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Angular Measurements

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- ✓ Angle measuring instruments
- ✓ Error sources
- ✓ Checking
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Concepts

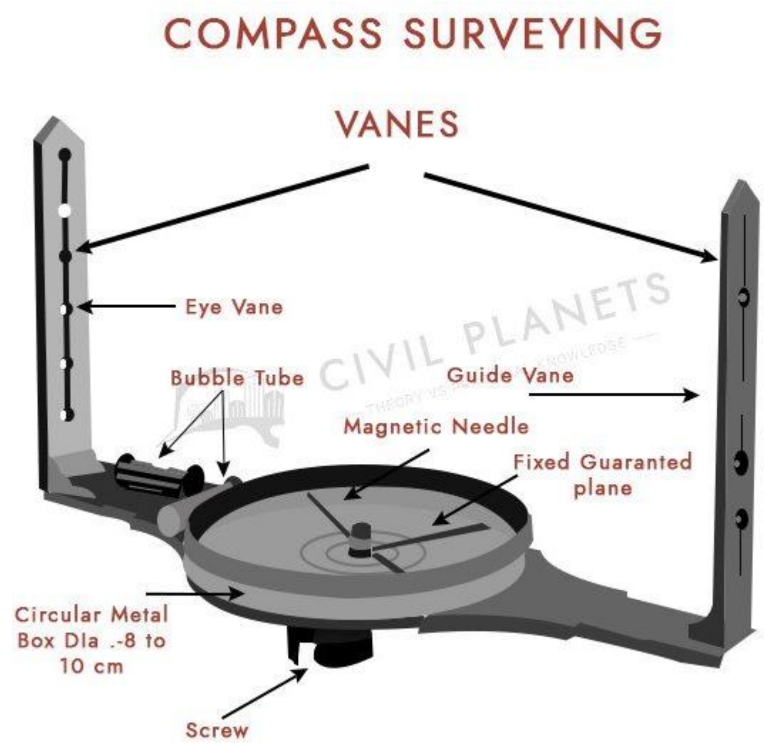
- The most basic measurable quantities in surveying are **angles and distances**. These two quantities allow a structure or feature to be positioned both in the vertical and plan (3D).
- Horizontal and vertical angles can be measured approximately using a compass and clinometer, respectively; for more accurate work, a theodolite or total station will be needed.

Concepts

- The theodolite is a precision instrument used for measuring horizontal and vertical angles. This is one of the most important instruments for exact survey work and many types are available to meet varying requirements of accuracy and precision.
- Although there is a large variety of theodolites produced by various manufacturers, the instruments all have the same basic components arranged in the same geometric relationship. Thus mastery of one particular instrument enables the operator to master easily any other make encountered on site.

The Surveyor's Compass

The standard surveyor's compass is a hand-held device which shows the bearing of a line relative to magnetic north. A graduated circular card incorporating a bar magnet rests on a low-friction pivot; prisms or mirrors and sights are arranged so that the graduations on the card may be read whilst making a sighting on the distant point. Bearings may be read to 0.5° (or 1 part in 120, when the angle is converted to radians).



