THEODOLITE SURVEYING

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INTRODUCTION

- Theodolite is an intricate instrument mainly used for accurate measurement of horizontal & vertical angles
- Because of its various uses it is sometimes known as "Universal Instrument"
- Different purposes
  - Horizontal angle
  - Vertical angle
  - Deflection angle
  - Magnetic bearing
  - Horizontal distance between points
  - Vertical height of an object
  - Difference of elevation between various points
  - Ranging of a line

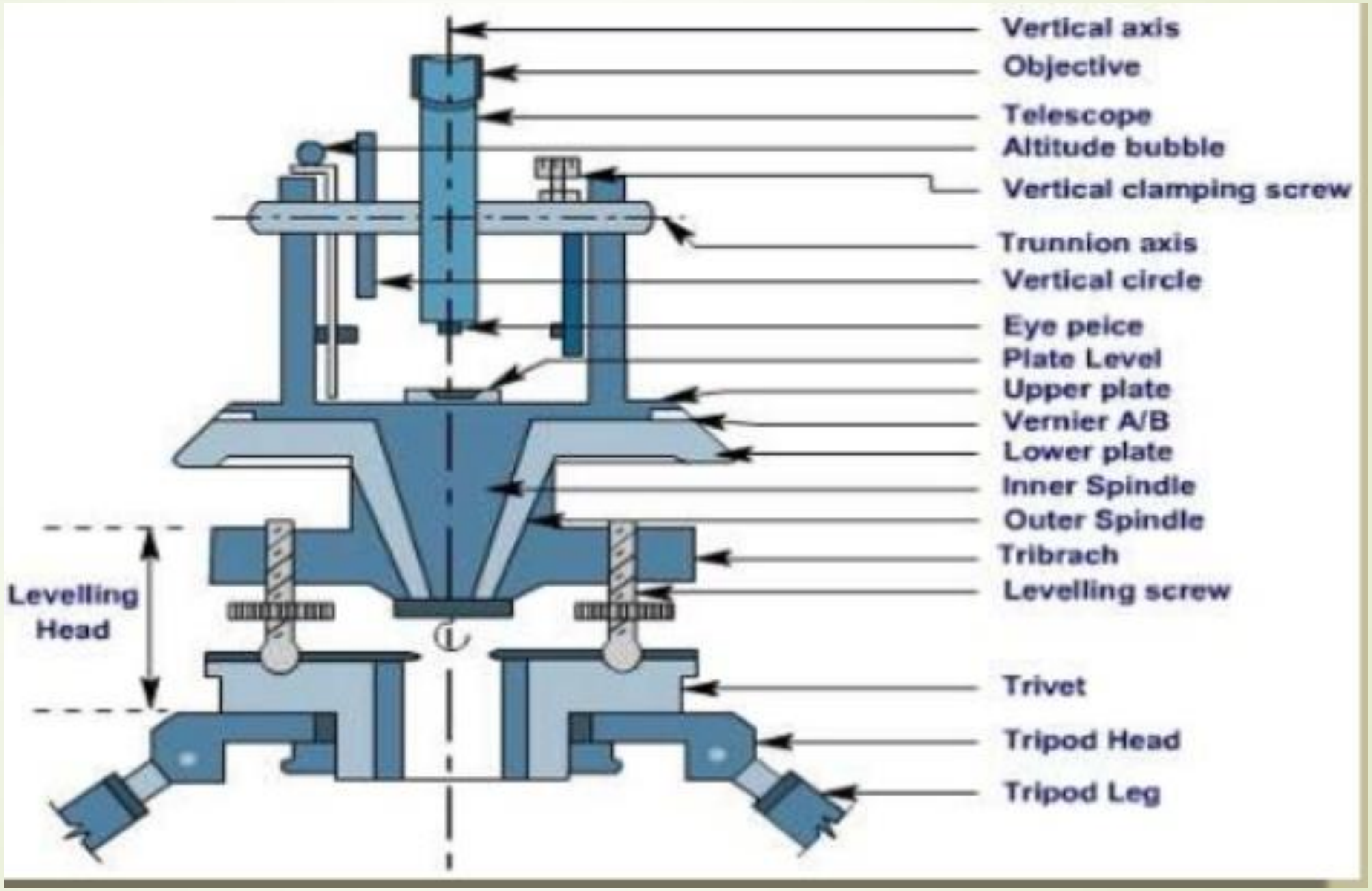
CLASSIFICATION OF THEODOLITE

- Primarily classified as:
  1. Transit Theodolite

     - In transit theodolite, the telescope can be revolved through a complete revolution about its horizontal axis in a vertical plane
  2. Non-transit theodolite

     - Here, the telescope cannot be revolved through complete revolution in the vertical plane
- Theodolites can also be classified as
  1. Vernier theodolite
  2. Micrometer theodolite

