Fieldwork Surveying FS01

4. Lecture

Angular measurement

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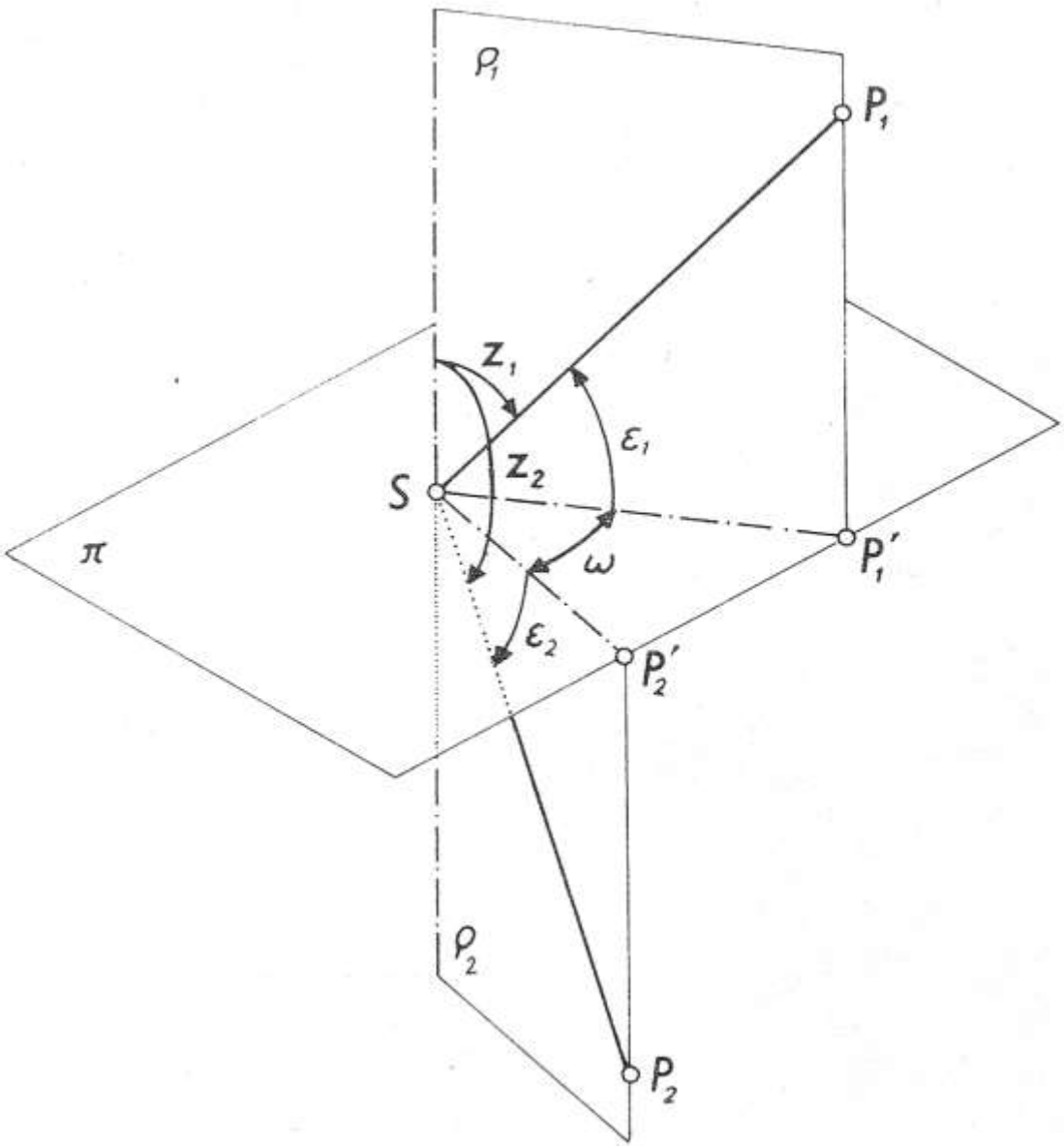
Basic terms


ρ_1
P_1
z_1
ε_1
z_2
S
π
ω
P_1'
ε_2
P_2'
ρ_2
P_2

Line of sight – the join of the points S and P

Horizontal direction – the intersection between the vertical plane ρ_i where is line of sight and the horizontal plane π

Horizontal angle ω – the angle between the vertical planes ρ_1 and ρ_2 (in the horizontal plane π)

