M5: Direction Measurements

Angle measurements (3L): Concept of direction, azimuth, meridian; Theodolite, fundamental characteristic of theodolite and adjustment, measuring angles, sources of error

- Definitions
- Bearings, azimuths, deflection angles
- Direction measurements with compass
- Direction measurements with theodolite

Definitions

(i) Geographical poles: Earth rotates from W to E on its axis, called geographic axis. The end of axis which points towards north is north geographical pole (NGP) and other end is south geographical pole (SGP).

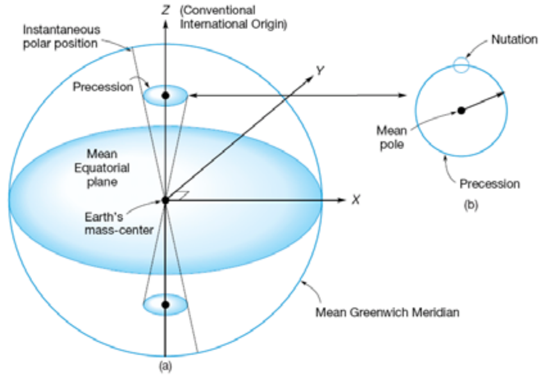
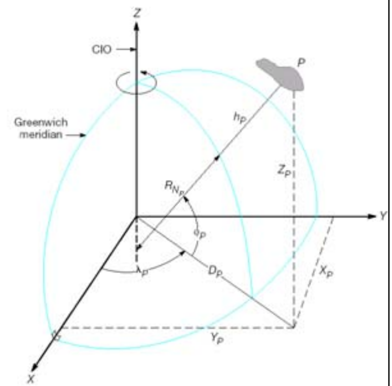
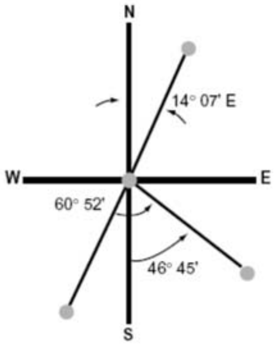


Figure 19–2 Motions of the Earth's polar axis (a) three-dimensional, and (b) plan, views.





(ii) North seeking pole (NSP)/south seeking pole

- The end of the magnet which points to north pole when freely suspended is NSP, the other end being SSP. The earth is considered a huge natural magnet whose poles are located near N and S geographical poles.

(iii) Magnetic declination/Variation:

- The freely suspended magnetic needle's direction does not coincide with geographical axis of earth and makes certain angle with it. The horizontal angle between true meridian and magnetic meridian is called magnetic variation or declination.
- Denoted as θ^0E or W. θ^0W means magnetic north makes angle θ towards west of true north (TN).
- Amount of magnetic variation/declination is not constant due to unequal distribution of magnetism. Various types of variation: (a) Secular variation (b) Annual variation (c) Diurnal variation (d) Irregular variation

(iv) Isogonic lines: Lines joining places of equal declination. The change in variation is due to unequal distribution of magnetism.

(v) Agonic lines: Lines joining places of zero declination.

(vi) Dip/inclination: A freely suspended needle is found to dip and make an angle with horizontal plane. The angle is called dip. In northern hemisphere the north end of needle is deflected downwards.

(vii) Isoclinic lines: Lines of equal dip.

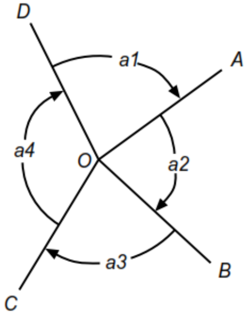
(viii) Aclinic lines: Lines of zero dip, near equator at poles needle will be vertical.

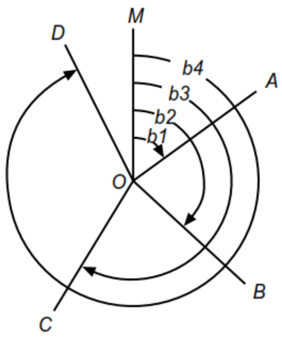
Ways to report directions

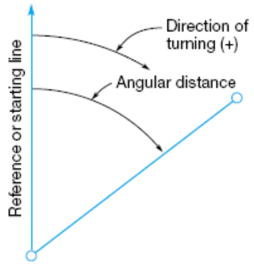
Meridian

Meridian is a line of reference which may be chosen to which all angles are referred.

The direction of any line with respect to the line of reference is given by the angle between the lines and its direction of rotation.



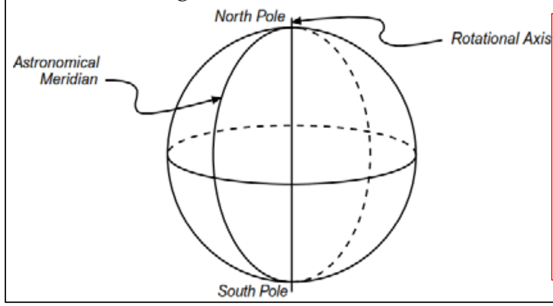




Types of meridians

True or astronomic or geographic meridian

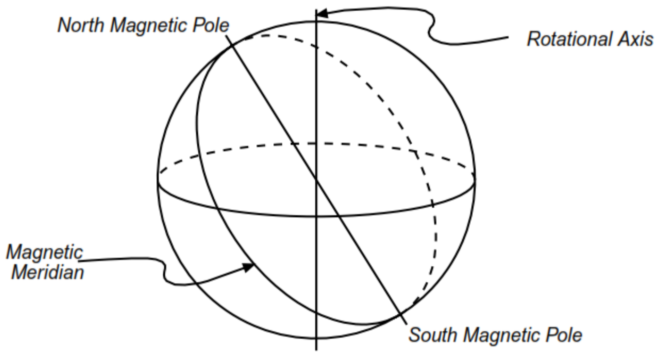
- If north-south line passing through geographical north is chosen. Determined by astronomical observations. For a given point on earth, its direction is always the same. True meridian converge at poles.
- A plane passing through a point on the surface of the earth and containing the earth's axis of rotation defines the astronomical or true meridian at that point. Astronomical meridians are determined by observing the position of the sun or a star. For a given point on the earth, its direction is always the same and therefore directions referred to the astronomical or true meridian remain unchanged. This makes it a good line of reference.



- Astronomical or true meridians on the surface of the earth are lines of geographic longitude and they converge toward each other at the poles.
- Amount of convergence between meridians depends on the distance from the equator and the longitude between the meridians.

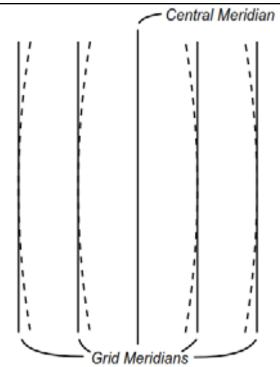
Magnetic meridian

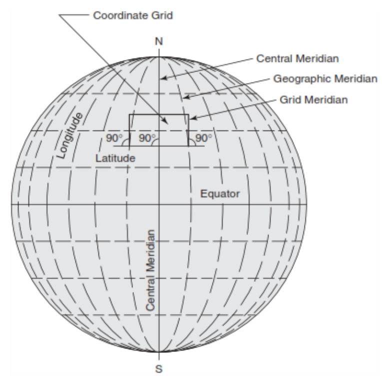
- If reference line is parallel to magnetic line of forces of earth as indicated by direction of magnetic needle.
- Its direction is taken as that of a freely suspended magnetic needle. Magnetic meridian is not parallel to true meridian. Location of magnetic poles always changing hence the magnetic meridian also changes. Therefore, not a good reference. It is employed for rough surveys such as compass surveys.



Grid meridian

- If reference line is a line parallel to a central true meridian. In rectangular/plane survey work of limited extent, it is convenient to choose one central meridian which coincides with a true meridian, all remaining meridians are parallel to this central meridian and are called grid meridians.
- In plane surveying we assume that all measurements are projected to a horizontal plane and that all meridians are parallel straight lines. These are known as grid meridians.