PARTS & ITS FUNCTION



https://www.youtube.com/watch?v=CBlhQ76LAyI

BASIC DEFINITIONS

1. Centring

   -Setting of a theodolite exactly over a station mark by means of a plumb bob

2. Transiting or Plunging of telescope

   - Turning the telescope about its horizontal axis in a vertical plane through 180 degrees. Transiting results in change of face

3. Face Right/ Left

   - Face left means the vertical circle of theodolite is on the left of the observer at the time of reading

4. Swinging the telescope

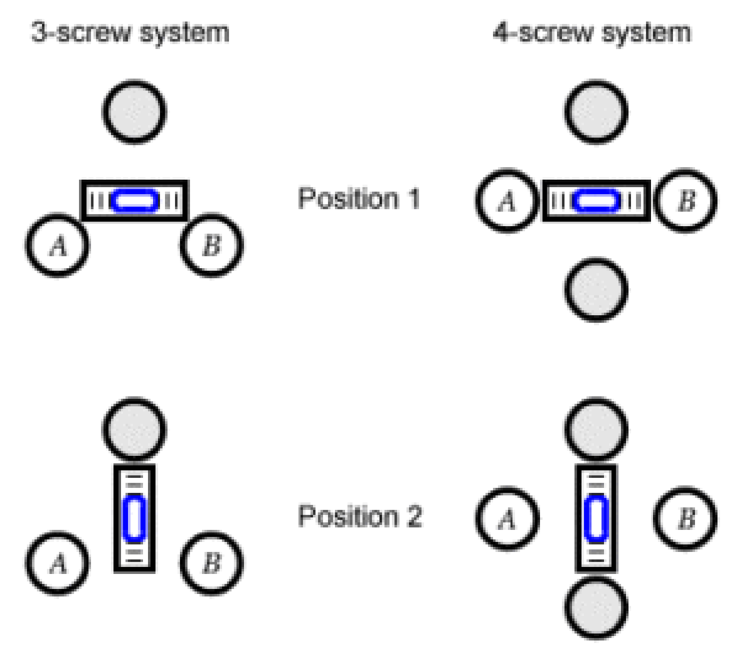
   -turning the telescope in a horizontal plane. It is called right swing if the telescope is turned clockwise and left swing if telescope is turned anti clockwise

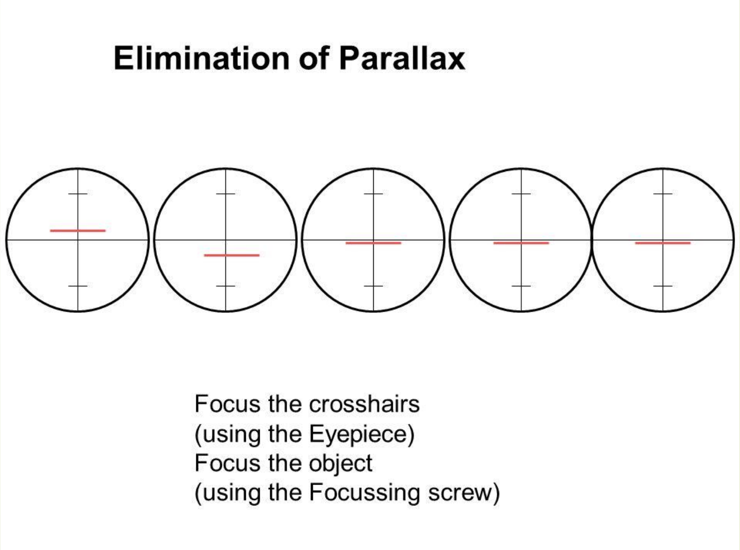
5. Line of collimation

   - Imaginary line passing through optical centre of objective glass and its continuation