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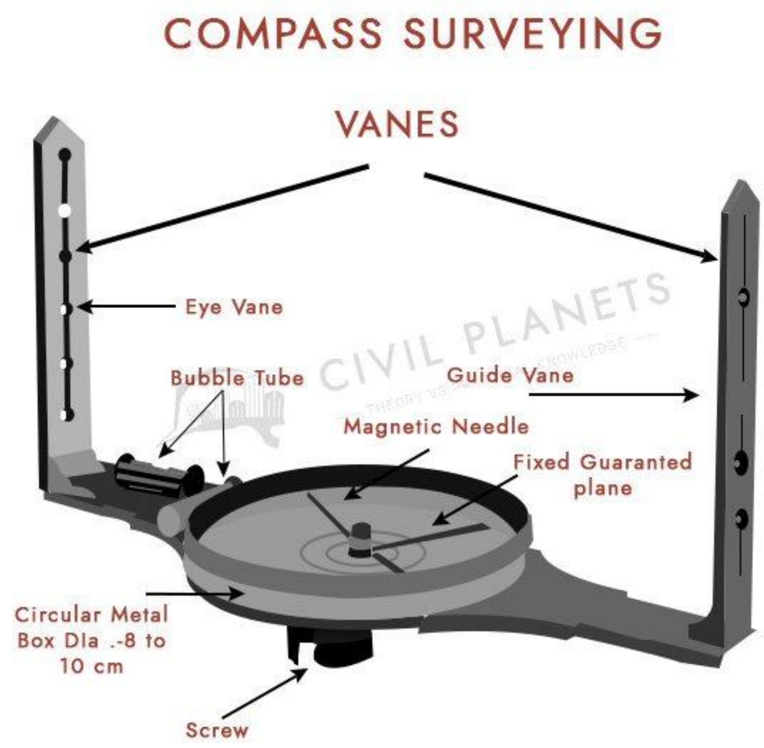
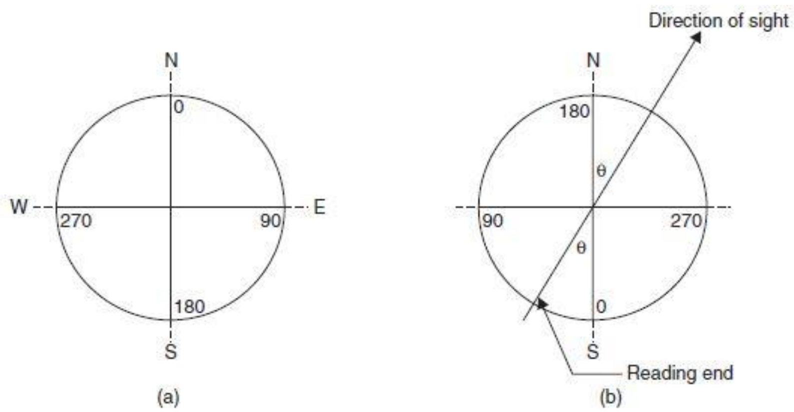


The Surveyor's Compass

The angle subtended by two stations at a third one can thus be estimated to within a degree by taking the magnetic bearings of the two stations from the third, and subtracting one reading from the other. Note however that the bearings themselves are shown with respect to magnetic north, rather than true north (where all the meridians meet) or grid north.



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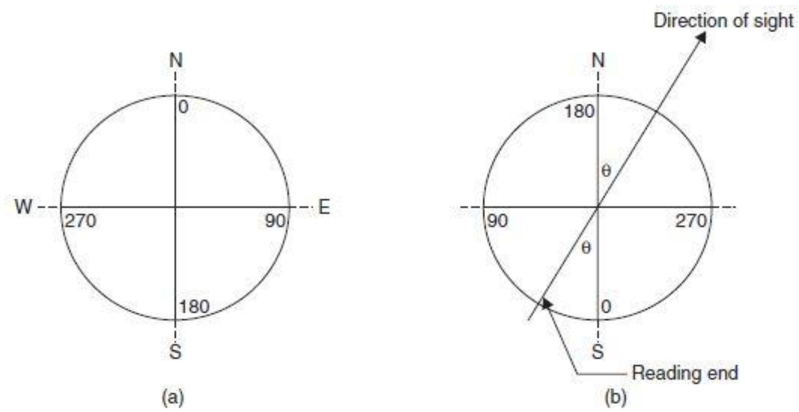
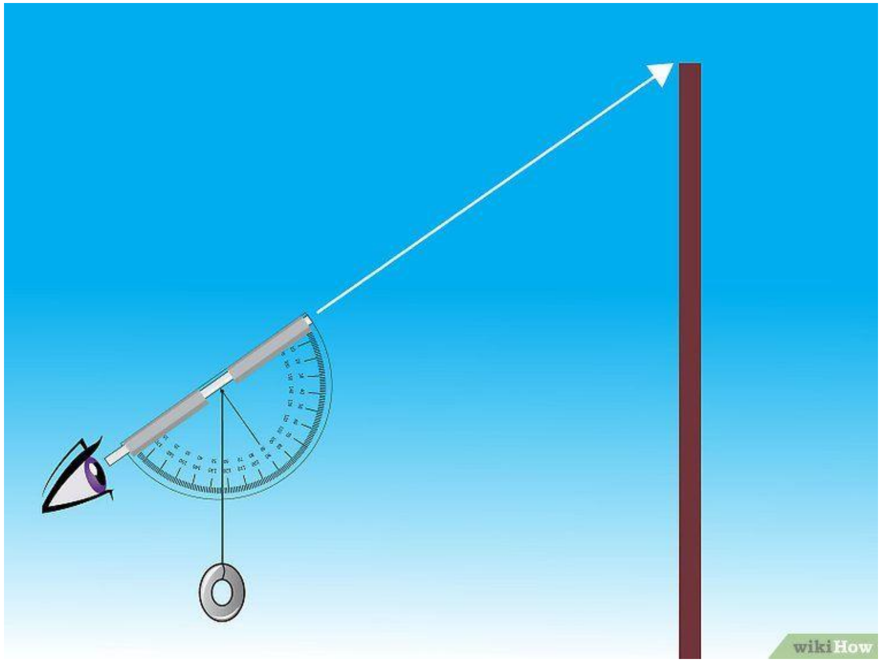