Relationship between grid and geographic meridian

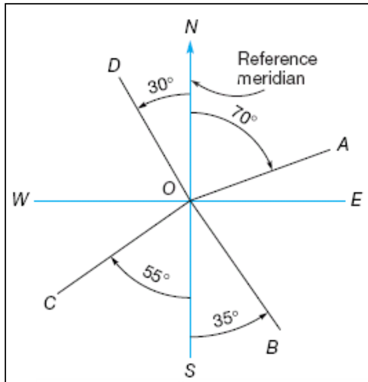
Geodetic meridian

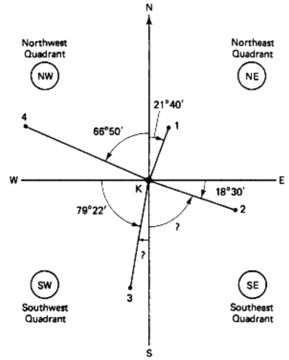
- If reference line is a north-south line passing through Geodetic north is chosen.

Assumed meridian

- If reference direction is arbitrarily chosen.
- On certain types of localized surveying, it may not be necessary to establish a true, magnetic, or grid direction. However it is usually desirable to have some basis for establishing relative directions within the current survey. This may be done by establishing an assumed meridian.
- An assumed meridian is an arbitrary direction assigned to some line in the survey from which all other lines are referenced. This could be a line between two property monuments, the centerline of a tangent piece of roadway, or even the line between two points set for that purpose.
- The important point to remember about assumed meridians is that they have no relationship to any other meridian and thus the survey cannot be readily (if at all) related to other surveys. Also, if the original monuments are disturbed, the direction may not be reproducible.

Bearing





Line	Bearing
K-1	N.21°40'E
K-2	S.71°30'E
K-3	S.10°38'W
K-4	N.66°50'W

- Direction of a line with respect to given meridian. Can be true (astronomic), magnetic or assumed depending upon the type of reference meridian used.
- A bearing is the direction of a line given by the acute angle between that line and a meridian.
- Bearing angle, which can be measured clockwise or counterclockwise from the north or south end of a meridian, is always accompanied by the letters that describe the quadrant in which the line is located (NE, SE, SW, and NW).
- Indicated by quadrant in which the line falls and the acute angle that the line makes with the meridian in that quadrant.

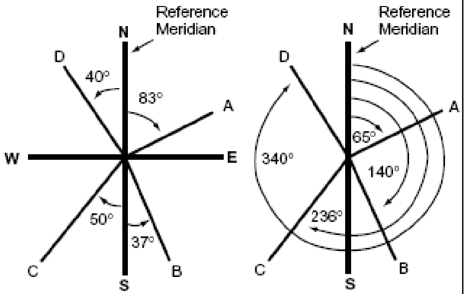
Bearing

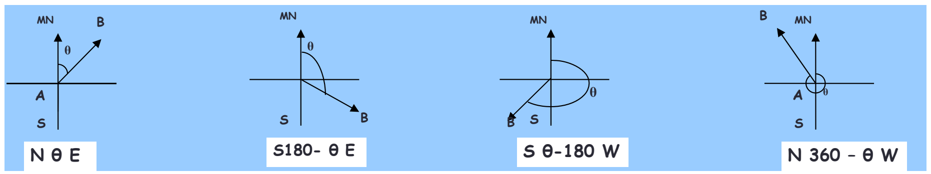
(i) Magnetic Bearing: of a line is the angle it makes with direction of magnetic north in clock wise direction.

(ii) True Bearing: of a line is angle with true north in clockwise direction Range: (0^0 to 360^0).

(iii) Whole circle bearing (WCB): since major/true bearings recorded on 0 to 360 scale i.e. full circle.

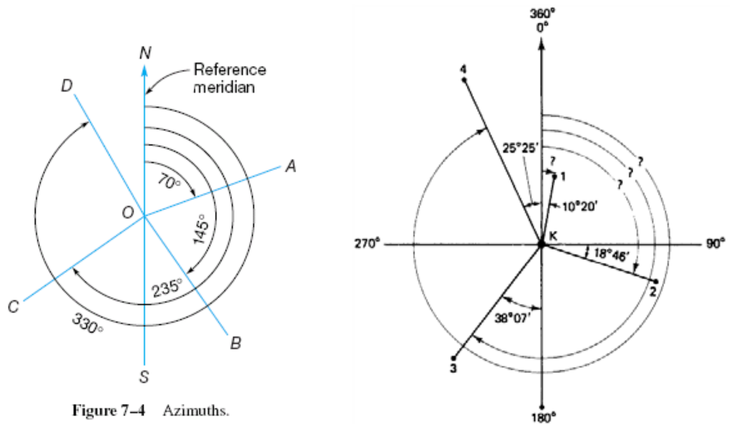
(iv) Reduced/Quadrantal bearing: It is the smallest of the two angle, the given line makes with N-S line. Always fixed by quadrant. It helps us in finding trigonometric functions if angle < 90^0.





Azimuths

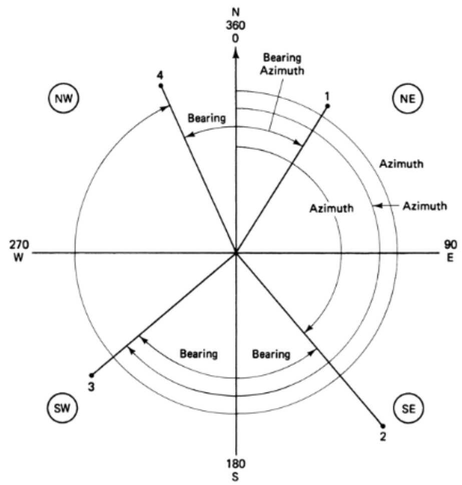
- It is the direction of a line with respect to a reference meridian and given by the angle the line makes with the meridian.
- Azimuths may be true (astronomic), magnetic or assumed depending upon the type of reference meridian used.
- Values lie between 0 to 360° and usually measured from north in clockwise direction.



Line	Azimuth
K1	10°20′
K2	108°46′
K3	218°07′
K4	334°35′

Figure 7–4 Azimuths.

Relationship between bearing and azimuth



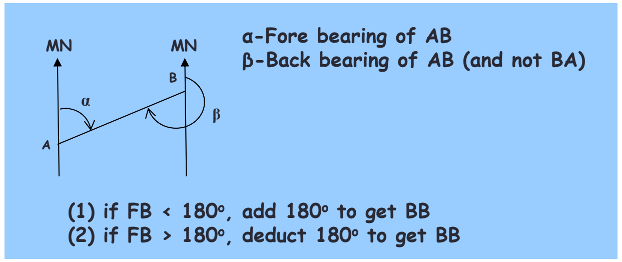
1. NE quadrant: bearing = azimuth
2. SE quadrant: bearing = 180° − azimuth
3. SW quadrant: bearing = azimuth − 180°
4. NW quadrant: bearing = 360° − azimuth

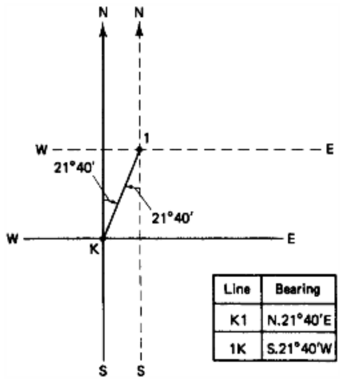
Fore bearing

Compass readings taken from a station to other station in a direction in which the survey is conducted.

Back/reverse bearing

Bearing taken from the next station to its preceding station from which the fore bearing was taken.





Line	Bearing
K1	N.21°40'E
1K	S.21°40'W

Fore and back/reverse bearing

Deflection angle

- Angle between a line and the prolongation of the preceding line. These angles are recorded as right or left depending upon the line to which the measurements are taken lies to the right (clockwise) or left (counterclockwise) of the prolongation of the previous line.
- In any closed polygon, algebraic sum of deflection angles is equal to 360°.

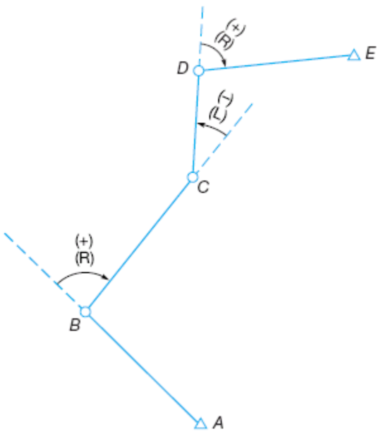


Figure 7–3 Deflection angles.