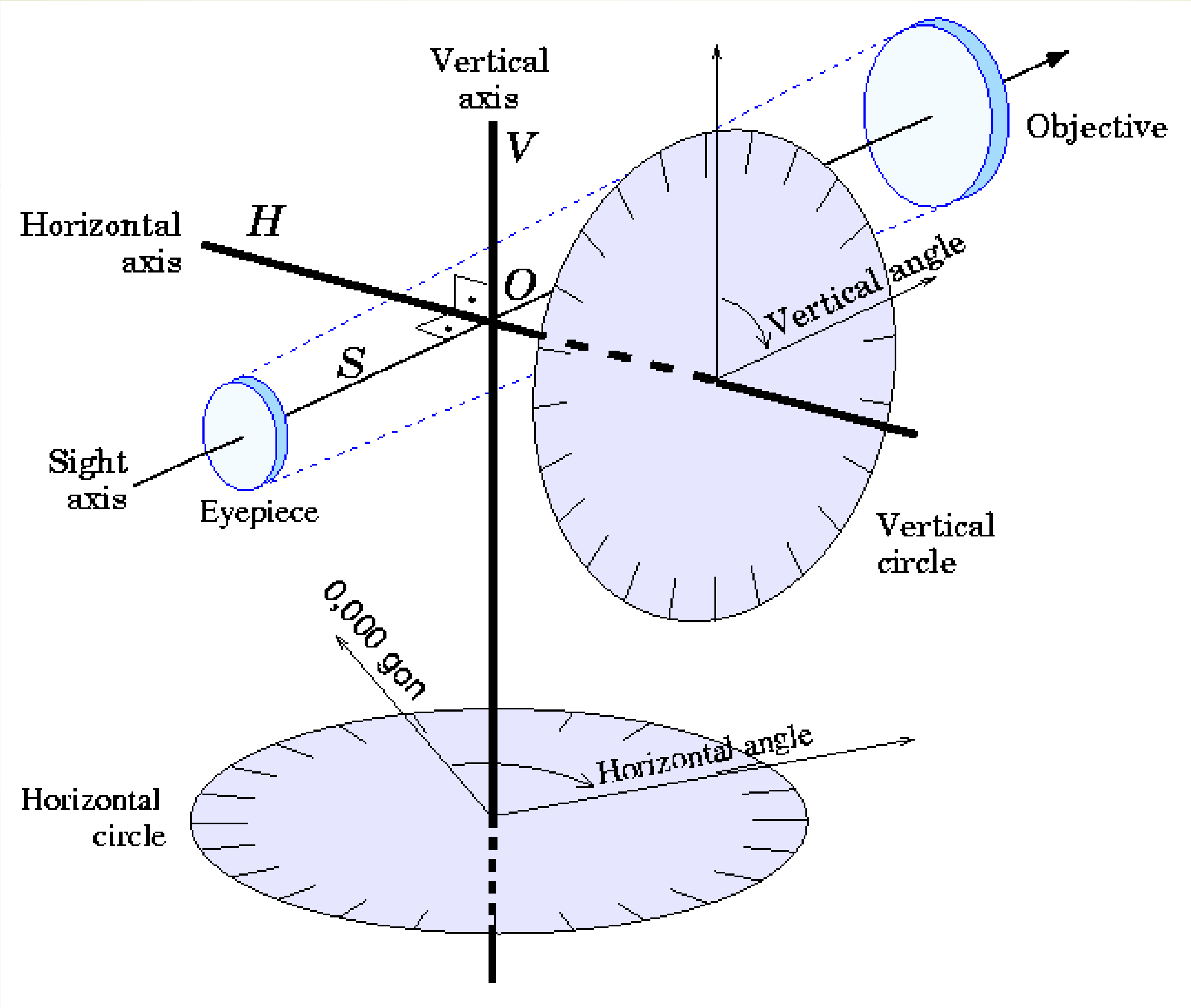
TEMPORARY ADJUSTMENTS

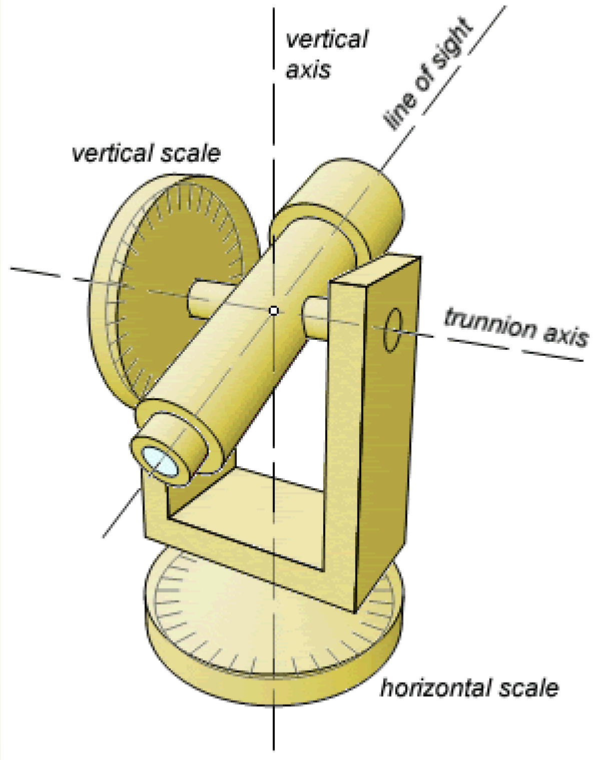
1. Setting up of theodolite over a station
2. Levelling Up
3. Focusing of eye piece & elimination of parallax
   - Focusing of eyepiece: clear and distinct view of cross hairs
   - Focusing of object glass : parallax elimination i.e., the image of object formed will be in the plane of cross hairs





