

5. The Sextant

THE FIRST ELEMENT required in any problem of celestial navigation is the angular altitude of the body observed. This altitude is measured by means of a sextant or an instrument of the sextant family. Measuring the angle is done by bringing into coincidence at the eye rays of light received directly from the horizon and by reflection from the celestial body, the measure being afforded by the inclination of a movable mirror to a fixed one. The handle, the triangular frame with apex above and scaled arc below, the telescope, eye-shade glasses, and horizon mirror, whose

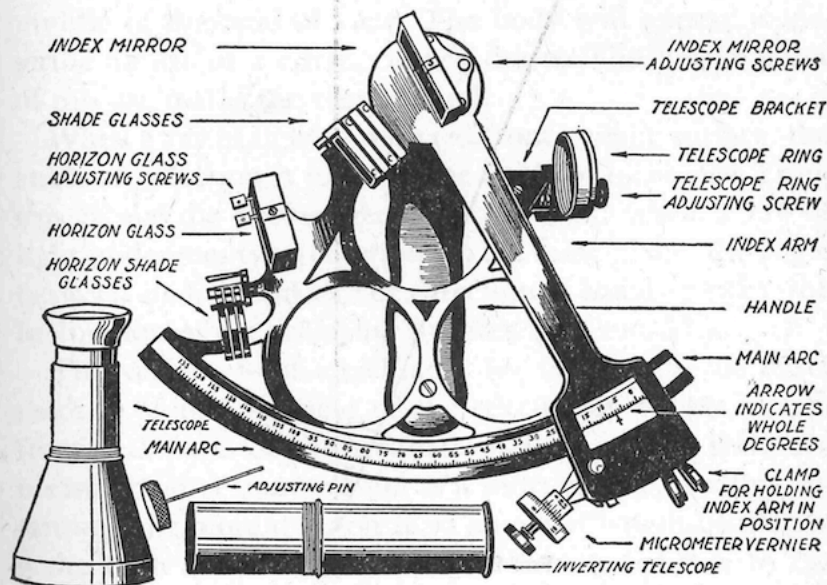


FIG. 26. Sextant.

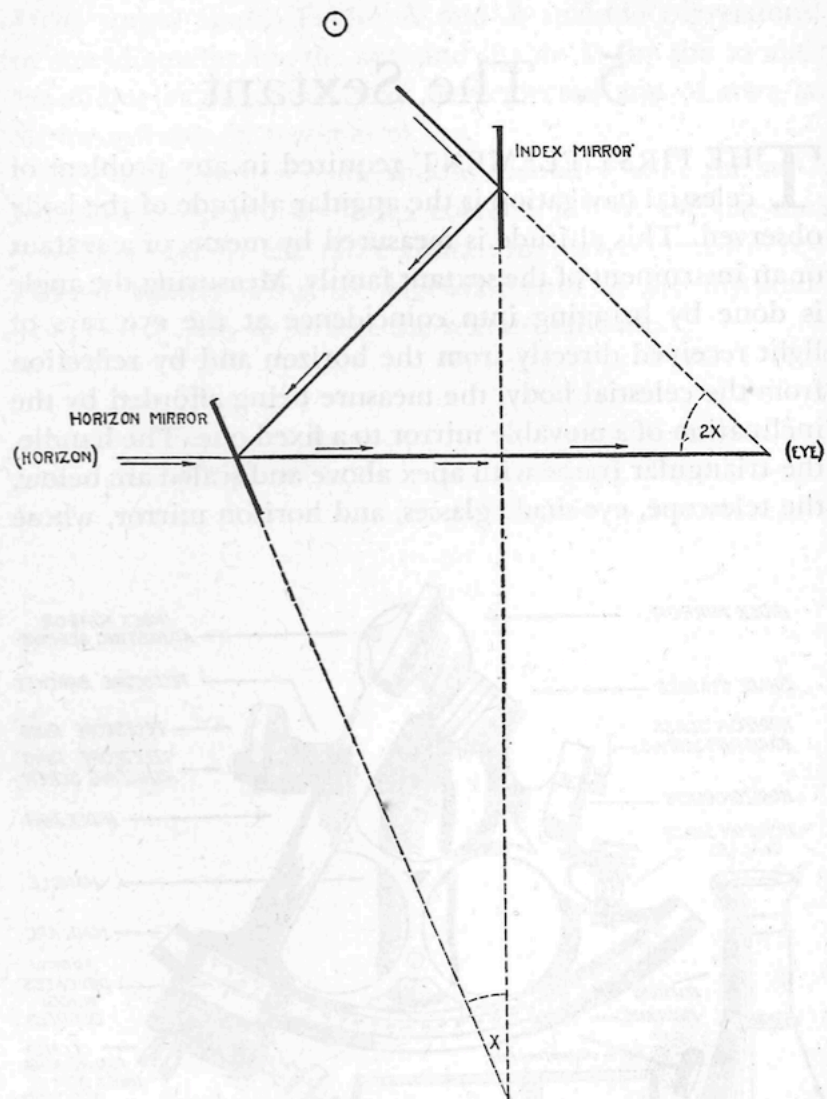


FIG. 27. Sextant Angles.