Example: Clockwise traverse

Line	Length	FB
AB	200	50^0
BC	320	170^0
CD	430	230^0
DA	-	310^0

- Get internal angles
- Plot traverse and give value of DA
- First compute BB
- Then compute internal angles
- Check summation of all internal angles is (2N – 4) right angles = 360° in this case

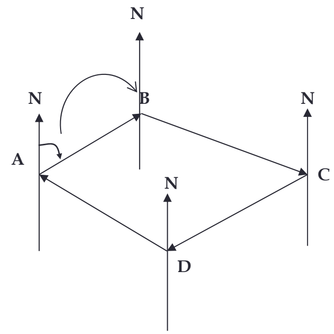
Line	FB	BB
AB	50^0	230^0
BC	170^0	350^0
CD	230^0	50^0
DA	310^0	130^0

$$\angle B = 230° - 170° = 60°$$

$$\angle C = 350° - 230° = 120°$$

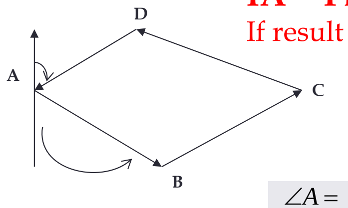
$$\angle D = (50° + 360°) - 310° = 100°$$

$$\angle A = 130° - 50° = 80°$$



Example: Anti-clockwise traverse

Line	Length	FB	BB (from FB)
AB	200	130^0	310^0
BC	300	50^0	350^0
CD	400	350^0	170^0
DA	--	230^0	50^0



IA = FB of forward line - BB of preceding line

If result is –ve then it should be deducted from 360^0

$\angle A =$ FB of AB (the forward line) -BB of DA (the preceeding line)

$= 130° - 50° = 80°$

$\angle B = 50 - 310 = -260°$, $\therefore$ -ve hence deducted from 360°

$\angle B = 360° - 260° = 100°$

$\angle C = 350° - 230° = 120°$

$\angle D = 230° - 170° = 60°$

Ex-1: Computation of azimuths with included angles

Table 4-1

Counterclockwise Solution		
Course	**Azimuth**	**Bearing**
BC	270°28′	N 89°32′ W
CD	209°05′	S 29°05′ W
DE	134°27′	S 45°33′ E
EA	62°55′	N 62°55′ E
AB	330°00′	N 30°00′ W
Clockwise Solution		
Course	**Azimuth**	**Bearing**
AE	242°55′	S 62°55′ W
ED	314°27′	N 45°33′ W
DC	29°05′	N 29°05′ E
CB	90°28′	S 89°32′ E
BA	150°00′	S 30°00′ E

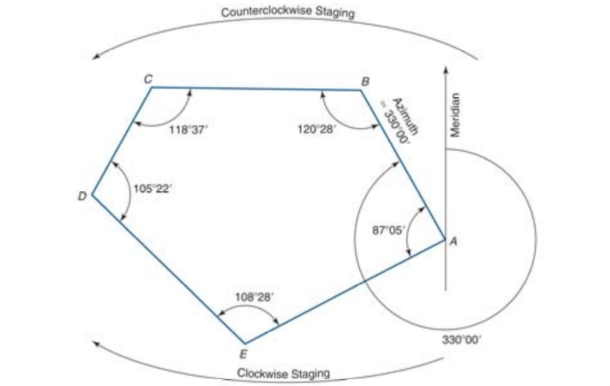


FIGURE 4-10 Sketch for azimuth calculations. Computations can be staged to proceed clockwise or counterclockwise

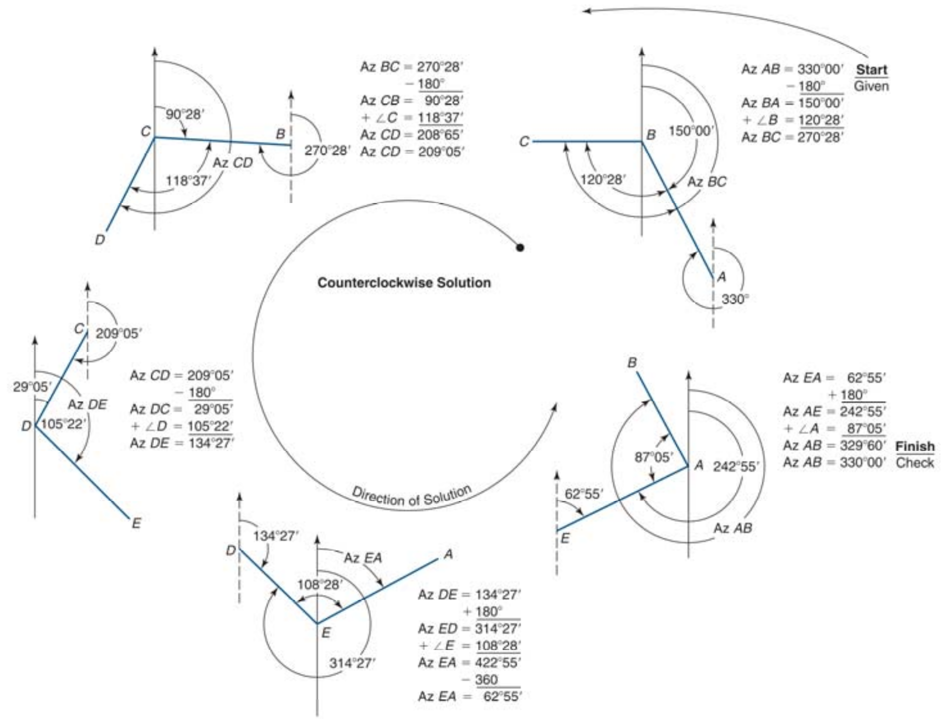


FIGURE 4-11 Azimuth calculations: counterclockwise solution

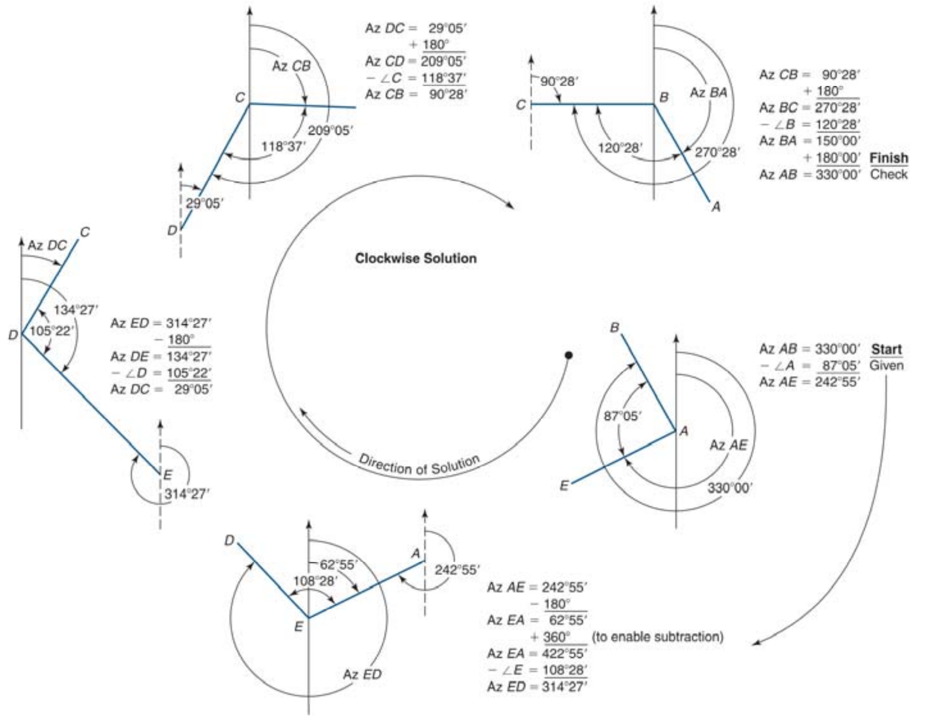
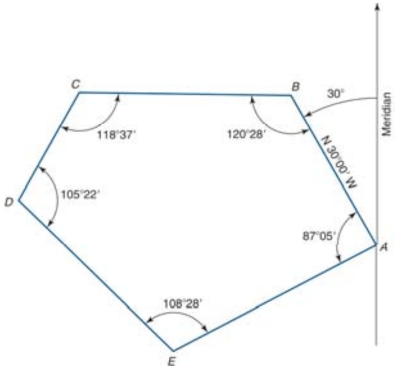