FUNDAMENTAL AXES OF THEODOLITE



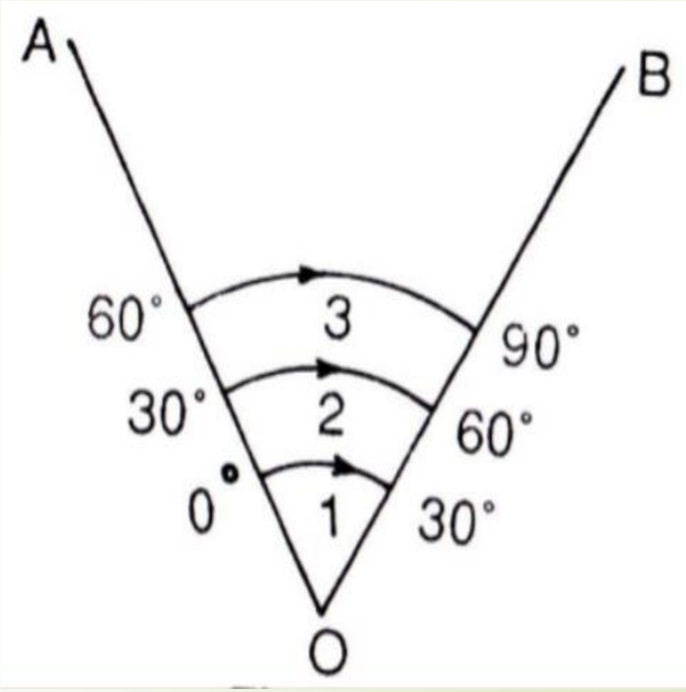


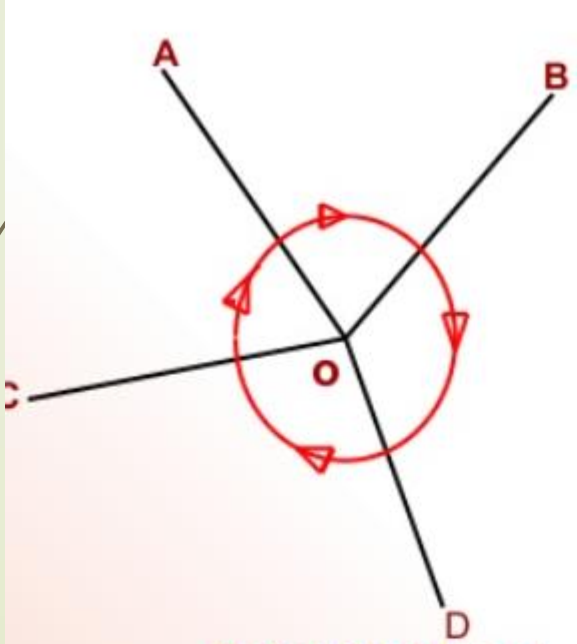
The desired relationships between the fundamental lines are as follows:

- The axis of the plate level must be perpendicular to the vertical axis
- The line of collimation should coincide with the optical axis of the telescope and should also be perpendicular to the vertical axis.
- The axis of telescope must be parallel to the line of collimation.
- The line of collimation must be perpendicular to the horizontal axis. And the vertical circle should read zero when the line of collimation is horizontal.

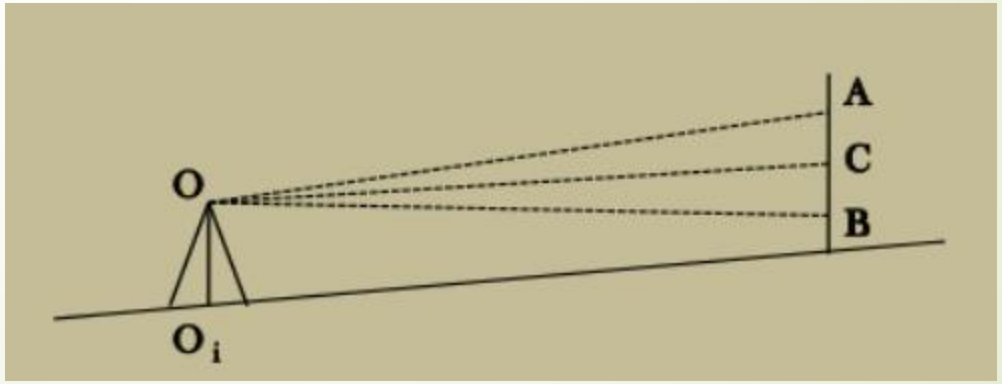
MEASUREMENT OF ANGLES

1. To measure horizontal angle (Repetition Method)
2. To measure horizontal angle (Reitration Method)
3. To measure deflection angle
4. To measure vertical angle





Reiteration Method



Station	Object	Angle	Observation	Reading on vernier		Angle on vernier		Mean angle of vernier	Mean angle of observation	Remark
				A	B	A	B			
1	2	3	4	5	6	7	8	9	10	11
O	A	∠AOB	Face left	0°0′0″	180°0′0″	30°20′20″	30°20′40″	30°20′30″	30°20′30″	
	B			30°20′20″	210°20′40″					
O	A	∠AOB	Face right	0°0′0″	180°0′0″	30°20′40″	30°20′20″	30°20′30″		
	B			30°20′40″	210°20′20″					

