GEODESY

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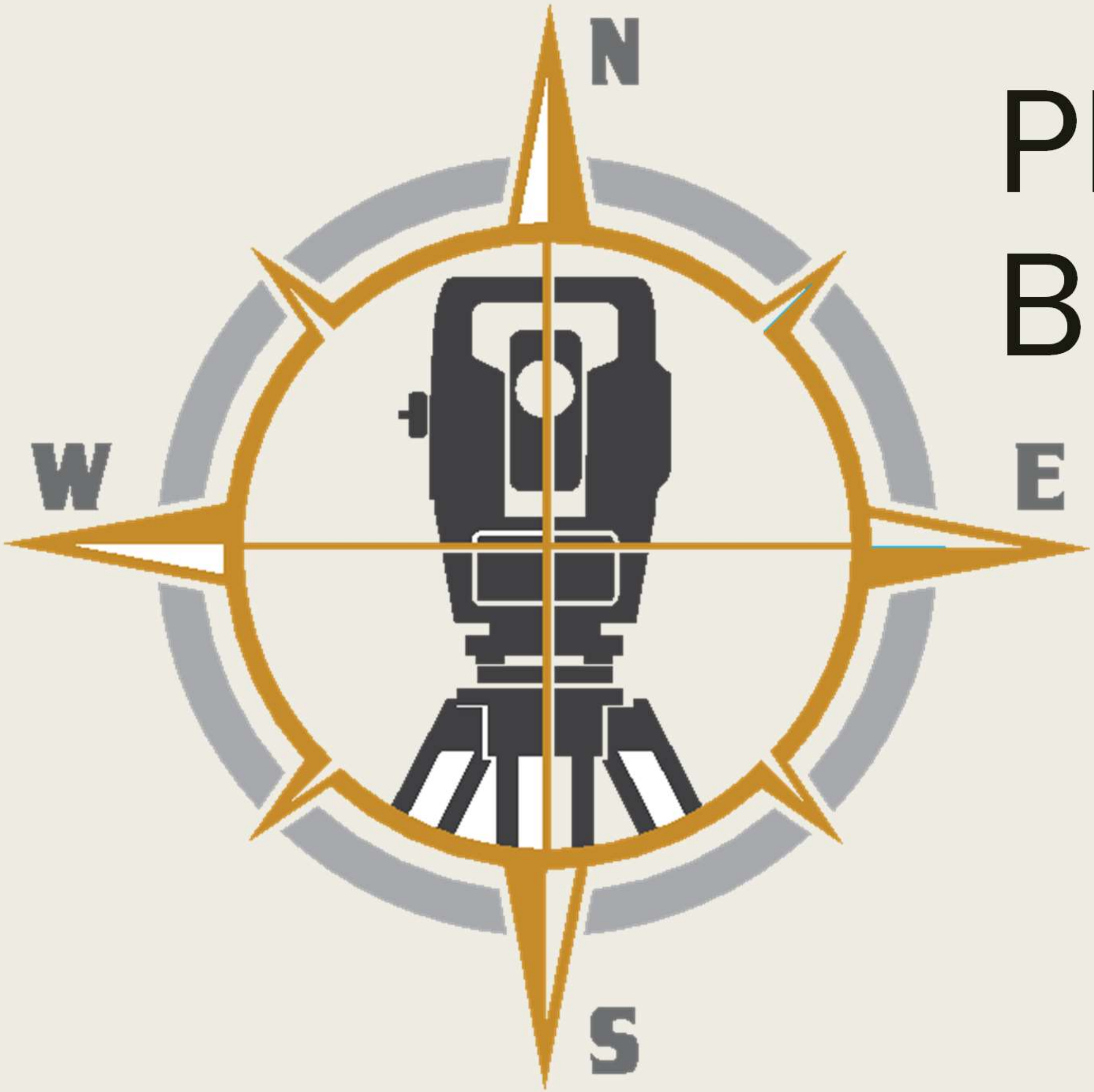
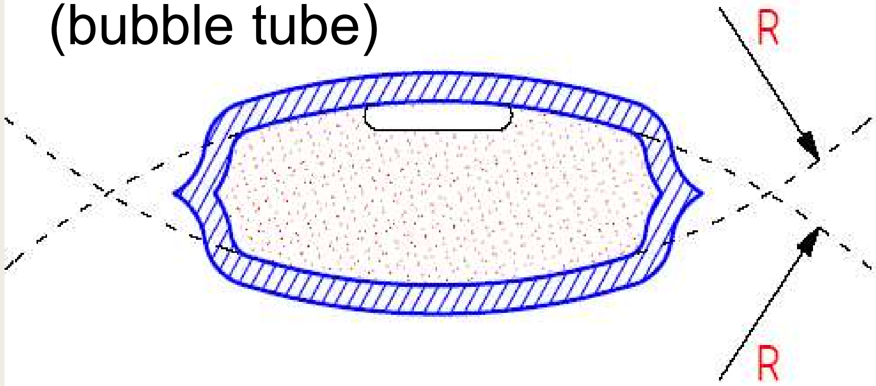
Instrument parts