FIGURE 4-12 Azimuth calculations: clockwise solution

Bearing computation



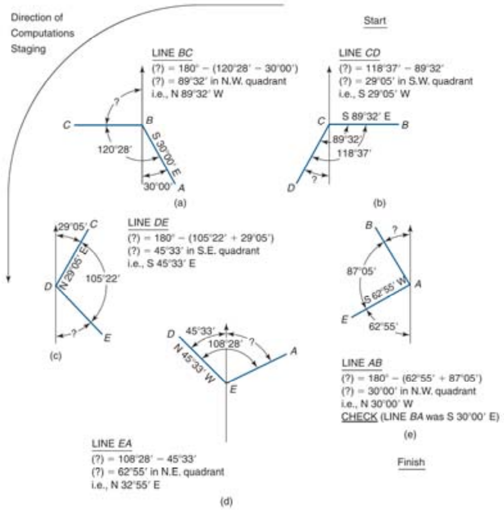


Table 4-1

Counterclockwise Solution		
Course	**Azimuth**	**Bearing**
BC	270°28′	N 89°32′ W
CD	209°05′	S 29°05′ W
DE	134°27′	S 45°33′ E
EA	62°55′	N 62°55′ E
AB	330°00′	N 30°00′ W
Clockwise Solution		
Course	**Azimuth**	**Bearing**
AE	242°55′	S 62°55′ W
ED	314°27′	N 45°33′ W
DC	29°05′	N 29°05′ E
CB	90°28′	S 89°32′ E
BA	150°00′	S 30°00′ E

Summary of calculations

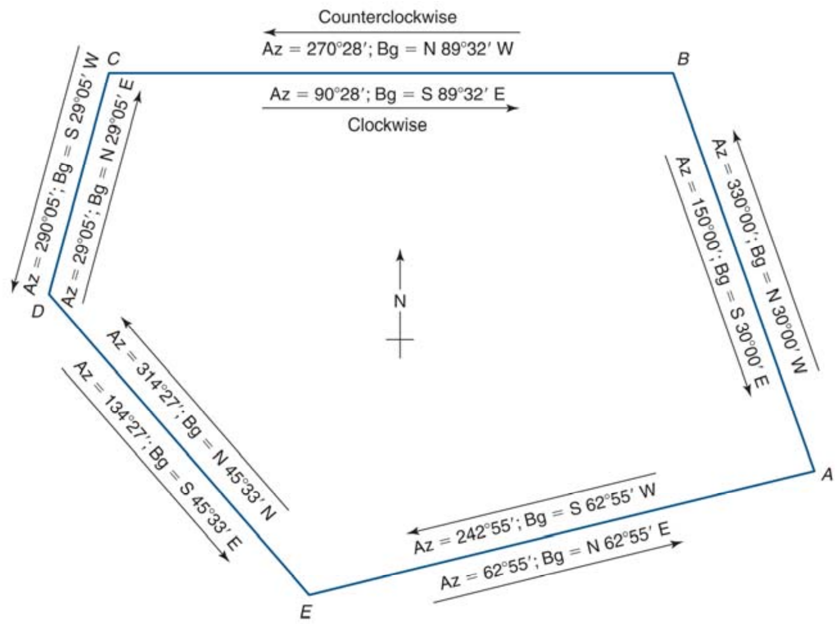
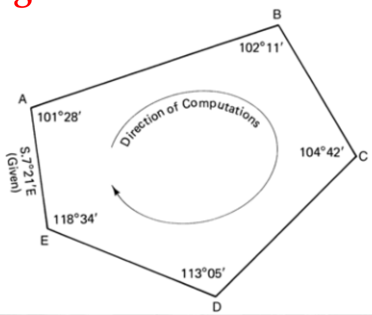
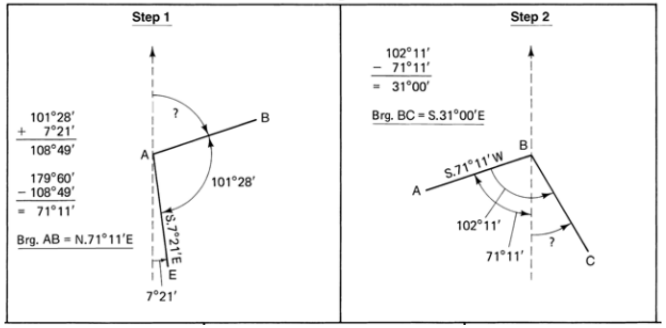


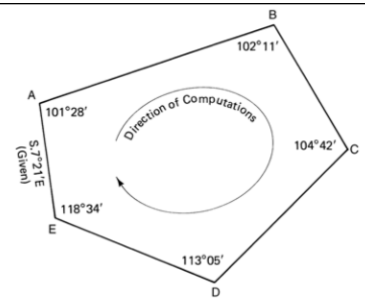
FIGURE 4-15 Summary of results from clockwise and counterclockwise approaches

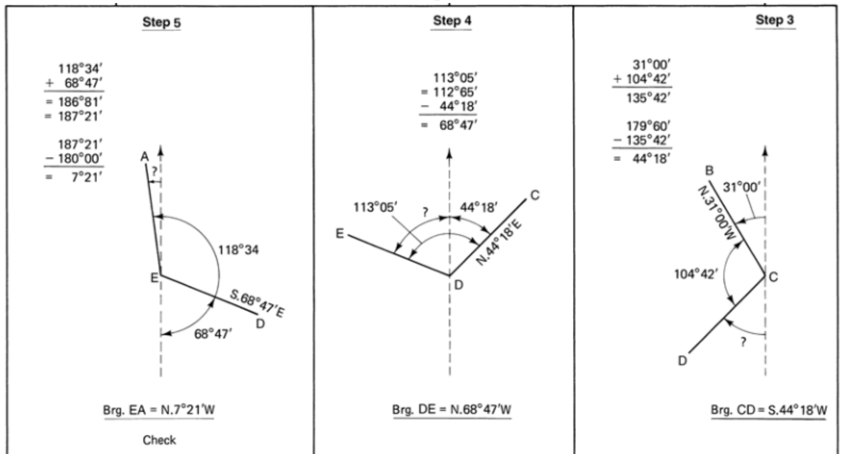
Ex-2: Computation of bearing

(given: included angle in a closed traverse and clockwise mode)