THEODOLITE TRAVERSE

INTRODUCTION

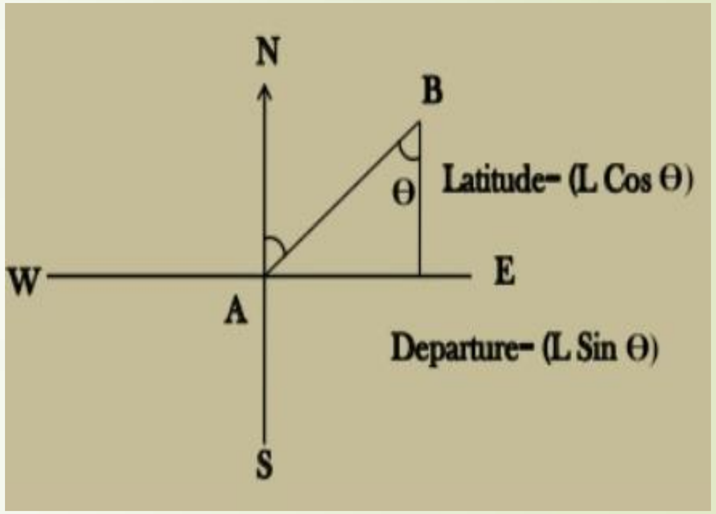
- Methods of traversing
  - Measurement of angles between successive lines
    - Included angles
    - Direct angles or angles to the right
    - Deflection angles
  - Direct measurement of bearings of survey line
    - Used for small works

TRAVERSE COMPUTATION

- Theodolite traverse is plotted by computing latitude and departures

LATITUDE

- Latitude of a line is the distance measured parallel to the N-S line
- Latitude is positive when measured towards North (called as Northing) and negative towards south (southing)
- Latitude of a line = l $\cos\theta$ where l is the length of the line and θ is the reduced bearing of the line



DEPARTURE

- Departure of a line is the distance measured parallel to E-W Line
- Departure is positive when measured towards East (called as Easting) and negative towards west (westing)
- Departure of a line = l $\sin\theta$ where l is the length of the line and θ is the reduced bearing of the line

Line	Length (L)	Reduced Bearing (Θ)	Latitude (LCOS Θ)	Departure (L Sin Θ)
AB	L	NΘE	+ L cos Θ	+ L sin Θ
BC	L	SΘE	-L cos Θ	+ Lsin Θ
CD	L	SΘW	-L cos Θ	-L sin Θ
DA	L	NΘW	+ Lcos Θ	-L sin Θ

Line	Length	Reduced Bearing	Consecutive Coordinates			
	(L)	(Θ)	Northing (+)	Southing (-)	Easting (+)	Westing (-)
AB	L	NΘE	L cosΘ		L sin Θ	
BC	L	SΘE		Lcos Θ	Lsin Θ	
CD	L	SΘW		Lcos Θ		Lsin Θ
DA	L	NΘW	L cosΘ			Lsin Θ

Check for Closed Traverse
Sum of Northing= Sum of Southing
Sum of Easting= Sum of Westing

CO-ORDINATES

- CONSECUTIVE CO-ORDINATES
  - Latitude and departure of any point with reference to the preceding point
- INDEPENDENT CO-ORDINATES
  - Co-ordinates of any point wrt a common origin
  - It may be obtained by adding algebraically the latitudes or departures of the lines between the points and the origin

BALANCING THE TRAVERSE

- In a closed traverse, the sum of northings must be equal to that of southings & sum of eastings should be equal to westings
- But in actual practice, some closing error always exist in traverse computation
- This is eliminated by balancing the traverse
- Here total errors in latitude and departure is computed and these errors are then distributed between traverse stations proportionately according to certain rules
- Rules for balancing a traverse
  - Bowditch's Rule
  - Transit Rule
  - Modified Transit Rule

BOWDITCH'S RULE

- Also called as compass rule
- Used to balance traverse when the linear and angular measurements are equally precise
- By this rule, the total error in latitude & departure is distributed in proportion to the lengths of the sides
- Correction in latitude/ departure

$$= \text{Total error in latitude/ departure x } \frac{\textit{Length of that side}}{\textit{Perimeter of traverse}}$$

TRANSIT RULE

- Used to balance the traverse when angular measurements are more precise than linear measurements
- Correction in latitude

$$= \text{Total error in latitude x } \frac{Latitude\ of\ that\ side}{Arithmetic\ sum\ of\ all\ latitudes}$$

- Correction in departure

$$= \text{Total error in departure x } \frac{departure\ of\ that\ side}{Arithmetic\ sum\ of\ all\ departures}$$

Question 1

Calculate latitudes, departures & closing error for the following traverse and adjust using Bowditch's rule

Line	Length	WCB
AB	89.31	$45°10'$
BC	219.76	$72°05'$
CD	151.18	$161°52'$
DE	159.10	$228°43'$
EA	232.26	$300°42'$