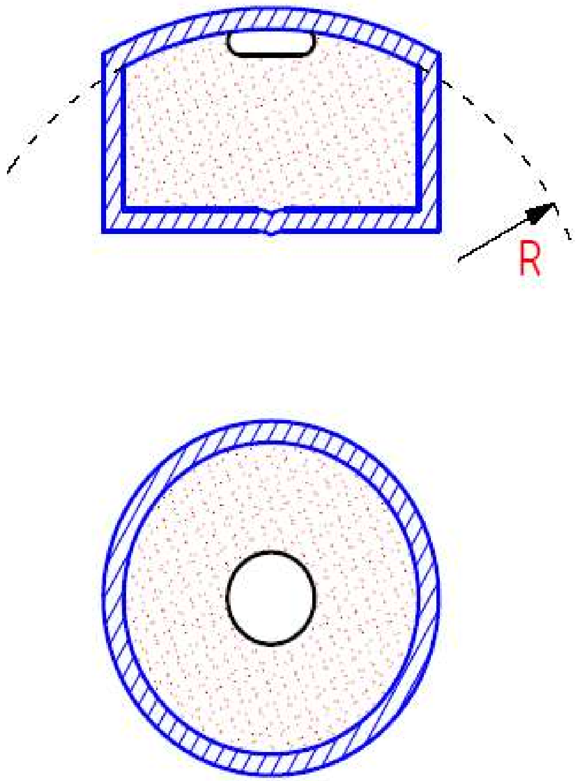
PLUMB-BOB, BUBBLE

Bubbles

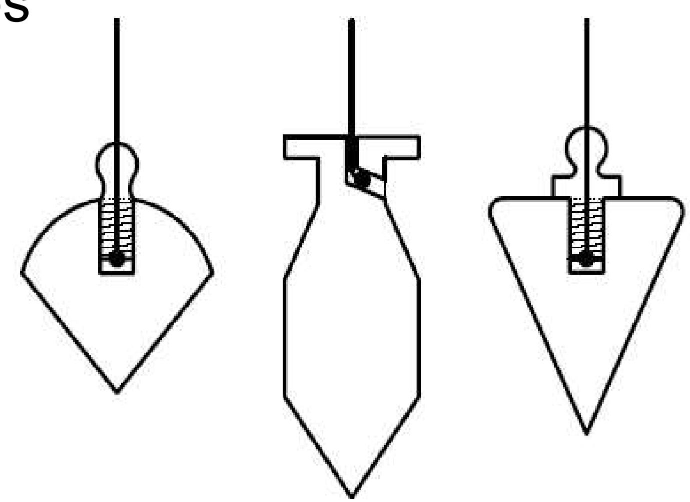
Tubular bubble
(bubble tube)