Zenith angle z_i – the angle in the vertical plane ρ_i measured between the vertical and the line of sight

Elevation angle ε_1 – the angle between the horizontal plane π and the line of sight (the angle is above the horizontal plane π)

Depression angle ε_2 – the angle between the horizontal plane π and the line of sight (the angle is under the horizontal plane π)

Units

1° (degree) = (π/180) rad

1^g (gon) = (π /200) rad

Full angle	Right angle
2 π	π /2
360°	90°
400 gon = 400^g	100 gon = 100^g

Sexagesimal x centesimal measure

Theodolites

= instruments for angular measurements

Classification with respect to a construction:

- **optical-mechanical theodolites**
- **electronic theodolites** – a distance meter is usually built-in (so-called total stations)

Classification with respect to accuracy:

- **one-minute theodolites** – the least division of the scale is 1 or 2 minutes (sexagesimal or centesimal)

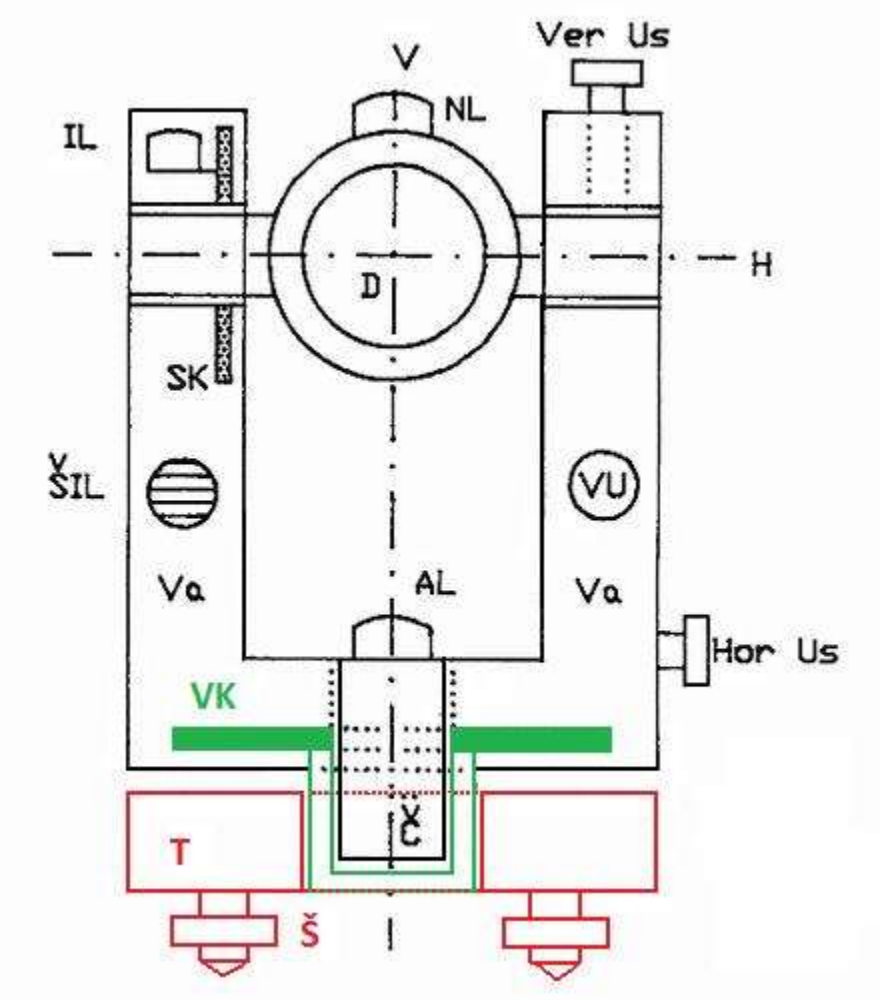
- **one-second theodolites** – the least division of the scale is 1 or 2 seconds (sexagesimal or centesimal)