Line	Length	WCB	RB	Latitude		Departure	
				N	S	E	W
AB	89.31	45°10′	N45°10′E	62.967		63.335	
BC	219.76	72°05′	N72°05′E	67.605		209.10	
CD	151.18	161°52′	S18 8E		-143.67	47.05	
DE	159.10	228°43′	S48 43W		-104.97		-119.556
EA	232.26	300°42′	N 59 18W	118.578			-199.709
Perimeter – 851.61			Sum	249.15	248.64	319.485	319.265

Total error in latitude = Sum of northings – Sum of southings

= 249.15-248.64 = +0.51

Since error is positive correction will be negative

Total error in departure = Sum of E – Sum of W

= 319.485 – 319.265 = +0.22, Correction -ve

- Correction in latitude/ departure

$$= \text{Total error in latitude/ departure x } \frac{\textit{Length of that side}}{\textit{Perimeter of traverse}}$$

Correction in Latitude

Correction in line AB = 0.51 x $\frac{89.31}{851.61}$ = 0.0534

Similarly in BC = 0.1316, CD = 0.0905, DE = 0.0952 & EA = 0.1390

Corrected latitude of line AB = 62.967 – 0.0534 = 62.9136

Similarly latitude of BC = 67.4734, CD = -143.7605, DE = -105.0652 & EA = 118.439

Correction in Departure

Correction in line AB = 0.22 x $\frac{89.31}{851.61}$ = 0.0230

Similarly in BC = 0.0567, CD = 0.0390, DE = 0.0411 & EA = 0.060

Corrected departure of line AB = 63.335 – 0.0230= 63.312

Similarly departure of BC = 209.0433, CD = 47.011, DE = -119.5971& EA = -199.769

Question 2

An abstract from a traverse sheet for a closed traverse is given below. Balance the traverse using transit rule

Line	Latitude	Departure
AB	-173.20	100
BC	-314.50	128.40
CD	86.60	50
DE	250.00	0
EA	154.90	-280

Line	Latitude	Departure
AB	-173.20	100
BC	-314.50	128.40
CD	86.60	50
DE	250.00	0
EA	154.90	-280
Sum	979.2	558.4

Error in latitude = -173.20-314.50+86.60+250+154.90 = +3.8 (correction –ve)

Error in departure = 100+128.4+50+0-280 = -1.6 (correction +ve)

- Correction in latitude= Total error in latitude x $\frac{Latitude\ of\ that\ side}{Arithmetic\ sum\ of\ all\ latitudes}$
- **Correction in Latitude**

Correction in line AB = 3.8 x $\frac{173.2}{979.2}$ = 0.6721

Similarly in BC = 1.2204, CD = 0.3360, DE = 0.9701 & EA = 0.6011

Corrected latitude of line AB = -173.20-0.6721 = -173.8721

Similarly latitude of BC = -315.7204, CD = 86.264, DE = 249.0299& EA = 154.2989

- Correction in departure= Total error in departure x $\frac{departure\ of\ that\ side}{Arithmetic\ sum\ of\ all\ departures}$
- **Correction in Departure**

Correction in line AB = 1.6 x $\frac{100}{558.4}$ = 0.2865

Similarly in BC = 0.3679, CD = 0.1432, DE = 0 & EA = 0.8022

Corrected latitude of line AB = 100+0.2865 = 100.2865

Similarly latitude of BC = 128.7679, CD = 50.1432, DE = 0 & EA = -279.1978

Question 3

Balance the given traverse

Line	Length	Bearing
PQ	159.10	S $18°08' E$
QR	232.26	S $48°43' W$
RS	89.31	N $59°18' W$
ST	219.76	N $45°10' E$
TP	151.18	N $72°05' E$

OMITTED MEASUREMENTS

Various Cases

- Lengths of two sides omitted
- Bearings of 2 sides omitted
- Length of one side and bearing of other side omitted
- Bearing of one side omitted
- Length of one side omitted
- Bearing & length of one side omitted

Q1) A traverse ABCDA was run but due to an obstruction between the stations A & B, it was not possible to measure the length and direction of line AB. The following data could only be obtained

Line	Length	RB
AD	44.5	N50°20′E
DC	67.0	S69°45′E
CB	61.3	S30°10′E
BA	?	?