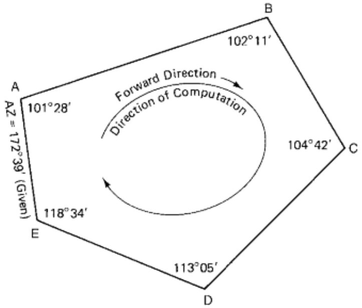


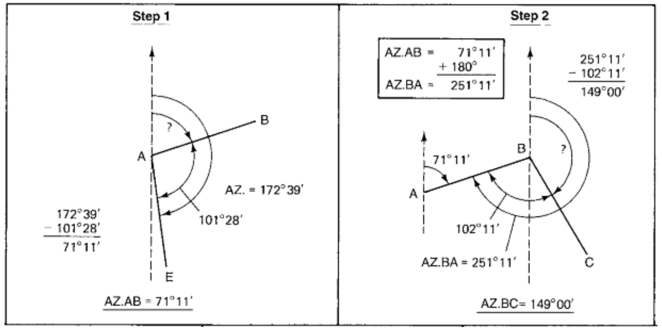


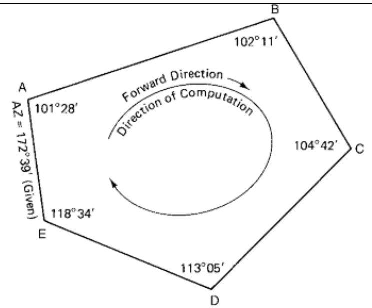


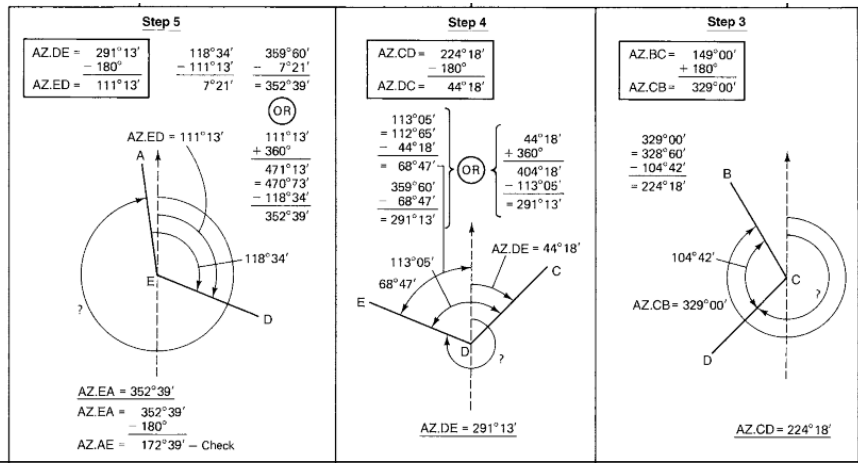


Computation of Azimuth

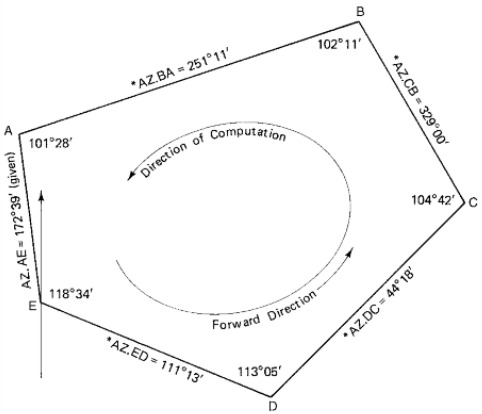








Azimuth computation counter-clockwise computation



AZ.AE =	172°39′	Forward Azimuth
	+ 180°	
AZ.EA =	352°39′	Back Azimuth
+ E	118°34′	Interior Angle
AZ.ED =	470°73′	Forward Azimuth
↓ OR	− 360°	↓
*AZ.ED =	111°13′	Forward Azimuth
	+ 180°00′	
AZ.DE =	291°13′	Back Azimuth
+ D	113°05′	Interior Angle
AZ.DC =	404°18′	Forward Azimuth
↓ OR	− 360°	↓
*AZ.DC =	44°18′	Forward Azimuth
	+ 180°	
AZ.CD =	224°18′	Back Azimuth
+ C	104°42′	Interior Angle
*AZ.CB =	329°00′	Forward Azimuth
	− 180°	
AZ.BC =	149°00′	Back Azimuth
+ B	102°11′	Interior Angle
*AZ.BA =	251°11′	Forward Azimuth
	− 180°	
AZ.AB =	71°11′	Back Azimuth
+ A	101°28′	Interior Angle
*AZ AE =	172°39′ CHECK	Forward Azimuth

*Computed Counterclockwise Forward Azimuth

Technique for Counterclockwise Solution:
Back Azimuth of Previous Course + Interior Angle = Forward Azimuth

Computation of Azimuths/bearings from included angles (IA)

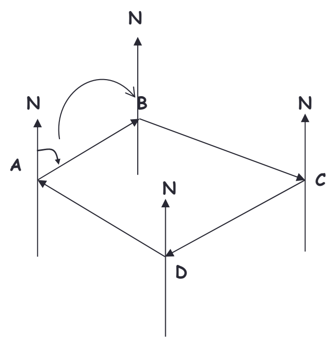
- When survey is conducted in Clockwise direction, we have

Included angle B = BB of preceding line (AB) – FB of forward line (BC)

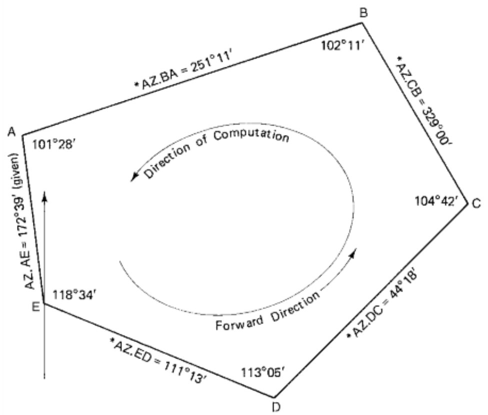
Included angle ABC = ∠NBA - ∠NBC

= BB of preceding line - FB of forward line

However, if FB to be deducted from BB is greater then BB then add 360° to BB and proceed.



Azimuth computation counter-clockwise computation



AZ.AE =	172°39′	Forward Azimuth
	+ 180°	
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*AZ.ED =	111°13′	Forward Azimuth
	+ 180°00′	
AZ.DE =	291°13′	Back Azimuth
+ D	113°05′	Interior Angle
AZ.DC =	404°18′	Forward Azimuth
↓ OR	− 360°	↓
*AZ.DC =	44°18′	Forward Azimuth
	+ 180°	
AZ.CD =	224°18′	Back Azimuth
+ C	104°42′	Interior Angle
*AZ.CB =	329°00′	Forward Azimuth
	− 180°	
AZ.BC =	149°00′	Back Azimuth
+ B	102°11′	Interior Angle
*AZ.BA =	251°11′	Forward Azimuth
	− 180°	
AZ.AB =	71°11′	Back Azimuth
+ A	101°28′	Interior Angle
*AZ.AE =	172°39′	$\boxed{\text{CHECK}}$ Forward Azimuth

*Computed Counterclockwise Forward Azimuth

Technique for Counterclockwise Solution:
Back Azimuth of Previous Course + Interior Angle = Forward Azimuth

Local attraction (LA)

Magnetic needle influenced by:

- Presence of steel or bunch of keys likely to attract magnetic needle. Hence readings by compass will be in error.
- The deflection of magnetic needle due to the presence of some magnetic substances is known as local attraction.
- If the difference between fore bearing and back bearing of a line does not equal to 180^0, it is concluded that one of the two stations is suffering from local attractions.
- In order to find out which station is suffering from LA, select a point O lying on line AB.
- Assuming O to be free from LA, check which line segments (OA or OB do not satisfy relationship between fore bearing and back bearing.

Example

Line	FB	BB	Difference
AB	$24^037'$	$204^037'$	180
BC	$48^013'$	$225^010'$	$176^057'$
CD	$37^027'$	$221^00'$	$183^033'$
DE	$18^04'$	$137^033'$	$179^029'$

1. A and B free from local attraction as BB – FB = 180^0.
2. FB of observed BC from B is taken as correct.
    1. Hence for a correct FB of BC as $48^013'$, the correct BB of line BC from C will be $48^013' + 180^0 = 228^013'$, but actually it is $225^010'$.
    2. Hence, C is suffering from LA and Magnetic North is deflected to east by $3^03'$. Hence, bearing from C is increased by $3^03'$ so as to correct bearings taken from C. Therefore, correct BB of BC = $228^013'$. Hence correct FB of CD = $37^027' + 3^03'$.

3) For correct FB of $40^030'$ from C of line CD, the correct BB should be $40^030' + 180^0 = 220^030'$, But actually it is 221^0 hence D also has local attraction and needle is deflected to west by 30′. Hence, all bearings taken from D need to be reduced by 30′. Therefore, correct BB of CD will be $220^030'$ and correct FB of DE = $18^04' - 30' = 17^034'$,

4) For a correct FB of $17^034'$ of line DE, the BB of DE should be $17^034' + 180^0 = 197^044'$ and not $197^033'$ (as observed). Hence, E also has LA and magnetic needle at E deflected by 1′ to East.

CORRECT ANSWER

Line	FB	BB	Diff
AB	$24^037'$	$204^037'$	180^0
BC	$48^013'$	$228^013'$	,,
CD	$40^030'$	$220^030'$	,,
DE	$17^034'$	$197^034'$	,,

Instruments for measuring directions

- Compass
- Transit/Theodolite
- Total Station

Types of compasses

Mainly three types

- Trough
- Prismatic
- Surveyor's compass.

