‘Surveying-2’
Lecture-2
“Angle Measurement and Theodolites”

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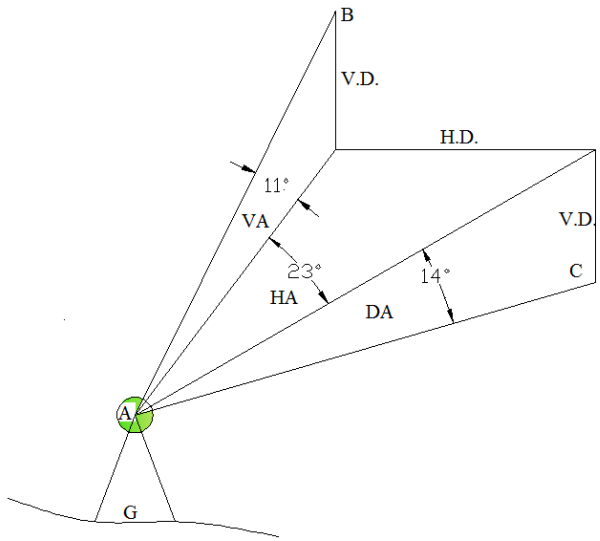
Outline

- ✓ **Angle measurement**
- ✓ **Types of angle measurement**
- ✓ **Theodolite**
- ✓ **Units of angle measurement**
- ✓ **Methods of angle measurement in Theodolite**
- ✓ **A numerical example**

Angle

- It is the amount of rotation about axis of intersection between two planes until they coincide.

Types of angles



Types of angles

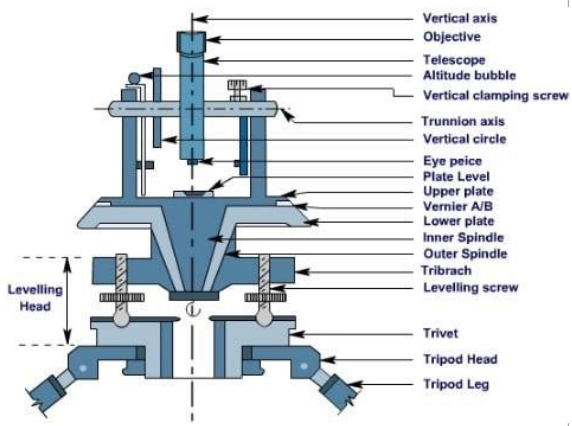
- Point G is a point on the ground, where the angles are measured.
- Point A is the intersection point of horizontal and vertical axis of the instrument.
- Horizontal plane containing point A.
- Point B is above horizontal plane.
- Point C is below the horizontal plane.

- **Horizontal Angle (HA):** it is the angle between vertical planes containing AC and AB.

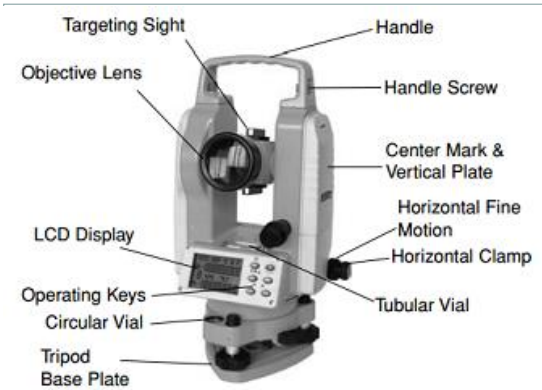
- **Vertical Angle (VA):** it is the angle between horizontal plane through (A) and inclined plane upward containing (AB).
- **Depression Angle (DA):** it is the angle between horizontal plane through (A) and the inclined plane downward from (A) containing (AC).
- **Zenith Angle (ZA).** It is the angle in vertical plane between the vertical axis above the instrument and line of sight.
- These angles are measured by an instrument called **Theodolite**.
- **Theodolite**: it is an instrument manufactured precisely for measurement of angles.

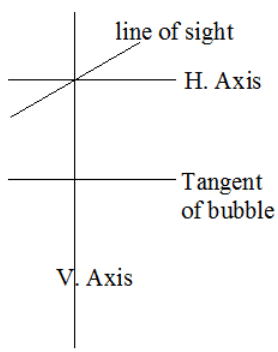
- **There are two types of Theodolite**
- **Electronic Theodolite:** the readings are displayed automatically.
- **Optical Theodolite:** the readings are performed manually.
- These angles are many types of theodolite manufactured may be classified according to (smallest reading) may be taken which varies 1’ minute to 0.1” second.
- Where we use these angles?
- Horizontal angles are used in the calculation of bearings and direction and to layout points during construction and preparing detail maps.
- Vertical angles (zenith angles) are use for determination of elevations, slope angles, convert slope distance to H. distance.