Step 1: Find L & D

Line	Length	RB	Latitude	Departure
AD	44.5	N50°20′E	28.405	34.25
DC	67.0	S69°45′E	23.18	62.85
CB	61.3	S30°10′E	52.99	30.804
BA	?	?	L	D

Step 2:

For closed traverse, $\sum L = 0$

i.e., 28.40+23.18+52.99+L =0 L = -104.57

Also, $\sum D = 0$

34.25+62.85+30.80+D = 0 D = -127.9

Step 3: Bearing of line AB

$\tan\theta = \frac{D}{L} = \frac{127.9}{104.57} = 50°43'51''$

Bearing of line AB = S $50°43'51''$W

Step 4: Length of line AB

l = $\sqrt{L^2 + D^2} = \sqrt{-104.57^2 + -127.9^2}$ = 165.20 m

Check L = l cosθ

i.e., 104.57 = l cos ($50°43'51''$)

l = 165.20 m

Q2) Due to some problems with equipment, the bearing of two sides were not taken for a closed traverse ABCDEA. From the available data, compute the missing data

Line	Length	RB
AB	230.5	S36°45′E
BC	250.2	S82°48′E
CD	210.8	S10°15′E
DE	240.3	?
EA	265.4	?

Step 1: Considering lines from AB to DE

Line	Length	RB	Latitude	Departure
AB	230.5	S36°45′E	-184.68	137.91
BC	250.2	S82°48′E	-31.358	248.22
CD	210.8	S10°15′E	-207.42	37.51
DE	240.3	?	L1	D1

For closed traverse, $\sum L = 0$,

-423.45 + L1 = 0 L1= 423.45

Also, $\sum D = 0$,

423.64+D1 = 0 D1=-423.64

Bearing of line DE

$\tan\theta = \frac{D}{L} = \frac{423.64}{423.45} = 45°0'46''$

Bearing of line AB = N $45°0'46''$W

Step 2: Considering lines from AB to EA

Line	Length	RB	Latitude	Departure
AB	230.5	S36°45′E	-184.68	137.91
BC	250.2	S82°48′E	-31.358	248.22
CD	210.8	S10°15′E	-207.42	37.51
DE	240.3	N45°0′46″W	169.874	-169.922
EA	265.4	?	L2	D2

For closed traverse, $\sum L = 0$,

-253.6+ L2= 0 L2= 253.6

Also, $\sum D = 0$,

253.68+D2 = 0 D2= -253.68

Bearing of line EA

$$\tan\theta = \frac{D}{L} = \frac{253.68}{253.6} = 45°0'30.5''$$

Bearing of line AB = N 45°0′30.5″W

Q3) The details of a part of theodolite survey are as under. Calculate the distance between a point P on AB 60 m from A and a point Q on CD 250 m from C and also determine the bearing of line PQ.

Line	Length	Bearing
AB	200	300°20′
BC	500	25°30′
CD	300	145°30′

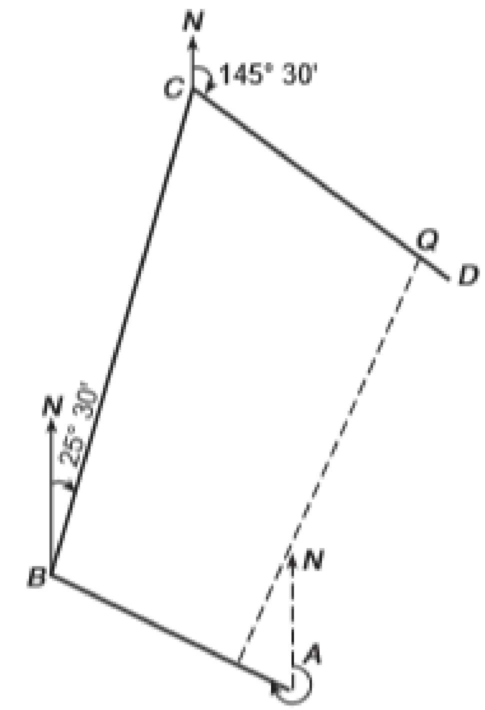


Fig. 12.33.

Assume PBCQ as a closed traverse with co-ordinates of P as (0,0)

PB = 200-60 =140 m   CQ = 250m

Line	Length	RB	Latitude	Departure
PB	140	N59°40′W	70.7	-120.83
BC	500	N25°30′E	451.29	215.26
CQ	250	S34°30′E	-206.03	141.60
QP	?	?	L	D

For closed traverse, $\sum L = 0$

i.e., 70.7+451.29-206.03+L=0   L = - 315.96 m

Also, $\sum D = 0$

-120.83+215.26+141.6+D = 0   D =236.03 m

Bearing of line PQ , $\tan\theta = \frac{D}{L} = \frac{236.03}{315.96}$ = S 36°45′38″E

Length of line PQ, l = $\sqrt{L^2 + D^2}$ = 394.39 m

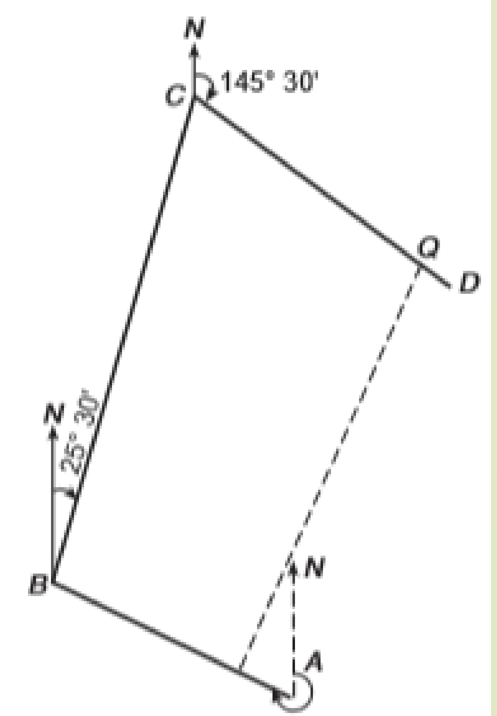


Fig. 12.33.