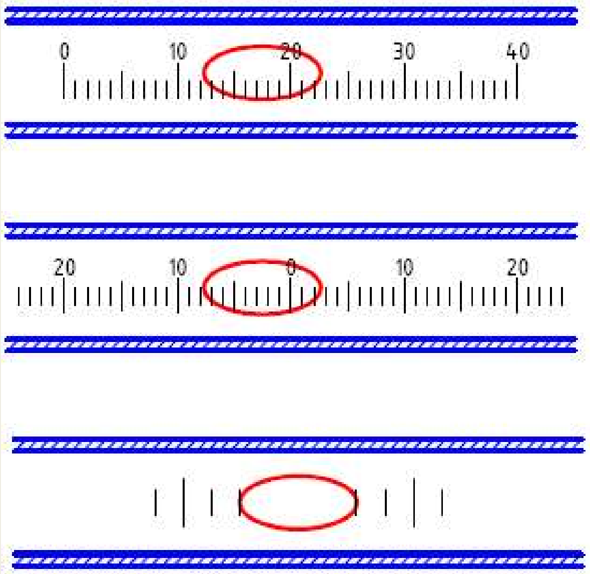
Circular bubble



Plumb-bobs



Bubble tube scales

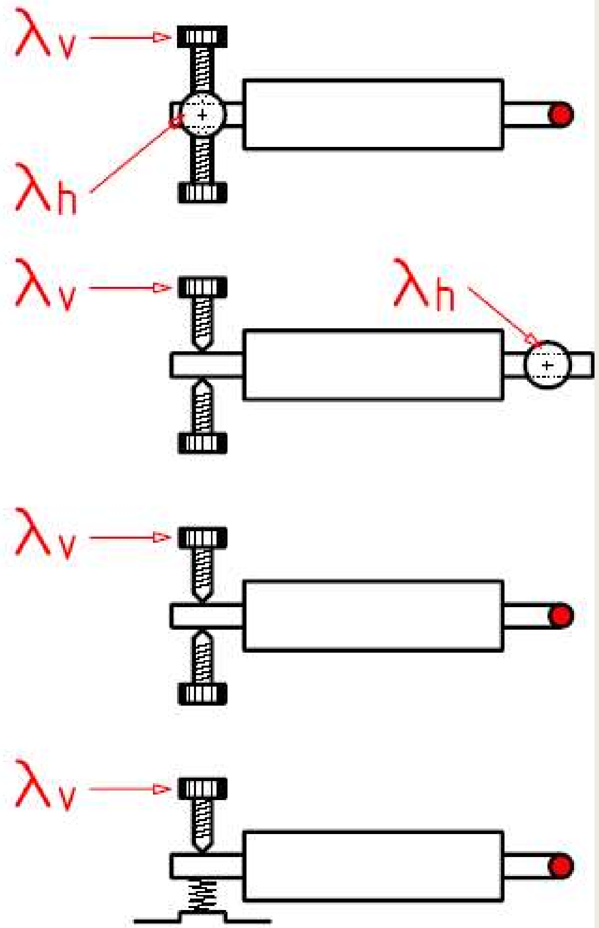


astrological

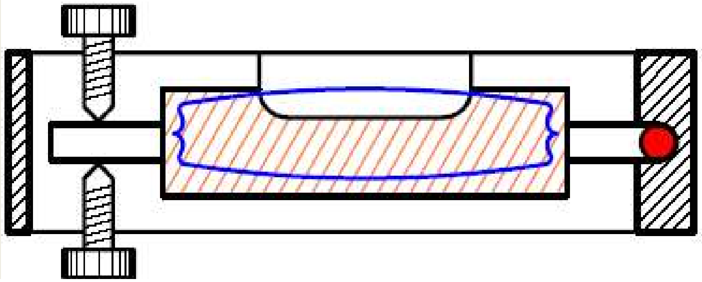
geodesic

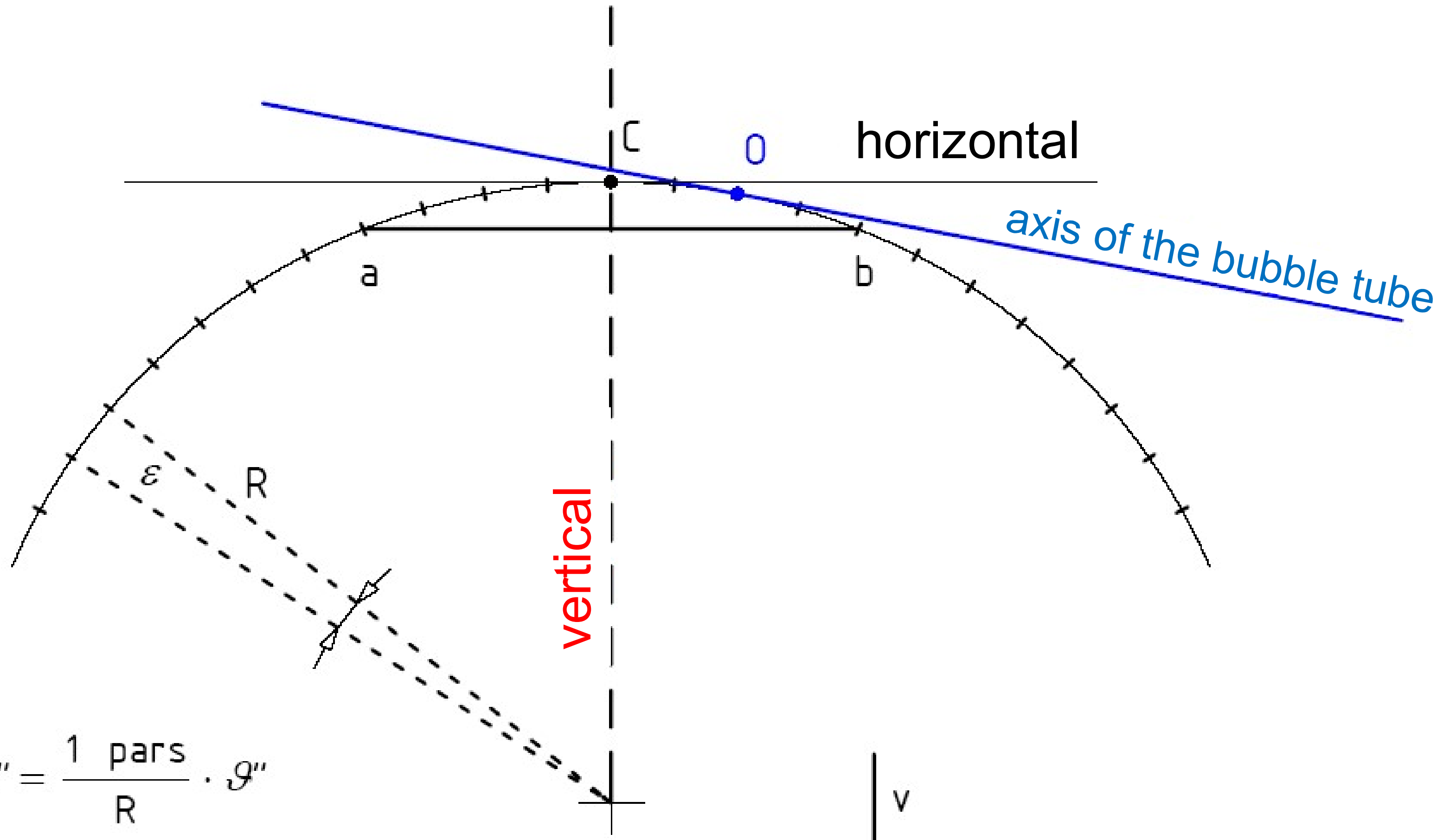
incomplete