The Clinometer



In its simplest form, a clinometer consists of an optical sighting system with a pendulum attached to it. The pendulum has a protractor attached to it, so that the inclination of the sight line can be measured. A distant object is observed through the sights, and a prism enables the protractor to be read at the same time, giving the vertical angle between the observer's eye and the distant object to approximately 20 seconds.

The Clinometer

When using a clinometer, be sure to note whether a zenith angle is being read (i.e. the angle made with the vertical) or a slope angle (i.e. the angle made with the horizontal).

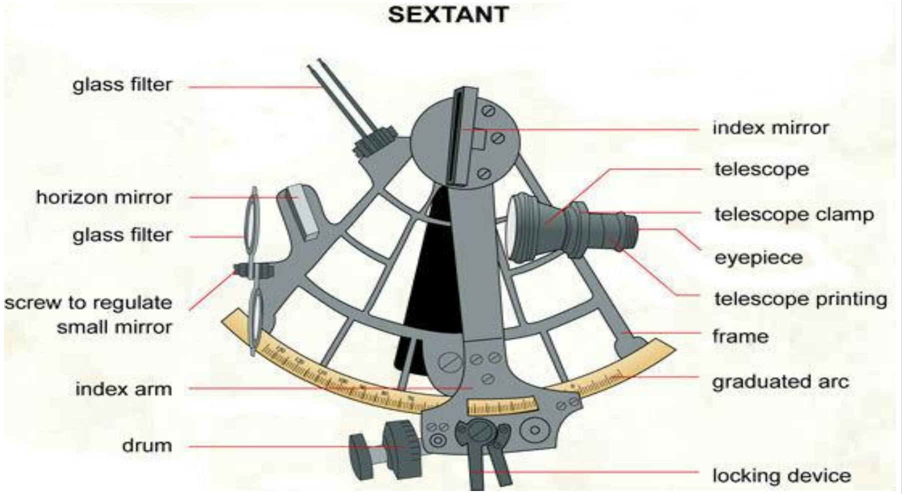
A variation on the clinometer is the sextant, which is typically used at sea to measure the vertical angle of the sun or of another star. Here, the horizon is used as a reference direction instead of a pendulum, and the optics of the device allows the difference in vertical angles to be observed. This is more useful on a boat at sea where (a) the horizon

Equipment: Sextant

Sextant

This is a tool for position fixing.