Q4) Find the length & bearing of line AB from the given co-ordinates

Point	Co-ordinates
A	975.50, 830.20
B	1189.70, 579.30

Latitude of AB = 1189.70-975.50 = 214.2

Departure of AB = 579.30-830.20 = -250.9

- Bearing of line AB, $\tan\theta = \frac{D}{L} = \frac{250.9}{214.2} = N49°30'42''W$
- Length of line AB, l = $\sqrt{L^2 + D^2} = 329.897$ m

Gales traverse table

- Calculation for a closed traverse may be done in a tabular form known as gale's traverse table using following steps:

1. Sum up all included angles. There sum should be equal to $(2N\pm4)90°$, where N is the number of sides. If there is error make necessary correction
2. From the given lengths & bearings, calculate consecutive co-ordinates
3. Take the sum of co-ordinates and see if correction is required. If yes, correct using balancing rules
4. From the corrected consecutive-co-ordinates calculate independent co-ordinates of points so that all are positive. Then the whole traverse will lie in the first quadrant.

INST. STN.	ANGLE			CORRECTION	CORRECTED ANGLE			LINE	LENGTH	W.C.B.	CONSECUTIVE CO-ORDINATES				LINE	CORRECTION eLn OR eDn				CORRECTED CONSE. CO-ORDINATES				INDEPENDENT CO-ORDINATES	
											LAT= $l_n \cdot \cos \Theta_n$		DEP= $l_n \cdot \sin \Theta_n$			LATITUDE		DEPARTURE		LATITUDE		DEPARTURE			
	0	0'	0"		0	0'	0"				NORTHING	SOUTHING	EASTING	WESTING		NORTHING	SOUTHING	EASTING	WESTING	NORTHING	SOUTHING	EASTING	WESTING	NORTHING	EASTING
A	85	28	20	27' 38"	85	55	58																	5	5
								AB	88.4	2	88.34		3.08		AB	0.05		0.005		88.29		3.075			
B	78	38	40	25' 23"	79	2	3																	93.29	8.075
								BC	38.10	103		8.50	37.21		BC		0.004	0.07			8.504	37.14			
C	128	15	50	41' 5"	128	58	55																	84.808	45.215
								CD	83.8	157		77.14	32.74		CD		0.044	0.058			77.184	32.882			
D	68	42	55	22' 11"	69	5	6																	7.512	77.897
								DA	72.8	288		2.51		72.78	DA		0.002		0.127		2.512		72.887		
																								5	5
∑ Actual Angle	358	3	45	1^0 58' 15"							∑ N= 88.34	∑ S=88.24	∑E= 73.02	∑W=72.78		$\sum C_N$=0.05	$\sum C_S$=0.05	$\sum C_E$=0.133	$\sum C_W$=0.129	∑ N= 88.29	∑ S=88.29	∑E= 72.887	∑W=72.887		
											EL=∑N-∑S=0.1		ED=∑E-∑W=0.28			$\sum C_L=\sum C_N+\sum C_S$=0.1		$\sum C_D=\sum C_E+\sum C_W$=0.28							

Q5) Calculate independent co-ordinates from the given consecutive co-ordinates

Line	Length	RB	Latitude		Departure	
			N	S	E	W
AB	89.31	N45°10′E	62.967		63.335	
BC	219.76	N72°05′E	67.605		209.10	
CD	151.18	S18° 8'E		-143.67	47.05	
DE	159.10	S48°43'W		-104.97		-119.556
EA	232.26	N59°18'W	118.578			-199.709

Corrected Latitude		Corrected Departure		Independent co-ordinates	
N	S	E	W	N	E
62.9136		63.312		200	200
67.4734		209.0433		267.4734	409.0433
	-143.7605	47.011		123.7129	456.0543
	-105.0652		-119.5971	18.6477	336.4572
118.439			-199.769	137.0867	136.6882

Q5) Calculate independent co-ordinates from the given consecutive co-ordinates

Line	Length	RB	Latitude		Departure	
			N	S	E	W
AB	89.31	N45°10′E	62.967		63.335	
BC	219.76	N72°05′E	67.605		209.10	
CD	151.18	S18° 8'E		-143.67	47.05	
DE	159.10	S48°43'W		-104.97		-119.556
EA	232.26	N59°18'W	118.578			-199.709