Adjusting screws schemes on a tubular bubble

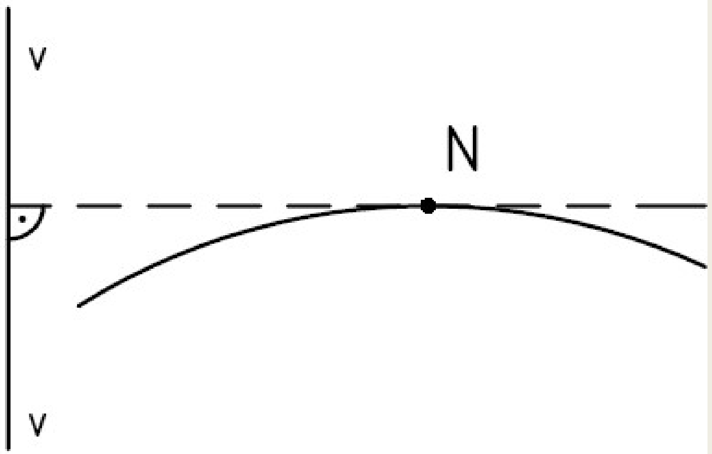


Tubular bubble in protective tube





$$\varepsilon'' = \frac{1 \text{ pars}}{R} \cdot \vartheta''$$



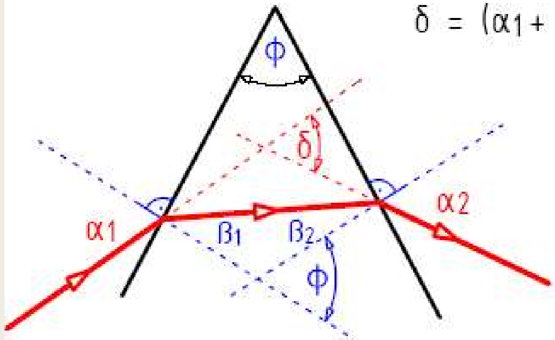