Optical-mechanical theodolite – parts

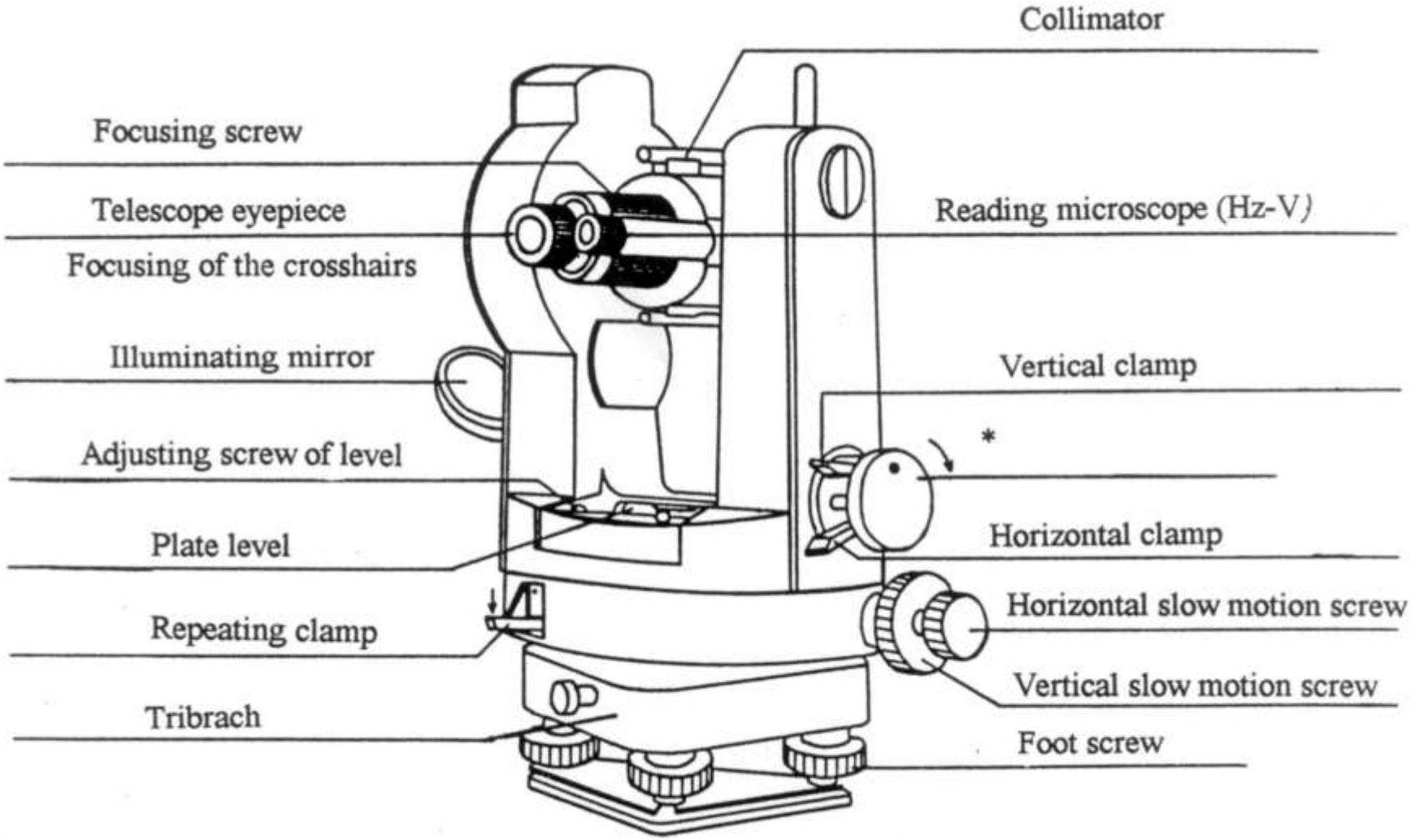
Tribrach

Limbus

Alidade

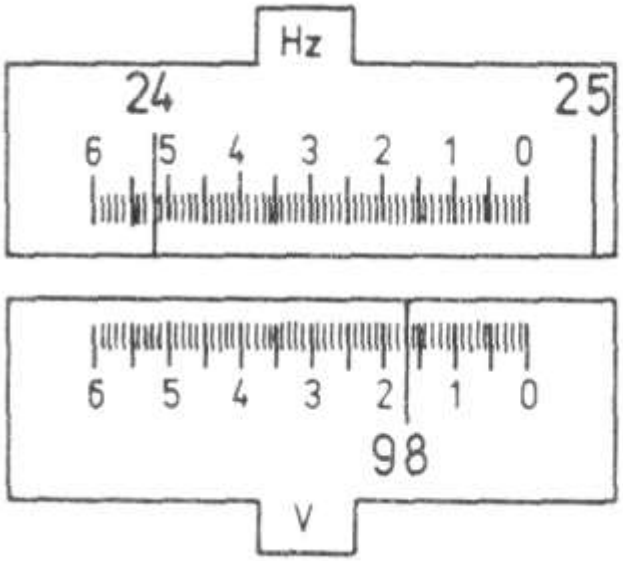


Optical-mechanical theodolite



* By turning this screw the reading of vertical circle is switched off or on

Scales for reading of angles (one-minute theodolite)