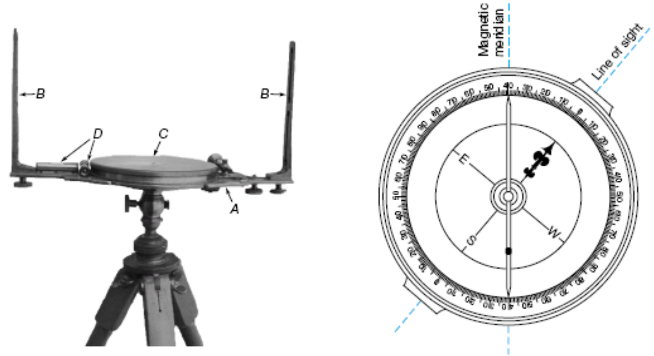


Figure 7–9 (a) Surveyor's compass. (Courtesy W. & L.E. Gurley.) (b) Compass box.

Sources of errors

Instrumental Errors

- Magnitude needle may not be perfectly straight.
- Pivot on which the needle rests may be bent.
- Needle might become dull.
- Pivot point may become dull.
- Magnitude needle may not move in a perfectly horizontal plane due to dip.
- Sides of compass may not be truly vertical.
- Graduated circle may not be truly horizontal.
- Line of sight may not pass through the center of the graduated ring.
- Vertical hair may be either too thick or too loose.

Personal Errors

- Inaccurate centering
- Non-horizontality of compass box.
- Imperfect bisection of objects.
- Reading graduation in wrong direction.
- Carelessness in recording the readings.

External Errors

- Magnetic Changes in the atmosphere on stormy days.
- Irregular variation due to magnitude storms or earthquakes.
- Variation in declination.
- Local attractions.

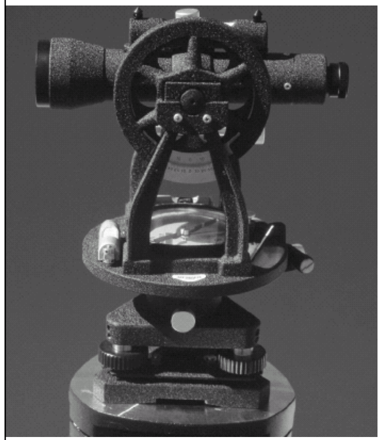
Applications

- Rough traverse.
- Preliminary/reconnaissance work.
- Filling of details in topographic survey.
- Military for night marches.
- Quick survey: when only limited time is available.
- Route survey.

Direction measurement with Theodolites

- Theodolites or transits are used to measure horizontal angles. These have evolved as follows:
  - Vernier theodolite (open face and Vernier equipped instruments)
  - Optical theodolite (enclosed with optical readouts with direct digital readouts or micrometer equipped readouts)
  - Electronic theodolites (enclosed with electronic readouts)
  - Total stations (electronic angle and distance measuring instrument)

Vernier theodolite



Temporary adjustments

- Centre the instrument over the station by tripods and plumb bobs.
- Make the vertical axis of instrument truly vertical by bringing the bubble of both the levels in centre of its run so that when the bubble is in the centre the level plates may revolve in a horizontal plane.
- Set eyepiece so as to get clear vision of diaphragm wires.
- Remove parallax by means of focusing screw so that image falls on the plane of diaphragm. This means that when eye is moved up and down while looking through the telescope there is no relative motion between the object and diaphragm wires.
- Set the Vernier and arc Vernier to read zero when line of collimation is horizontal by means of clip screws.

1. A vernier
2. azimuth axis
3. x vernier
4. center of half ball
5. elevation or horizontal axis
6. footplate
7. graduations of horizontal circle
8. half ball
9. half ring
10. horizontal circle (lower plate)
11. inner center, or alidade spindle
12. leveling screw
13. lower clamp screw
14. lower clamp drum contact
15. lower tangent screw for slow motion
16. nub for lower clamp
17. nub for upper clamp
18. outer center
19. plate level
20. shifting plate
21. shoe
22. telescope
23. threads for tripod
24. upper clamp screw
25. upper clamp drum contact
26. upper plate
27. upper tangent screw for slow motion
28. vertical circle
29. vertical-circle vernier
30. window, glass
31. telescope level
32. vertical tangent screw for slow motion
33. focusing screw for focusing on object sighted
34. eyepiece focusing ring

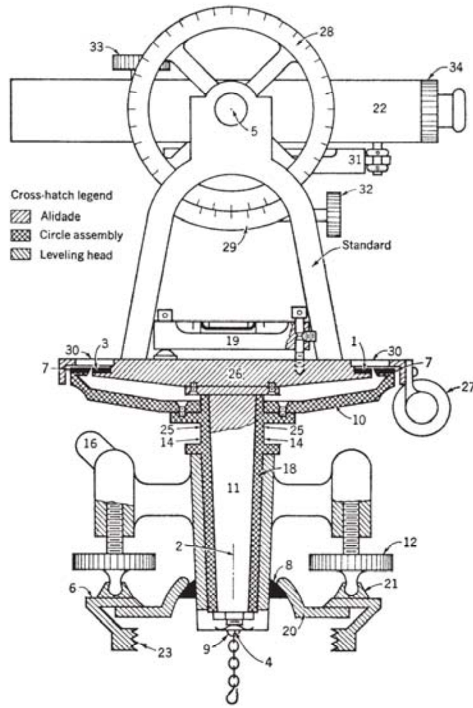


FIGURE A-1. Principle parts of the transit design.

Basic lines in Vernier

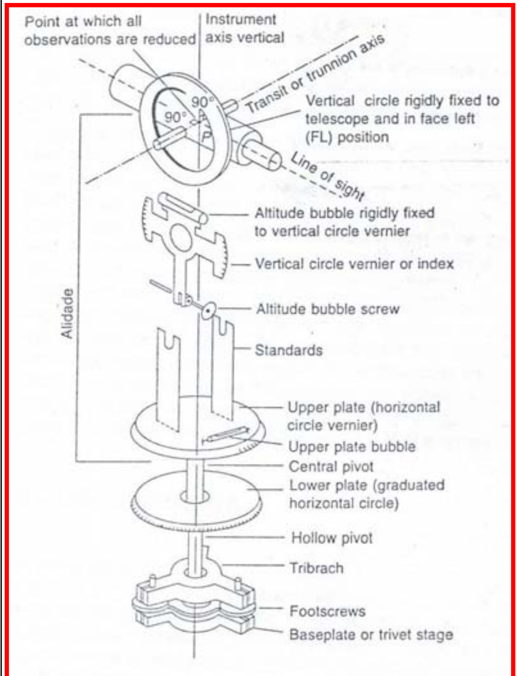


Fig. 4.3 *Simplified vernier theodolite*

- Vertical axis

  About which lower and upper plates rotate. Each plate and its own axis and both should coincide.

- Horizontal axis

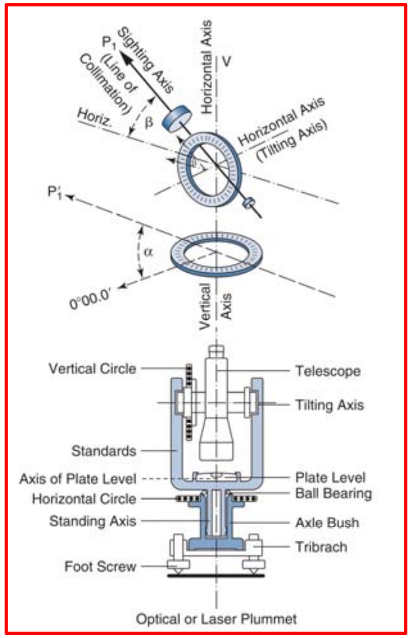
  About which telescope and vertical circle rotate.

- Line of sight or line of collimation

  A line passing through intersection of horizontal and vertical cross hairs in telescope and optical centre of object lens of telescope.

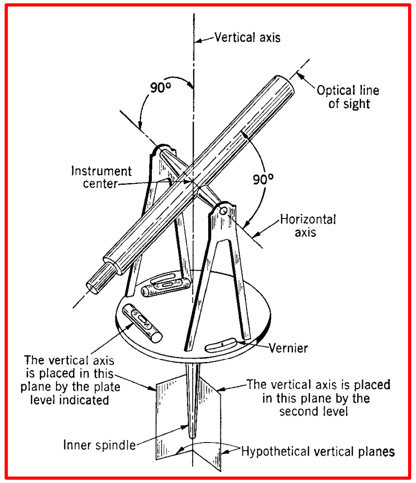
  This line should be perpendicular to the horizontal axis and it should also be truly horizontal when reading on the vertical circle is zero and bubble on the telescope or on Vernier frame is at its centre of its run.