right half alone is silvered, are all rigid parts of a unit. The index mirror at top to catch the rays from the body is part of the movable arm which terminates below in the vernier scale with its screws and magnifying glass. This is moved along the arc, tipping the index mirror until the two images are brought together. It is then clamped by a screw on the right and the tangent screw on the left is used for finer adjustment. The scale is then read to give the angle of altitude.

In measuring the altitude of a celestial body, it is necessary that the angle shall be measured to that point of the horizon which lies vertically beneath the body. To determine this point the observer should swing the instrument slightly to the left and right of the vertical about the line of sight as an axis, taking care to keep the body in the middle of the field of view. The body will appear to describe an arc of a circle, convex down. The lowest point of this arc marks the true vertical.

When a ray of light is reflected from a plane surface, the angle of reflection is equal to the angle of incidence. From this it may be proved geometrically that, when a ray of light undergoes two reflections in the same plane, the angle between its first and its last direction is equal to twice the inclination of the reflecting surfaces. (*See* FIG. 27.)

The vernier is an attachment for facilitating the exact reading of the arc scale of the sextant by which certain fractional parts of the smallest division of the scale are measured. A sextant vernier is a shorter scale usually containing one more division than an equal length of the arc scale. Both arc scale and vernier readings increase to the left. To read any sextant it is necessary to observe the arc

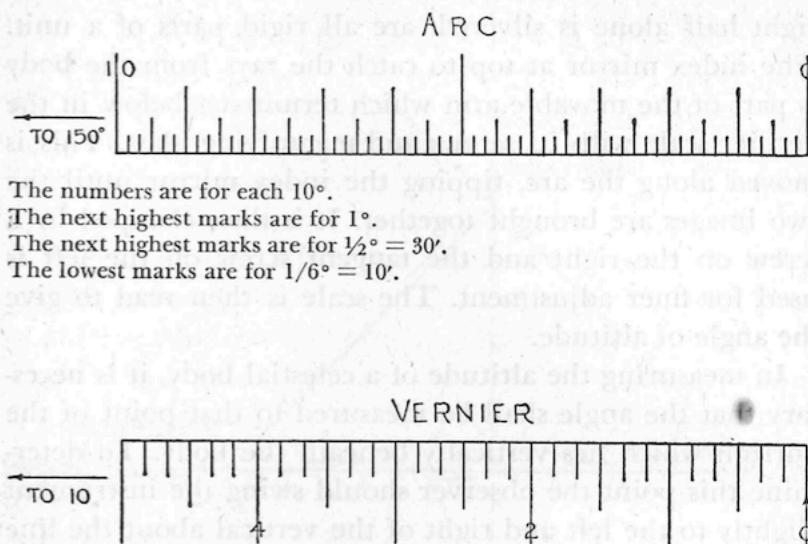


FIG. 28. Arc and Vernier Scales.

When 0 of Vernier is at 0° arc, 10 of vernier is at 19° 50' of arc. This is a proportion of 60 to 119. The vernier has double spaces for clearer reading. Otherwise, the proportion would be 120 to 119.

scale division next to the right from the vernier zero and add thereto the angle corresponding to that division of the vernier to the left which is most nearly in exact coincidence with a division of the arc scale. Figure 28 shows the arc scale and vernier on a typical sextant.

Rule: The smallest measure to which a vernier reads equals:

$$\frac{\text{length of 1 division of scale}}{\text{number of divisions of vernier}} \text{ as } \frac{10'}{60} = 10'' \text{ or } \frac{10'}{120} = 5'' \text{ etc.}$$

Hence, after observation read thus. (See FIG. 29):

Scale: right of vernier zero to degrees and 10' units.

Find line on vernier to left of its zero closest to a scale line.

Vernier number gives extra 1' units.

Vernier marks give extra 10'' units.

Index Error exists when, with index and horizon mirrors parallel, the zero of the vernier does not coincide with the zero of scale. Observe a star, or the sea horizon in daylight, directly through telescope and move index until reflected image coincides with direct. If now the vernier zero is to left of the scale zero, all readings will be too great by the amount of this divergence; if to right of scale zero, readings will be similarly too small. (See Chap. 24 for details.)

Index Correction (I. C.) is expressed as + or - the amount of arc to be applied to the observed amount.

Certain minute errors due to construction and not correctable by adjustment are usually noted in certificates accompanying the instrument when purchased.