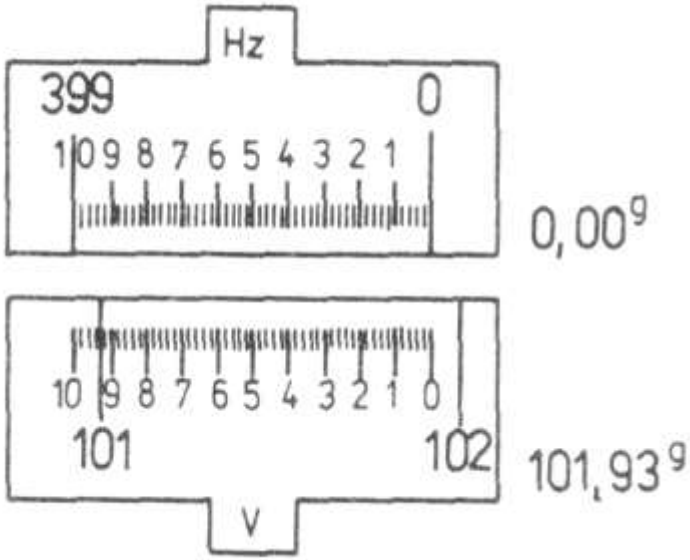


horizontální kruh

24° 52′

vertikální kruh

98° 17′



Preparation of a theodolite for a measurement

- **levelling** → the alidade axis V of the instrument is vertical
- **centering** → the axis V goes through the survey station

procedure of the instrument centering and levelling – see practical classes

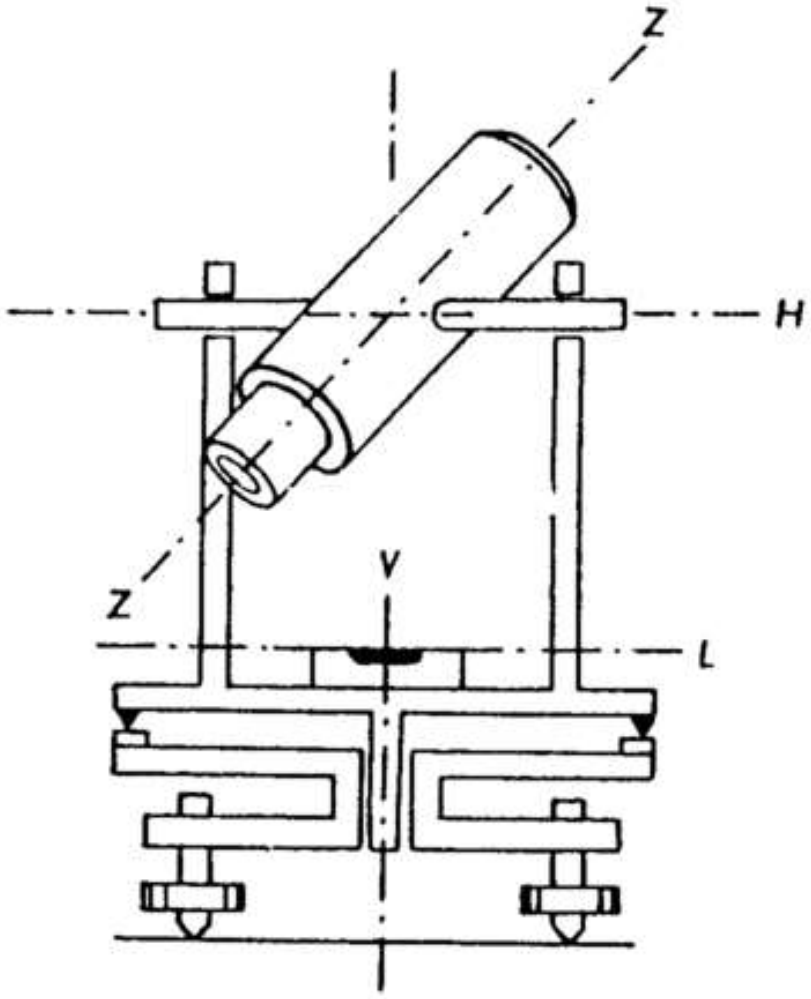
Axes of the theodolite

Z – collimation axis (axis of the sight)