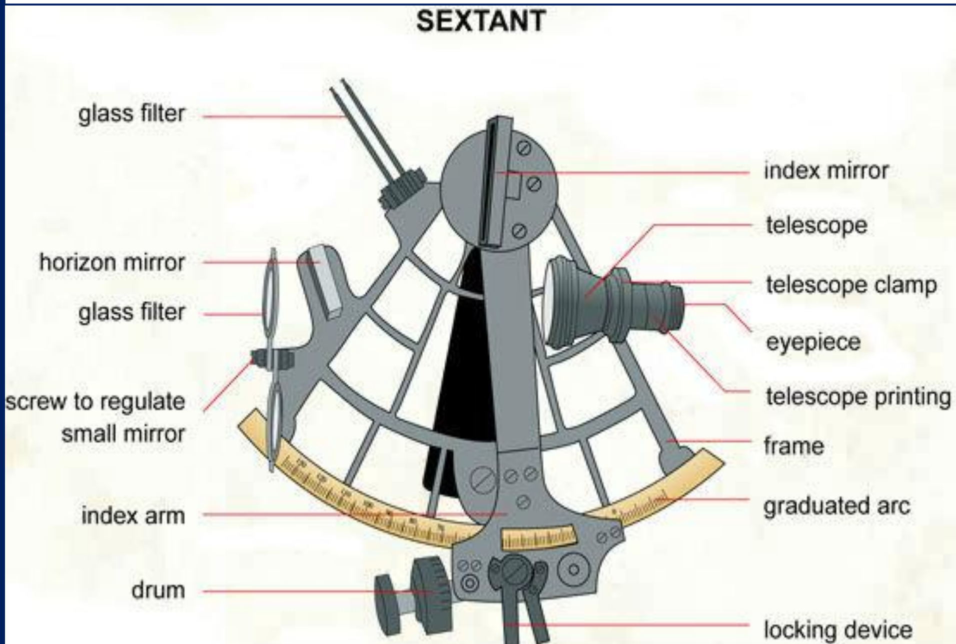
Two bodies above the horizon are brought into focus through the glass and mirror (un-silvered and silvered). I.e. two target images are brought into coincidence.

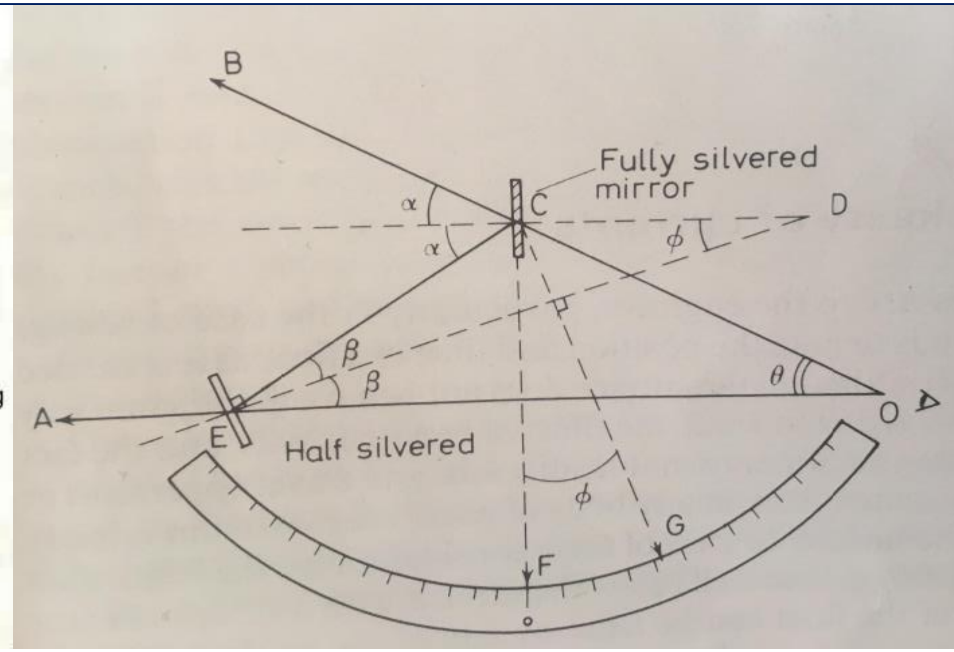


NB: The index arm and main frame move in a "scissors" like motion to bring the two images in coincidence.