Certain adjustments must occasionally be made. See Dutton, pp. 219-20, for detailed information as to:

Index mirror	Telescope	Horizon mirror
--------------	-----------	----------------

Properly speaking, instruments of the sextant family should be designated as follows:

Octant:	45° arc measures angles to 90°
Sextant:	60° arc measures angles to 120°
Quintant:	72° arc measures angles to 144°
Quadrant:	90° arc measures angles to 180°

The author's instrument, therefore, with an arc of 75° for angles to 150° would seem to qualify as a Super-Quintant!

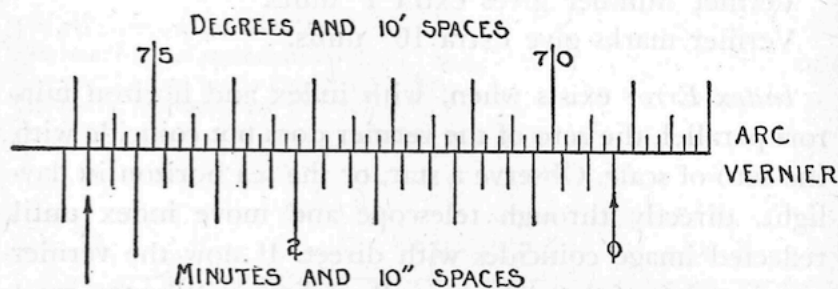


FIG. 29. Reading the Sextant.

Passing to left shows first coincidence at $75^\circ 50'$ of arc (Arrow).

Reading Arc	= $69^\circ 10'$
Reading Vernier	= $3' 20''$
Reading Total	= $69^\circ 13' 20''$

The U. S. Navy now uses a sextant fitted with an endless tangent screw which carries a micrometer drum from which the minutes and the tenths of a minute of arc are read. The tangent screw is thrown out of gear by pressing a lever so the index arm may be freely moved. Releasing the lever stops the arm at individual degrees and throws the tangent screw into gear again for finer adjustment. (See FIG. 26.)

An artificial horizon may be provided by a glass-roofed dish of mercury or even a saucer of ink placed in an uncovered box with sides low enough to let the body's rays in but high enough to keep moving air from rippling the ink. The angle between the celestial body and its reflection in the artificial horizon is measured by sextant. Half of

this angle equals the altitude of the body. (See Chap. 24 for details.)

A *bubble sextant* is an instrument containing a mechanism which supplies an artificial horizon. It is much more expensive and less accurate than the standard type of sextant but can be used when the natural horizon is invisible, as in hazy weather, or in polar regions, on the desert, or in an airplane high above the earth and clouds.

Historical

The evolution of the modern sextant probably began with the astrolabe, used by early Greek and Arab astronomers. It consisted of a graduated circle suspended in the vertical plane from a ring at the top. At its center a sighting bar was attached somewhat as a compass needle and, by looking along this at a body and noting the scale on the circle, altitude could be measured. Elaborate forms of the astrolabe were in use in the sixteenth century.

Capt. John Davis, an English navigator, developed a quadrant in 1594 which had two arcs and required sighting in two different directions. A later form was used with the observer's back to the sun. Many subsequent instruments depended on a plumb line.

In 1729 Pierre Bouguer invented an instrument which needed only a sight of the horizon while a beam from the sun was kept visible in line on a wooden peg.

The cross-staff, something like a T square, was also in use at about this time and necessitated sighting sun and horizon separately. It too was used both facing and with back to the sun.

The double reflecting mirror instrument was suggested in 1674 both by Robert Hooke, a professor of geometry in London, and Sir Isaac Newton, independently, but no models seem to have been made.

In 1730 Thomas Godfrey of Philadelphia and John Hadley, an English astronomer, independently constructed double reflecting instruments much like our sextants of today. Hadley, who was Vice-President of the Royal Society of London, probably suppressed Newton's notes and certainly ignored Godfrey's claim and obtained the credit for the invention.

Capt. Campbell in 1757 enlarged the arc to make it a true sextant. Up to 1775 the instruments were of all-wood construction. Various improvements followed and the all-metal sextant appeared in the early nineteenth century. Verniers then came into use although described by Pierre Vernier long before, in 1631. Commander Hull of the U. S. S. *Constitution* in 1812 used a sextant which had shade glasses, telescope, vernier, ivory arc, brass fittings and ebony frame while, at this same period, a similar instrument constructed of brass with a silver arc was in use by Nathaniel Bowditch. Relatively minor improvements followed but the sextant of today is not radically different from its ancestor of 100 years ago. (See *The Evolution of the Sextant* by Commodore E. S. Clark, U. S. N. I. P. Nov. 1936, *Navigational Antecedents* by Commander H. D. McGuire, U. S. N. I. P. May 1933 and *The American Inventor of the Reflecting Quadrant*, also by McGuire, U. S. N. I. P. Aug. 1940.)