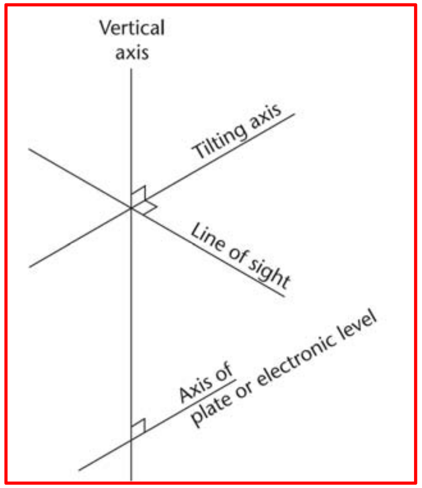
Conditions amongst important lines



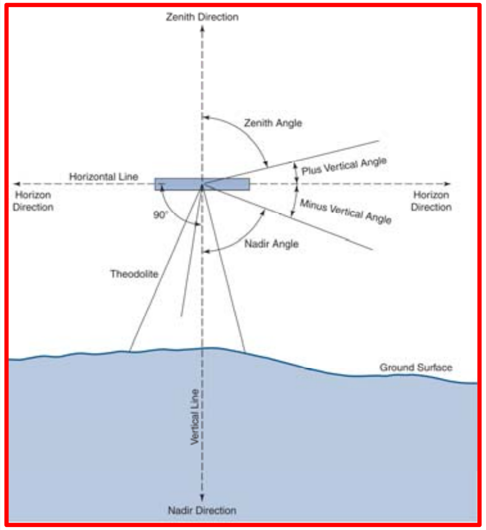
- Line of collimation should coincide with optical axis of telescope.
- The line of collimations should be perpendicular to trunnion axis.
- The trunnion axis should be horizontal and perpendicular to vertical axis of theodolite.
- The vertical axis should be truly vertical.
- The horizontal axis should be perpendicular to the vertical circle and should pass through the centre of vertical circle of graduation.
- The vertical circle should be perpendicular to the horizontal circle and pass through the centre of horizontal circle of graduation.

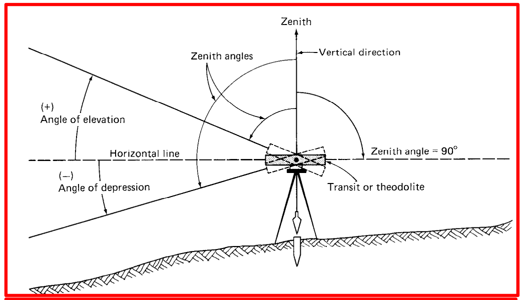
Schematic for various lines/axes in Theodolite/TS

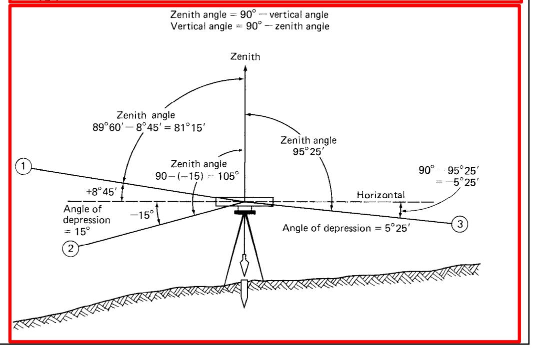




Relationships for vertical direction: horizontal, zenith and nadir

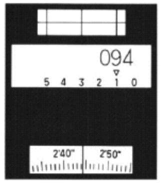


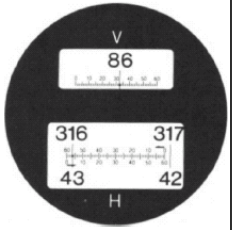




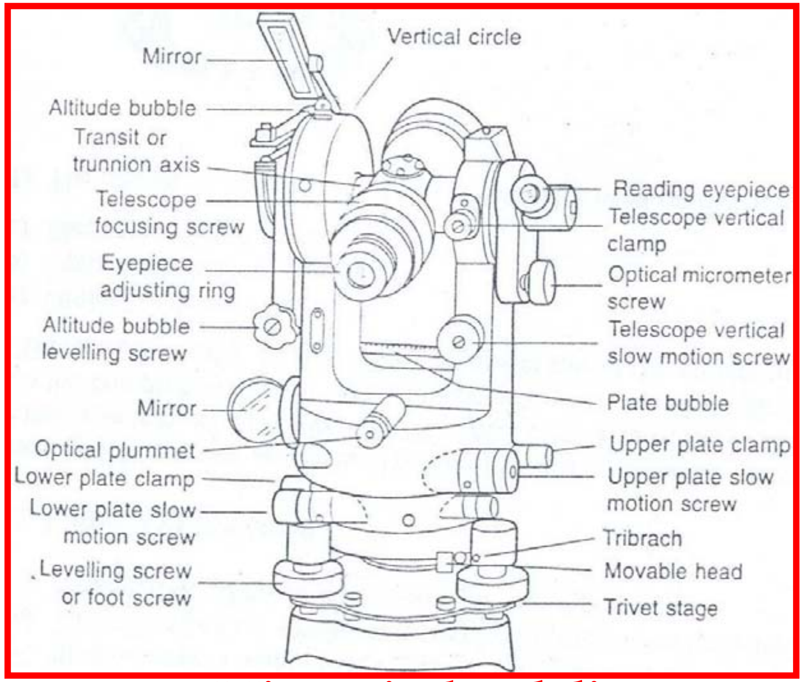
Microptic theodolites

Wild T-2 optical reading directional theodolite and reading system for the Wild T-2





Lietz T60E optical-reading repeating theodolite and reading system for optical-reading repeating theodolite.

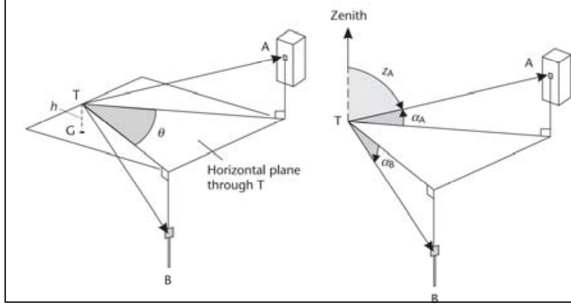


Microptic theodolite

Horizontal, vertical and zenith angles

Two points A and B and a theodolite or total station T set up on a tripod above a ground point G. Point A is higher than the instrument and is above the horizontal plane through T, whereas B is lower and below the horizontal plane. At T, the instrument is mounted a vertical distance h above G on its tripod.

- **Horizontal angle** at T between A and B is not the angle in the sloping plane containing A, T and B, but the angle θ on the horizontal plane through T between the vertical planes containing the lines of sight TA and TB.
- **Vertical angles** to A and B from T are α_A (an **angle of elevation**) and α_B (an **angle of depression**).
- **Zenith angle:** defined as the angle in the vertical plane between the direction vertically above the instrument and the line of sight, for example z_A.