Fig. 4

Equipment: Sextant Cont'd





As the index arm and main frame move in a "scissors" like motion to bring the two images in coincidence, ø is defined by the index arm displacement

Fig. 4

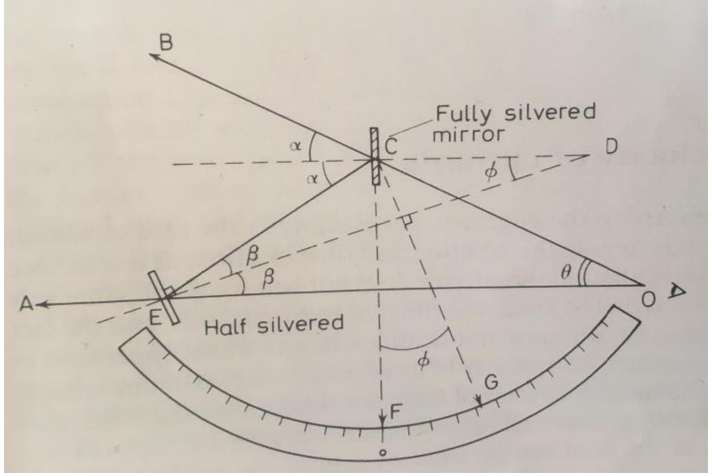
Equipment: Sextant Cont'd

Sextant

To measure the angle AOB, the target at A is viewed directly through the un-silvered glass at E. The image of target B is brought into coincidence with A in the silvered portion of the mirror at E, by manipulating the mirror arm CF to position CG. Now:

Angle $BOA = 2\alpha - 2\beta = \theta$

Angle $\mathrm{CDE} = \mathrm{FCG} = (\alpha - \beta) = \emptyset \therefore \theta = 2\emptyset$



The scale of the sextant is so graduated that the double angle $\emptyset = \theta$., can be read direct.

Equipment: Sextant Cont'd

Sextant & Elevations

Note that the angle AOB is measured in the possibly inclined view of the objects. If this elevation difference is highly significant, then we can utilize the geodetic triangles to reduce the geodesic to an equivalent horizontal using trig equations