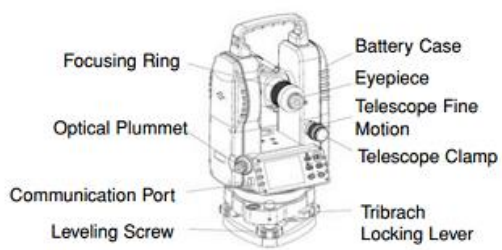
- **Main components of theodolite**
- Alidade
- Telescope
- Base plate
- Leveling screws
- Bubbles
- Telescope for centering
- H and V circles



- Two other screws (clumping screw for horizontal motion and clumping screw for vertical motion).







Conditions

1. Vertical axis must be truly vertical (along the direction of gravity).
2. Vertical axis must be perpendicular to the tangent of bubble.
3. Horizontal axis must be parallel to the tangent of bubble.
4. Line of sight must be perpendicular to the horizontal axis.

- Any theodolite does not comply with these conditions must not be used for angle measurement.

Units of angle measurements

There are three systems (kind of units) for angle measurement

1. Sexagesimal system

- The circle is divided to 360 units, each unit is called degree, and noted as (30°).
- Each degree is divided to 60 units, each unit is called minute, and written as (25’).
- Each minute is divided to 60 units, each unit is called second, and written as (23.5”).
- The angle is (30° 25’ 23.5”)

2. Centesimal system

- The circle is divided to 400 units, each unit is called grade, and written as (46^g).
- Each grade is divided to 100 units, each unit is called centigrade, and written as (54^c).
- Each centigrade is divided to 100 units, each unit is called centi-centigrade, and written as (86^{cc}).
- The angle is ($46^g\ 54^c 86^{cc}$).

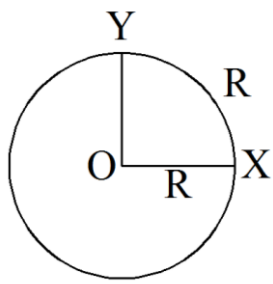
- $1^\circ = \left(\frac{10}{9}\right)^g \ and\ 1^g = \left(\frac{9}{10}\right)^\circ$

3. Radian system

- Radian angle: it is the angle at the center of the circle subtends by an arc whose length is equal to the radius.
- Circumference = 2πR
- So there are 2π radian angle in a circle = 6.283185307
- The circle is divided to 6000 or 6400 units, each unit is called milliem (mil).
- Radian angle = 360°/6.283185307 = 57° 17’ 44.81”
- Radian angle = 400/ 6.283185307 = 63.66197724

- Let OX = R
- Take an arc XY of the circle such that arc XY = R
- And join OY by definition <XOY = one radian
- Sum standard angle are given below

Degree	Radian
0°	0
30°	$\pi/6$
45°	$\pi/4$
60°	$\pi/3$
90°	$\pi/2$
180°	π



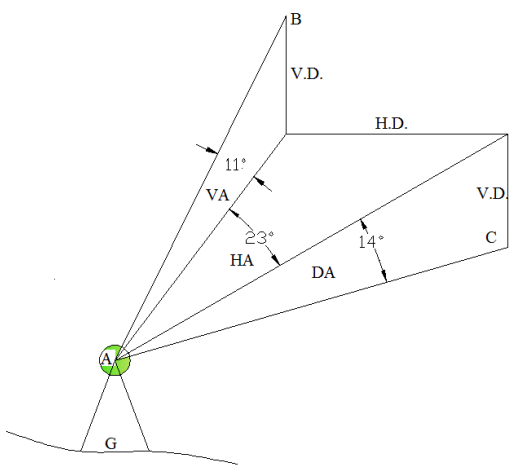
There are two methods of angle measurement

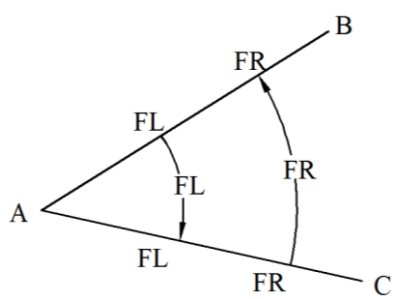
- Face Left (FL): it is the position of the instrument when vertical circle is at the left of observer.
- Face Right (FR): it is the position of the instrument, when the vertical circle is at the right of observer.
- Transit telescope from FL and then rotate 180° degree to FR
- If the instrument in the case of FL the measuring angle is increased with turning right. And If the instrument in the case of FR the measuring angle is increased with turning left.