PRIZM, MAGNIFIER, PLANPARALLEL GLASS PLAIN

Glass prism

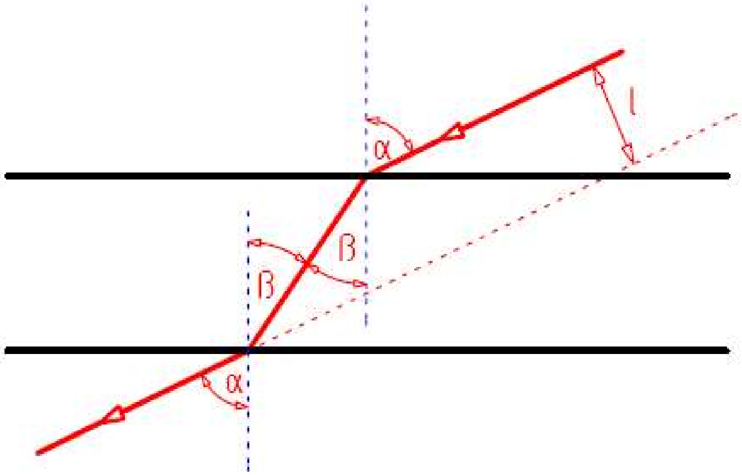
$$\delta = (\alpha_1 - \beta_1) + (\alpha_2 - \beta_2)$$

$$\beta_1 + \beta_2 = \phi$$

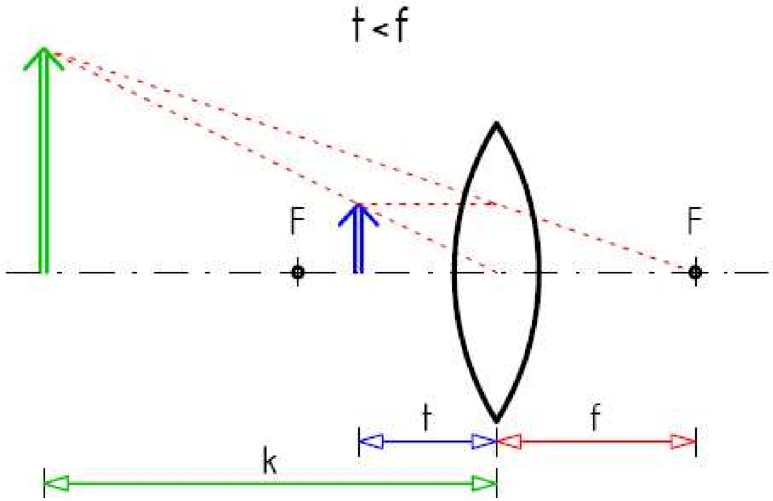
$$\delta = (\alpha_1 + \alpha_2) - \phi$$