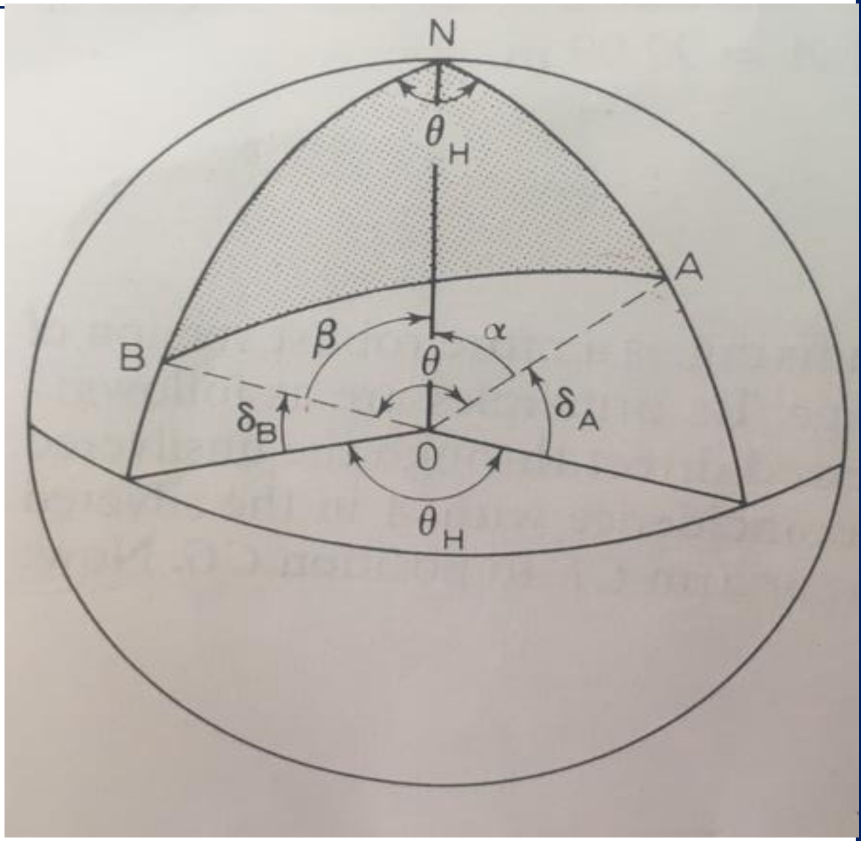


Fig.5

Equipment: Sextant Cont'd

Sextant & Elevations

$\cos\theta_H = \frac{\cos\theta - \cos\alpha\cos\beta}{\sin\alpha\sin\beta}$, where θ_H is the horizontal equivalent of the measured angle $\theta, and\ \alpha, \beta$ are vertical angles measured from the vertical, i.e. $\alpha = (90° \pm$

