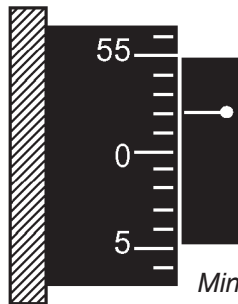


This sextant reads 56° 19.0'
not 56° 21.0'

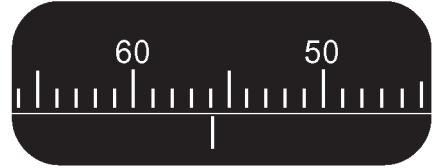
Minutes read from drum = 19.0

Step 3

In cases like these, first check the minutes on the drum so you can interpret the degrees on the arc. After checking the direction, you see this is 58', or almost one full degree. So the degrees part of the angle must be just under 56, not just over it. Caution: Always double check your readings, especially when the degrees marker is almost exactly lined up. This type of error, however, is a large one that will usually be apparent in a series of sights of the same object.



Degrees read from the arc = 55

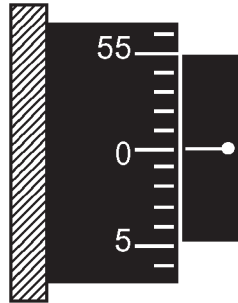


This sextant reads 55° 58.0'
not 56° 58.0' nor 56° 2.0'

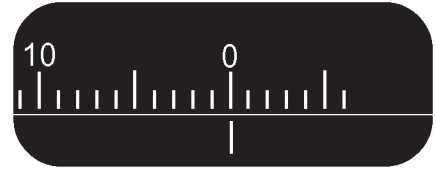
Minutes read from drum = 58.0

Step 4

If the sextant looked like this after aligning the reflected and direct views of the horizon, the instrument would have no index error. During actual sights, always record that you have checked it, however, even if it was zero. We discuss measuring the index correction (IC) in the next section. For now we just focus on dial reading.



Degrees read from the arc = 0



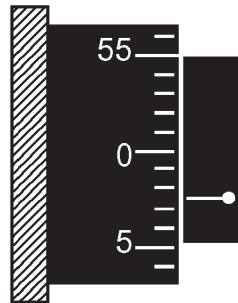
*This sextant reads 0° 0'
IC = 0.0'*

Minutes read from the drum = 00.0

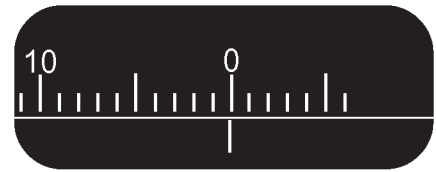
Step 5

Notice that the index mark on the arc is barely past the 0° mark. In many cases you cannot tell if it is to the left (on the scale) or to the right (off the scale). The drum reading, however, will always clarify this.

In this example, the index mark is halfway between the second and third mark, so the IC would be 2.5' on the scale. Notice, though, that without a vernier scale, we cannot really say if this is exactly 2.5. It could be 2.4 or 2.6.



Degrees read from the arc = 0+



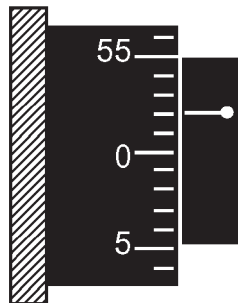
*This sextant reads 0° 02.5'
IC = 2.5' On the scale*

Minutes read from drum = 2.5

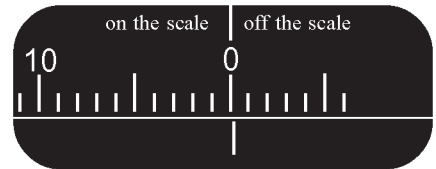
Step 6

For IC checks, you must nearly always tell from the minutes on the drum if you are off or on the scale. It will not be apparent on the arc for small corrections.

Be careful to count in the correct direction; this reads 58', not 2'. Alternatively, you can note it is off the scale, and then count the IC backwards. In this case, it reads 58 forward, which is the same as 2 backwards. With fractional readings (such as 58.7'), however, one must be careful with this, as covered later on.



Degrees read from the arc = 0-



*This sextant
reads less than zero
IC = 2.0' Off the scale*

Minutes read from drum = 58.0



This is the end of the sample.

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