V – alidade axis

H – horizontal axis (telescope rotary axis)

L – level axis (axis of the alidade level)



Requirements for the axes

1. $L \perp V$
2. $Z \perp H$
3. $H \perp V$

Fulfilment of these requirements has to be tested and an adjustment of the instrument has to be performed if it is necessary .

ad 1. if this requirement is not fulfilled, the alidade level has to be adjusted

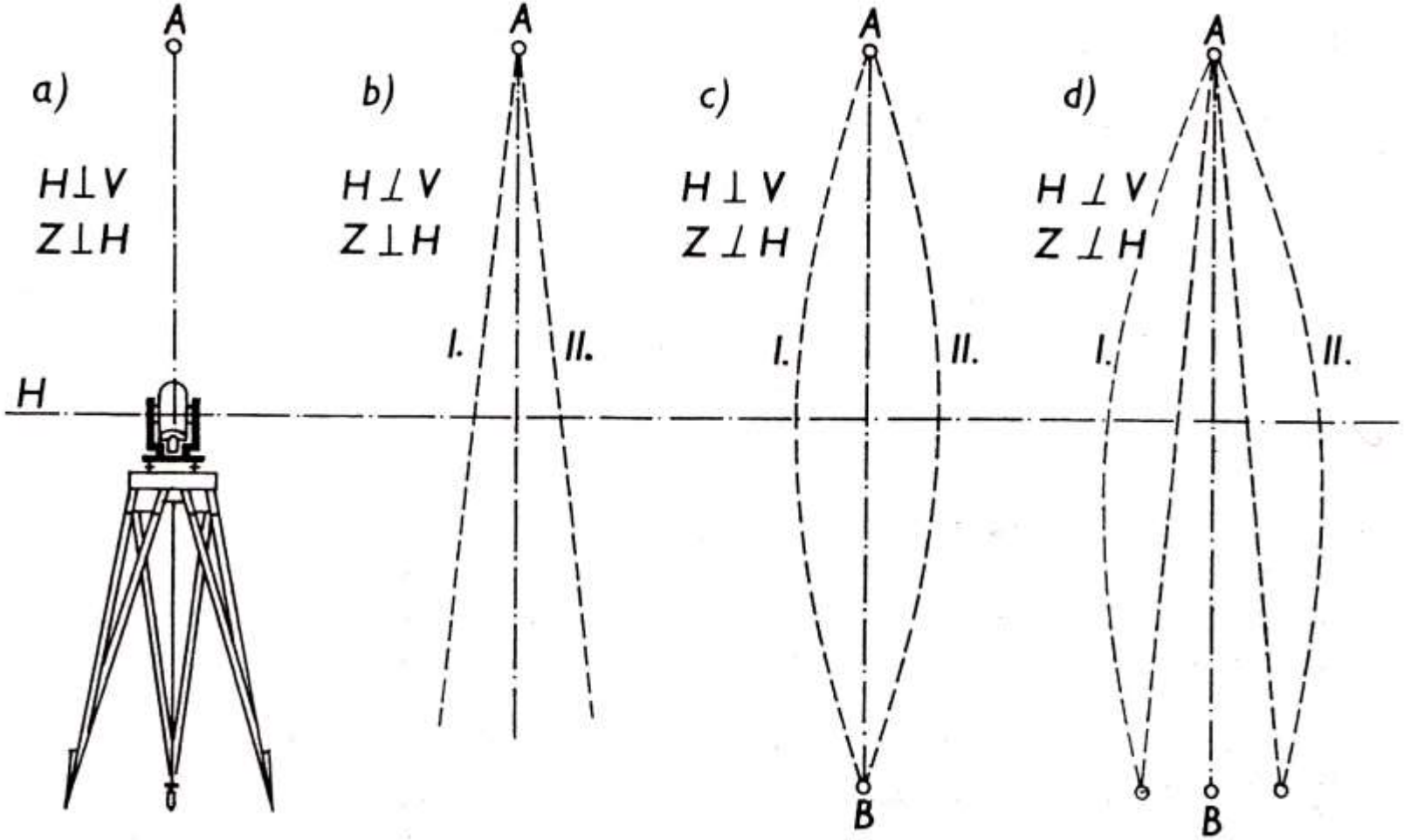
ad 2. if it is not realized $\rightarrow$ collimation error

measurement of horizontal angles in both positions of the telescope is used to avoid this error

ad 3. if it is not realized $\rightarrow$ error in incline

measurement of horizontal angles in both positions of the telescope is used to avoid this error