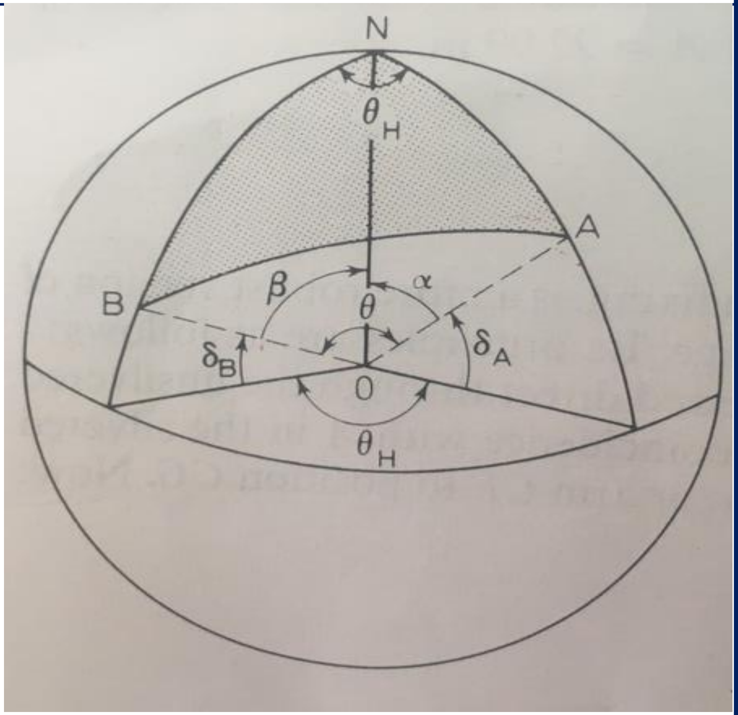


Fig.5

Theodolite

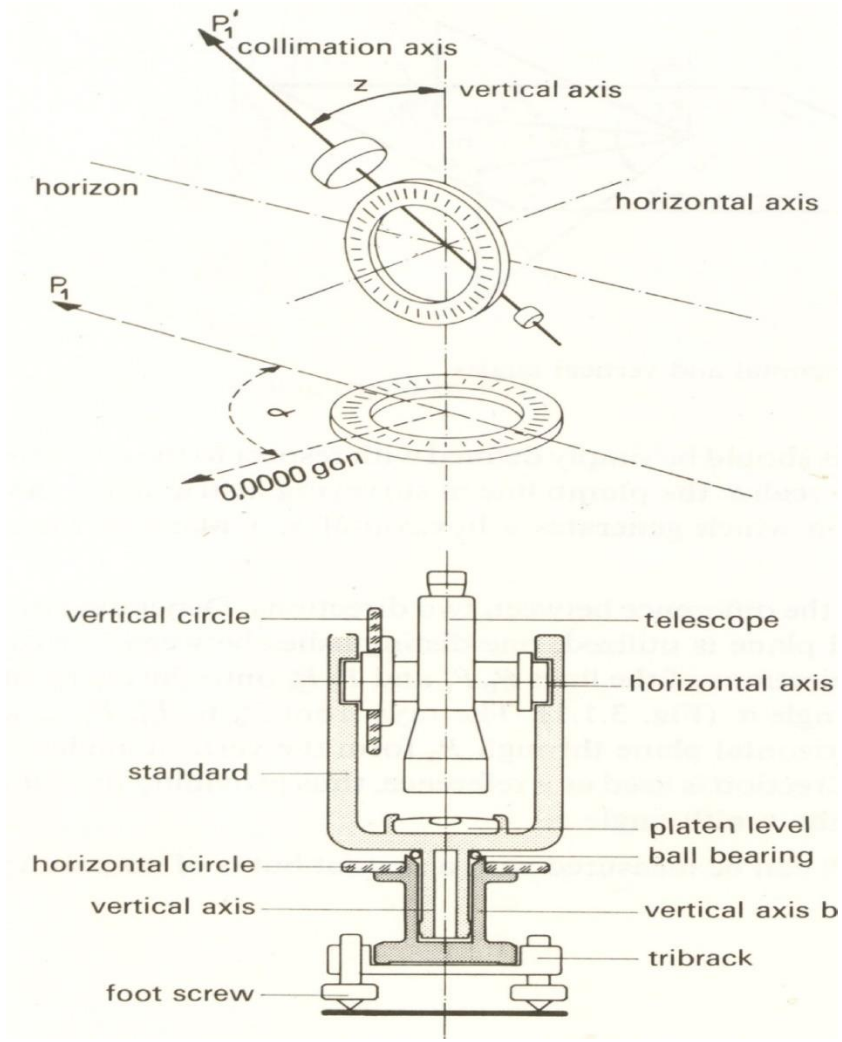
- Theodolites are normally classified by the precision to which they resolve angles, and vary from 1 minute to 0.1 seconds of arc.

- Two general types of theodolites on the market today are ***optical*** and ***electronic*** theodolites.

Theodolite

Theodolites consists of a fixed base and top part which can be rotated around the vertical axis. This top part consists of standards which connect the vertical and horizontal axes. The latter is supported by the axis bearings of the standards and carries the telescope and vertical circle, which is graduated in either degrees or gons. The vertical axis is part of the standards and fits onto the vertical axis bush of the base, which carries the horizontal circle. Again it is graduated in either gons or degrees. The standards are equipped with reading devices for the horizontal and vertical circles.

Major Parts of a theodolite



- Figure 1: Structure of a simple theodolite

- The base can be levelled with the aid of foot screws and platen level. The connection between the vertical axis socket and the tribrach can be either fixed or exchangeable for forced centring. (Fig 1.)

Electronic Theodolite

The overall design of the traditional optical theodolite (above) has remained virtually unchanged for the past 25-30 years. A major change however occurred in recent years with the introduction of electronic circle reading systems and electronic tilt sensing systems in the design of the theodolite.

Angles and Determination of Direction

- Angle – difference in direction of 2 lines
  - Another way of explaining is the amount of rotation about a central point
  - 3 kinds of Horizontal angles: Exterior ($\angle$ to right); Interior; Deflection
  - To turn an angle you need
    - A reference line
    - Direction of turning
    - Angular distance
  - Angular Units
    - Degrees, minutes, seconds (sexagesimal system)
      - Circle divided into 360 degrees
      - Each degree divided by 60 minutes
      - Each minute divided into 60 seconds
    - Radians
      - 1 radian = $1/2\pi$ of a circle = 0.1592*360 = 57°17’44. 8”
    - Grads (Centesimal System) – now called Gon
      - 1/400 of a circle or 0°54’00” (100 gon = 90°)