The procedure of measuring the angle

1. Set up the Theodolite at point “A”.
2. Set the instrument at FL.
3. Sight to point “B” approximately, and clump horizontal motion and vertical motion.
4. Use horizontal and vertical slow motion screws to sight exactly to the point.
5. Take horizontal and vertical readings “appeared on the display”.
6. Sight to point “C” approximately.
7. Repeat steps #4 and #5 [change FL to FR].
8. Sight again to point “C” in FR.

9. Repeat steps #4 and #5
10. Rotate alidade from left to right to point “B”.
11. Repeat steps #4 and #5.

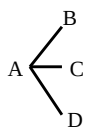




One round of angle measurement

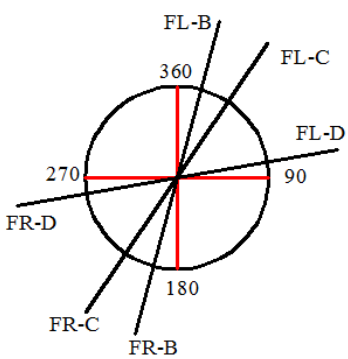
Example

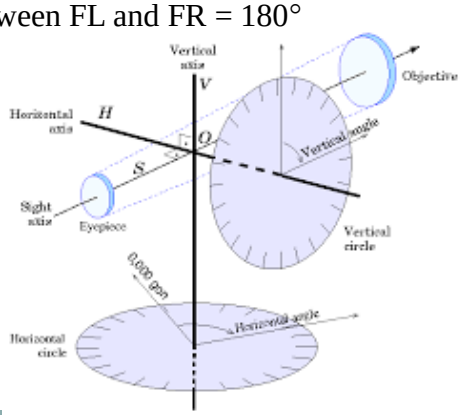
Instrument. Station	Target	Horizontal circle readings			Vertical circle readings			Remark
		FL	FR	Mean	FL	FR	Mean	
	B	0° 3′ 50"	180° 4′ 30"		88° 10′30"	271° 51′20"	+1° 50′ 25"	
				17° 18′30"				
A	C	17° 22′10"	197° 23′ 10"		89° 34′50"	270° 27′ 30"	+0° 26′ 30"	
				66° 36′ 45"				
	D	83° 58′ 50"	264° 00′ 00"		92° 48′ 20"	267° 13′ 40"	-2° 47′ 20"	



Calculation

- **Horizontal circle**
- The principal of horizontal circle are illustrated in the below figure.
- Note: theoretical difference between FL and FR = 180°

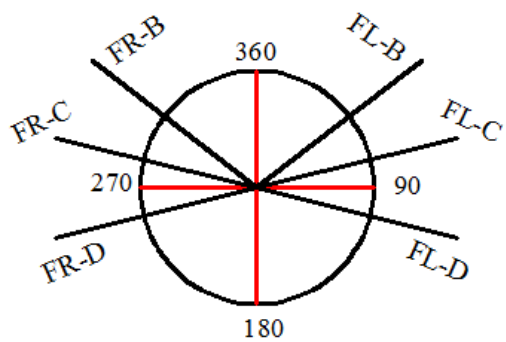




Horizontal angles	Horizontal angles
FL	FR
H. angle BAC	H. angle BAC
17° 22’ 10” - 0° 3’ 50”	197° 23’ 10” - 180° 4’ 30”
= 17° 18’ 20”	= 11° 18’ 40”
	Average = 17° 18’ 30”
H. angle to CAD	H. angle CAD
83° 58’ 50” - 17° 22’ 10”	264° 00’ 00” - 197° 23’ 10”
= 66° 36’ 40”	= 66° 36’ 50”
	Average = 66° 36’ 45”

Calculation

- **Vertical circle**
- In the vertical angles for each point that measured it has FL and FR readings. The average of these two angles where becomes vertical angle of this point.



Vertical angles	Vertical angles
FL	FR
Vertical angle to B	Vertical angle to B
90° - 88° 10’ 30” = 1° 49’ 30”	271° 51’ 20” - 270° = 1° 51’ 20”
	Average = + 1° 50’ 25”
Vertical angle to C	Vertical angle to C
90° - 89° 34’ 50” = 0° 25’ 10”	270° 27’ 30” - 270° = 0° 27’ 30”
	Average = + 0° 26’ 20”
Vertical angle to D	Vertical angle to D
92° 48’20” - 90° = 2° 48’ 20”	270° - 267° 13’ 40” = 2° 46’ 20”
	Average = - 2° 47’ 20”