Detection of theodolite axis errors



Errors in the construction of a theodolite

- **an excentricity of the alidade**

  The axis V does not go through the centre of the horizontal circle.

- **an irregular dividing of the horizontal circle**

  This error is not important at modern instruments.

Errors caused by standing of the instrument or the target

- wrong levelling of the instrument
- wrong centering of the instrument
- wrong centering of the target
- unstable tripod of the instrument

It is not possible to avoid these errors by procedure of the measurement.

Errors caused by the observer

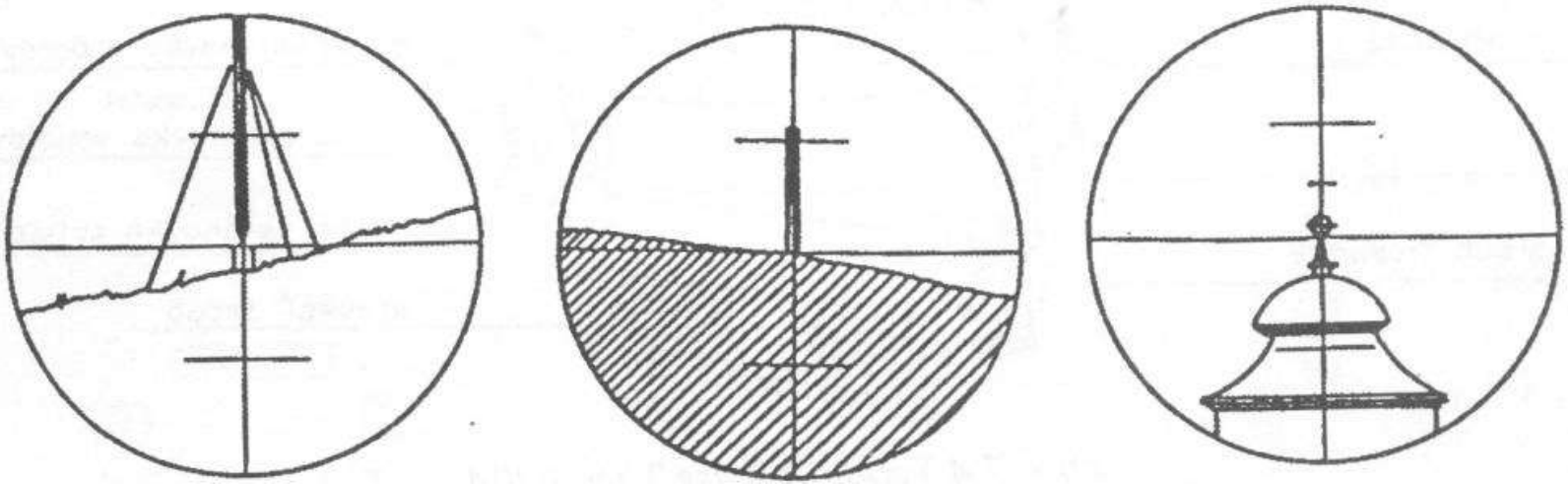
- **pointing error**

  It depends on features of the telescope and the target, on the atmospheric conditions and on abilities of the observer.