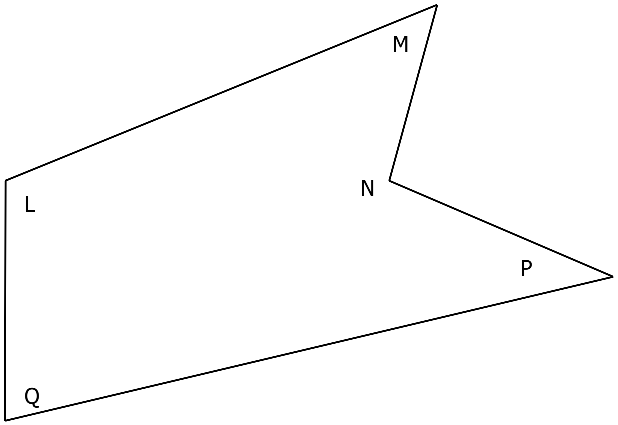
Observation Checks

- Angles turned in field must be accurate: **3X least count is max. error**
- Check #1 – Close horizon when turning
- If traverse is loop closed: sum of the interior angles should equal the sum of
  - ✓ (N-2)X180, N = Number of sides
    - 3 angles = (3-2) 180 = 180°
    - 4 angles = (4-2) 180 = 360°
    - 8 angles = (8-2) 180 = 1080°
    - 25 angles = (25-2) 180 = 4140°
  - ✓ If an exterior angle exists, subtract it from 360 to obtain the interior ∠
  - ✓ Angular closure should be checked before leaving the field

Angles and Determination of Direction

- If angular adjustment does not divide out equally:
  1. Do not go to decimal unless instrument reads to decimal
  2. Check field notes for angles with poor misclosure or where problems turning angles existed. Apply excess to these angles evenly.
  3. If unable to view field notes or no apparent source, generally apply excess to angles with shortest sides
- Bearings/Azimuths
  – **Quandrant Bearing** of a line is the acute horizontal angle between a reference meridian (North and South) and a line
  – **Azimuth** of a line is the horizontal angle measured from the True North meridian in a clockwise direction to the line of interest.

Example



Adjust interior angles:

Vertex	Field measured angle	adjustment	Adjusted angle
Q	75° 01' 24"	+0° 0' 04"	75° 01' 28"
P	41° 19' 20"	+0° 0' 04"	41° 19' 24"
N	251° 04' 40"	+0° 0' 04"	251° 04' 44"
M	54° 06' 24"	+0° 0' 04"	54° 06' 28"
L	118° 27' 52"	+0° 0' 04"	118° 27' 56"
Sum	539° 59' 40"		540° 00' 00"
	- 540°		
error	-0° 0' 20"		
	20" / 5 angles	= 4" / angle adjustment	

Traverse loop azimuth computations:

3. To compute azimuths in the **counterclockwise** direction, **add** the interior angle to the back azimuth of the previous course.

4. To compute azimuths in the **clockwise** direction, **subtract** the interior angle from the back azimuth of the previous course.

Angles and Determination of Direction

4 Point Comparison		
	Quadrant Bearing	**WCB**
1. Numeric Value	0-90°	0-360°
2. Method of Expressing	2 letters & number	Number only
3. Direction	Clockwise & counterclockwise	Clockwise
4. Direction of 0° orientation	North and South	North

It is always very important to have your field sketch properly oriented

Sources of Errors

In angular measurements, we consider the theodolite as a base instrument. Five major sources of errors are as follows:

1. ***Sighting*** – target bisection is rarely perfect due to human imperfection in sighting and touch. This results in both negative and positive errors. Thus repeated observation would reduce this error through their mean.
2. ***Reading and Setting Verniers:*** This too is human error, reduced by the mean of several observations
3. ***Instrument Operation***: that's turning wrong screw, failure to remove parallax, leaving lower plate unclamped, tripod movement. However all these errors should become apparent when booking the observations

Sources of Errors

4. *Booking Errors* – this has been found to be eliminated by booker reading the observation back to the observer. However, with modern digital software, this is completely eliminated
5. *Wrong data transformations:* This arises when carrying out system transformation due to wrong transformation parameters etc.
6. *Natural causes:* These are effects beyond human control such as refraction especially for long baselines. However, wind, differential expansion of the instrument's parts can be managed by way of very firmly established and shielded tripod from both wind and sun.