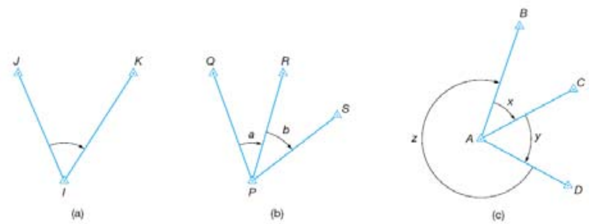


To measure horizontal and vertical angles, a theodolite or total station must be centred over point G and must be levelled to bring the angle reading systems of the instrument into the horizontal and vertical planes. Although centring and levelling ensure that horizontal angles measured at T are the same as those that would have been measured if the instrument had been set on the ground at point G, the vertical angles from T are not the same as those from G, and the value of h, the height of the instrument, must be taken into account when height differences are being calculate

Angle measurement methods

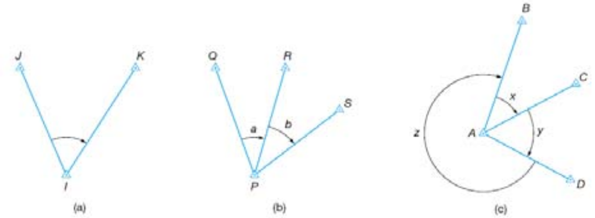
(a) Method of repetition

- Used when single angle is to be measured with great accuracy. Following errors are eliminated by this method:
  - Personal error in bisection.
  - Error in unequal bisection.
  - Angles can be read to less than least count of Vernier. $\angle AOB = n\alpha/n$



HORIZONTAL ANGLE MEASUREMENT

Angle	First Reading	Fourth Reading	Mean Angle
(1)	(2)	(3)	(4)
	° ′ ″	° ′ ″	° ′ ″
JIK	66 37 40	266 30 48	66 37 42



DIRECTIONS OBSERVED FROM STATION P

Repetition No.	Station Sighted	Reading Direct	Reading Reverse	Mean	Angle
(1)	(2)	(3)	(4)	(5)	(6)
		° ′ ″	° ′ ″	° ′ ″	° ′ ″
1	Q	0 00 00	0 00 00	0 00 00	
	R	37 30 27	37 30 21	37 30 24	37 30 24
	S	74 13 42	74 13 34	74 13 38	36 43 14
2	Q	0 00 00	0 00 00	0 00 00	
	R	37 30 32	37 30 28	37 30 30	37 30 30
	S	74 13 48	74 13 42	74 13 46	36 43 16
3	Q	0 00 00	0 00 00	0 00 00	
	R	37 30 26	37 30 26	37 30 26	37 30 26
	S	74 13 36	74 13 40	74 13 38	36 43 12
4	Q	0 00 00	0 00 00	0 00 00	
	R	37 30 34	37 30 30	37 30 32	37 30 32
	S	74 13 48	74 13 44	74 13 46	36 43 14

(b)

(b) Method of reiteration

- Adapted for horizontal angles in precise work when several angles are to be measured.

(c) Closing the horizon

CLOSING THE HORIZON AT STATION A

Position No.	Station Sighted	Reading Direct	Reading Reverse	Mean	Angle
(1)	(2)	(3)	(4)	(5)	(6)
		° ′ ″	° ′ ″	° ′ ″	° ′ ″
1	B	0 00 00	0 00 00	0 00 00	
	C	42 12 12	42 12 14	42 12 13	42 12 13
	D	102 08 26	102 08 28	102 08 27	59 56 14
	B	0 00 02	0 00 02	0 00 02	257 51 35
				Sum	360 00 02
2	B	0 00 00	0 00 00	0 00 00	
	C	42 12 12	42 12 14	42 12 13	42 12 13
	D	102 08 28	102 08 28	102 08 28	59 56 15
	B	0 00 04	0 00 04	0 00 04	257 51 36
				Sum	360 00 04
3	B	0 00 00	0 00 00	0 00 00	
	C	42 12 14	42 12 12	42 12 13	42 12 13
	D	102 08 28	102 08 26	102 08 27	59 56 14
	B	0 00 04	0 00 00	0 00 02	257 51 35
				Sum	360 00 02
4	B	0 00 00	0 00 00	0 00 00	
	C	42 12 14	42 12 12	42 12 13	42 12 13
	D	102 08 32	102 08 28	102 08 30	59 56 17
	B	0 00 04	0 00 04	0 00 04	257 51 34
				Sum	360 00 04

(c)

Methods of observation

- Set up the theodolite at O, level it and proceed as follows:

1)	Face Right	Swing Right	Approach Left	Initial zero 0°
2)	Face Right	Swing Left	Approach Right	Initial zero 90°
3)	Face Left	Swing Right	Approach Left	Initial zero 180°
4)	Face Left	Swing Left	Approach Right	Initial zero 270°

Face left/right (FL/FR)

- FL: When vertical circle to the left of observer while taking observations
- FR: If vertical circle is to the right of the observer then face right; Performed by translating the theodolite telescope and rotating the equipment in azimuth through 180°.

Swing right / left:

- If observation commences from some reference station such that they proceed in clockwise direction then swing right, otherwise swing left.

Approach left/right:

While making coincidences of cross wires with the object it is always the practice to undershoot the mark and by means of tangent screw make it coincident exactly from left hand side in case observations in clockwise direction and approaching from right hand side while making observation in anti-clockwise direction.

Initial Zero:

- The initial reading on starting station is said to be initial zero. It may not be necessary be 0°, may be 60°, 90°, 120° etc.

Elimination of errors

1) Errors eliminated by changing face:

a) Errors due to line of collimation not being perpendicular to transverse axis of telescope.

b) Errors due to transverse axis of telescope not being perpendicular to vertical axis.

c) Error due to line of collimation not coinciding with the axis of telescope.

2) Error eliminated due to change of zero:

a) Errors due to defects in graduations of main scale plate.

3) Error eliminated by reading Vernier several times:

a) Error due to axis of Vernier plate not coinciding with the axis of main scale plate.

b) Error due to unequal graduations.

4) Error eliminated due to swing left/right:

a) Error due to twist of instrument support.

5) Errors eliminated due to approaching from left/right:

a) Slip due to defective clamping and tangent screw arrangement.

Changing scene

- Last four decades revolutionized measurement techniques in surveying.
- Highly sophisticated and advanced tools for distance, direction and elevation measurements
- Main reason:
  - improvements in electronics, optics (larger resolution, magnification, less distortion), more precise graduations.
- Use of satellite sensors, use of computers, micro-computers
- Automation in instrumentation making data collection easier and fast.

Electronic angle and distance measurements

- Electronic Theodolites
- EDMs
- Total stations
  - Mechanical
  - Motorized
  - Robotic/Auto-lock

- Electronic Distance Measurement instruments
  - Digital readouts
  - Single and continuous measurement mode
  - Slope distance
  - Ability to be interfaced electronically to data collectors and computers for quick and error free data transfer
  - Ability to be mounted on theodolites
- Total Stations
  - All features of electronic theodolites and EDMs combined
  - Microprocessors for automatic monitoring the instrument status and a data collector to record and process field data to give Horizontal Distance, Vertical Distance, and X, Y, Z coordinates

Electronic Theodolite

- Electronic theodolites operate like any optical theodolite with one major difference that these instruments have only one motion (upper) and hence have only one horizontal clamp and slow motion screws.

Characteristics of electronic theodolites

- Angle least count can be 1″ with precision ranging from 0.5″ to 20″
- Digital readouts eliminate the personal error associated with reading and interpolation of scale and micrometer settings.
- Display window/unit for horizontal and vertical angles available at either one or both ends.
- Some digital theodolites have modular arrangement where they can be upgraded to be a total station or have an EDM attached for distance measurements.
- Vertical circles can be set to zero for horizon or zenith along with the status of battery shown in the display window.

Sokkia Electronic theodolite

- Typical specifications for digital theodolites can be given as follows:
  - Magnification: 26X to 30X
  - Field of view (FOV) 1.5°.
  - Shortest viewing distance 1.0 m
  - Angle readouts, direct 5″ to 20″
  - Level sensitivity: plate level vial 40″/2 mm, circular level vial 10″/2 mm

Specifications for Nikon electronic theodolite (NE203/202)

- Digital angle display is user-switchable from 5"/10" to 1 mgon/2 mgon (1"/5", 0.5 mgon/1 mgon, available as option on NE-203 only).
- Built-in vertical axis compensator automatically compensates for instrument inclination within ±3' (NE-203)
- Accuracy is 5"/1 mgon in 5"/1 mgon display mode.
- Large, dot-matrix dual-line LCD screen displays both vertical and horizontal angles simultaneously.
- LCD screen and keyboard are placed on both sides of the alidade for easier operation
- Telescope magnification of 30X with a 45 mm objective aperture diameter.
- Employs a unique linear focusing mechanism to simplify focusing at both short and long distances. Minimum focusing distance of 0.7 m/2.3 ft.
- Repeat horizontal angle measurement possible up to ±1999°59'55" or ±2222.2220G
- Continuous operation for up to 48 hours with fresh alkaline-manganese batteries (NE-202)