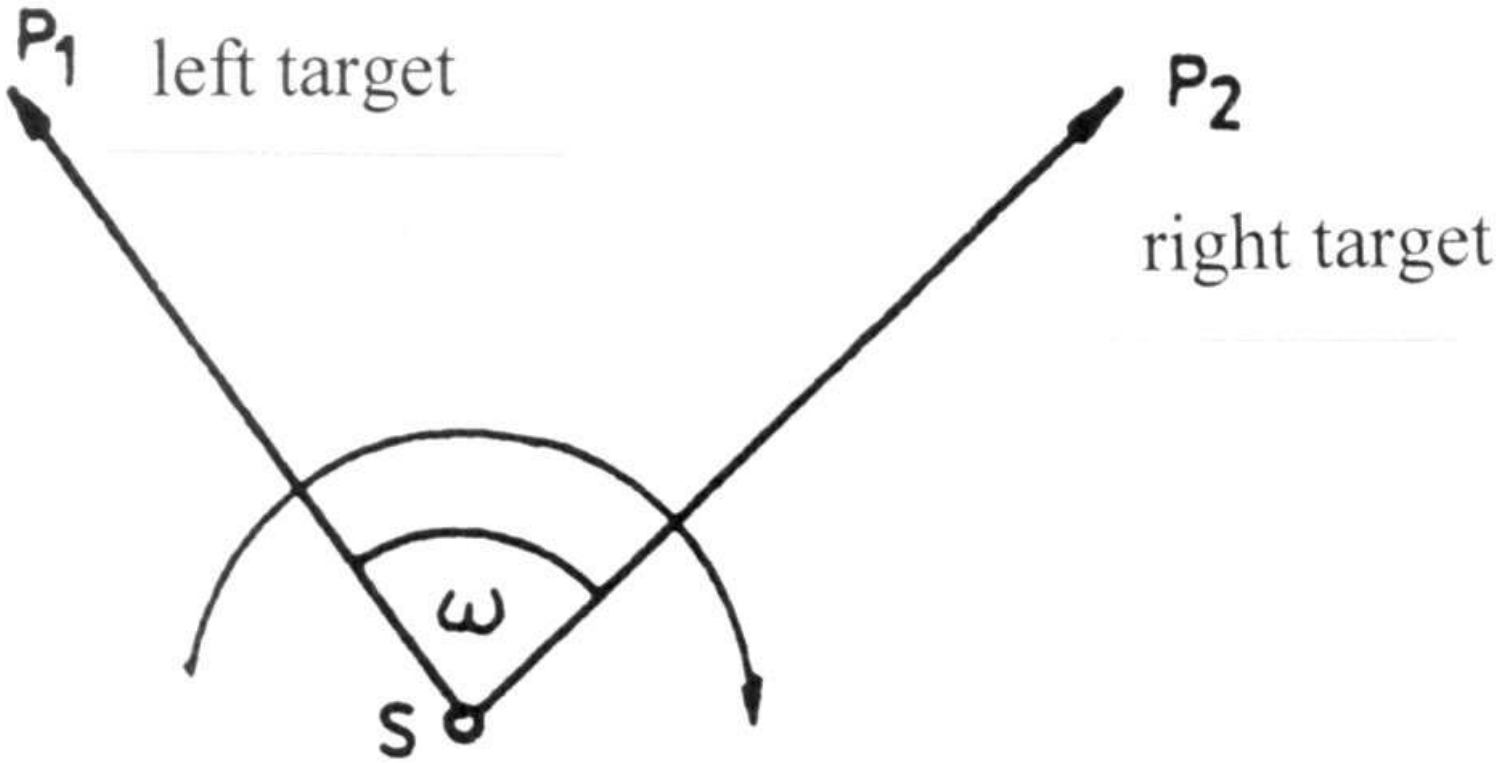
- **reading error**

  It depends on the least division of the reading scale and on the visual acuity of the observer.

Pointing



Measurement of a horizontal angle in one set



horizontal circle is numbered clockwise

Procedure

face left position

1. P_1
2. P_2

change the position of the telescope

face right position

3. P_2
4. P_1

Station		Direction to point No.	Horizontal directions														
No.				1st set			Aver. Red.		2nd set			Aver. Red.		{(6) + (8)} / 2			
(1)	(2)	(3)	(4)	(5)			(6)		(7)			(8)		(9)			
S		P_1	I	α_1			Ø	1-4									
			II	α_4													
		P_2	I	α_2			Ø	2-3									
			II	α_3										ω			
2		1	I	72	18		18	50									
			II	272	19												
		3	I	186	91		91	25									
			II	386	91	50								114	72	75	
6		5	I	0	00		99	00									
			II	199	98												
		7	I	164	27		26	50									
			II	364	26									164	27	50	
8		9	I	341	00	25	59	48									
			II	160	59	12											
		11	I	107	42	06	41	38									
			II	287	41	10								126	41	50	

Measurement of directions set in one set with repeated pointing at the first point

Station No.		Direction to point No.		Horizontal directions													
				1st set			Aver. Red.		2nd set			Aver. Red.		{(6) + (8)} / 2			
(1)	(2)	(3)	(4)	(5)			(6)		(7)			(8)		(9)			
5		11	I	0	03		03	50									
			II	200	04		00	00						0	00	00	
		12	I	18	28		28	50									
			II	218	29		25	00						18	25	00	
		13	I	113	76		77	00									
			II	313	78		73	50						113	73	50	
		11	I	0	03	50	03	75									
			II	200	04		00	25						0	00	25	

Measurement of zenith angles

A horizontal angle is the difference between two directions which are read on the horizontal circle (the difference between the left and the right target).

A zenith angle is read on the vertical circle after pointing at a target (the direction to the zenith is given $\rightarrow$ vertical).

The vertical circle rotates with tilting of the telescope and indexes of the reading scale are (or should be) in horizontal position during a measurement of the zenith angle.

The correct position of the indexes is ensured by

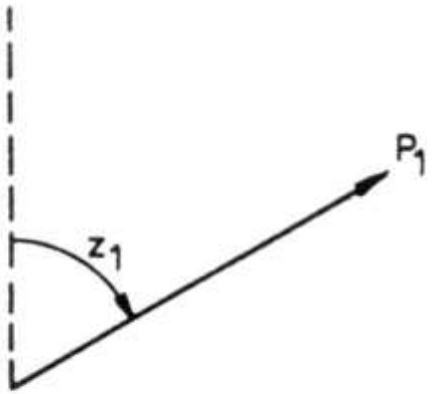
- collimation (index) level – older types of theodolites,
- compensator – it works automatically (modern instruments).

The mentioned requirements for axes of the theodolite have to be fulfilled during a measurement of zenith angles too.

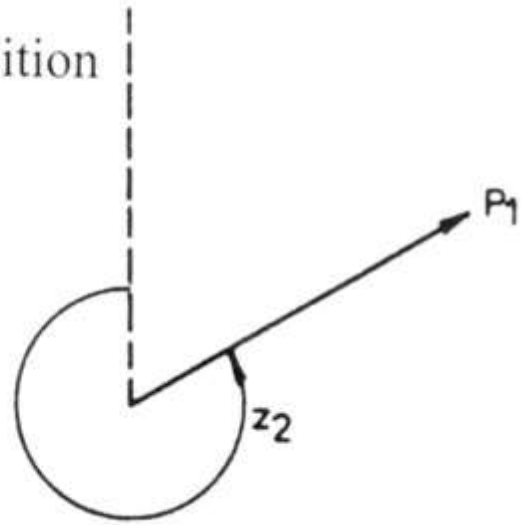
In addition to these requirements, a reading on the vertical circle should be 100 gon if the line of sight is horizontal. There is so-called **index error** if this requirement is not fulfilled. It is possible to avoid this error by measurement in both positions of the telescope and by calculation of a correction.

Measurement of a zenith angle in both positions of the telescope

face left position



face right position



If there is no index error, then

$z_1 + z_2 = 400^g$

If there is an index error, then

$z_1 + z_2 = 400^g + 2i$

$$i = \frac{z_1 + z_2 - 400^g}{2}$$

and the corrected zenith angle

$z = z_1 - i$

Zenith angles z								Distances				
		Reading			z			Measurement				Aver.
(10)	(11)	(12)			(13)			(14)	(15)	(16)	(17)	(18)
8	I	z_1			z			horiz.				
	II	z_2						slope.				
	Σ				i =			vertic.				
9	I	92	40		**92**	**39**		horiz.				
	II	307	62					slope.				
	Σ	400	02		i =	0,01		vertic.				
10	I	91	15		**91**	**15**	**50**	horiz.				
	II	308	84					slope.				
	Σ	399	99		i =	-0,005		vertic.				

Electronic theodolites

- another name – **total stations**
- battery-powered (internal or external)
- measured values are on the display (digital form)
- some instruments have a built-in compensator of the alidade axis position
- the correction of the index error can be introduced to measured values automatically
- therefore it is often possible to measure only in the face left position of the telescope

- measured values can be recorded to the memory of the instrument
- there are function buttons for setting of an arbitrary value of the horizontal circle reading, buttons for units option etc.
- descriptive or numeral information can be inserted in memory of some instruments
- some of the most modern instruments are motorized and then automatic pointing of the instrument is possible

Electronic theodolites