Planparallel glass plain

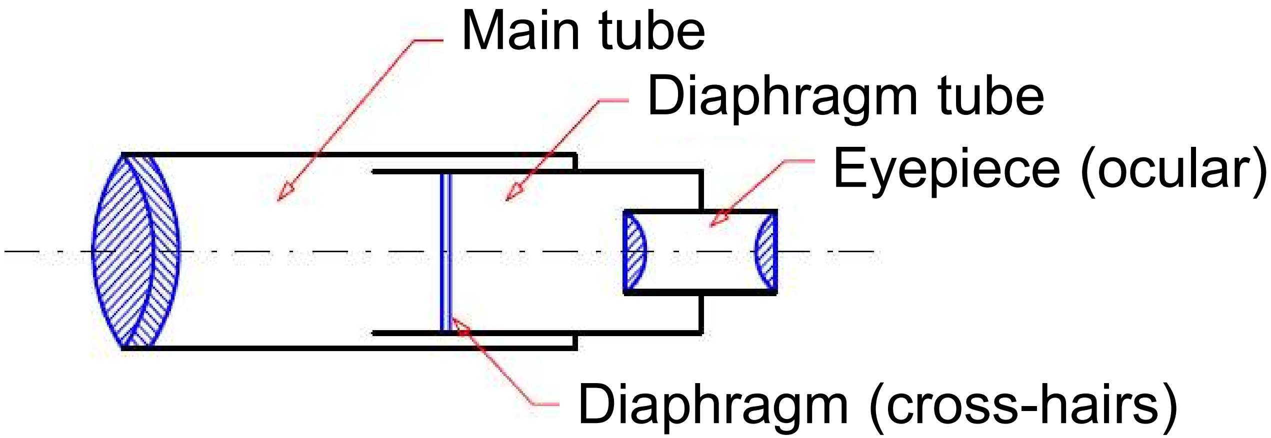


Magnifier

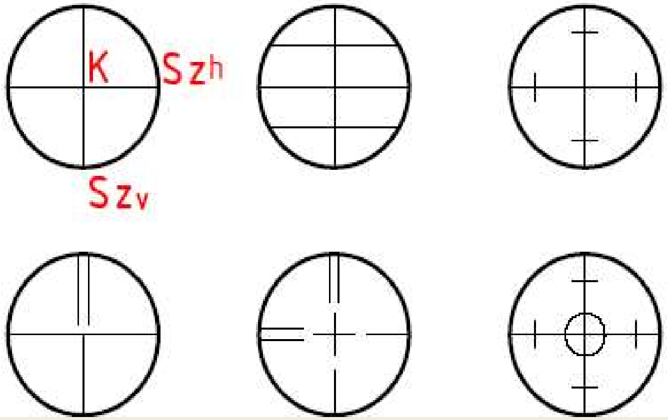


GEODESIC TELESCOPES

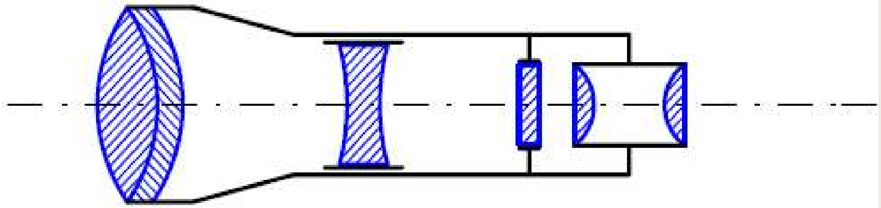
Simple geodesic telescope (constant focal length)

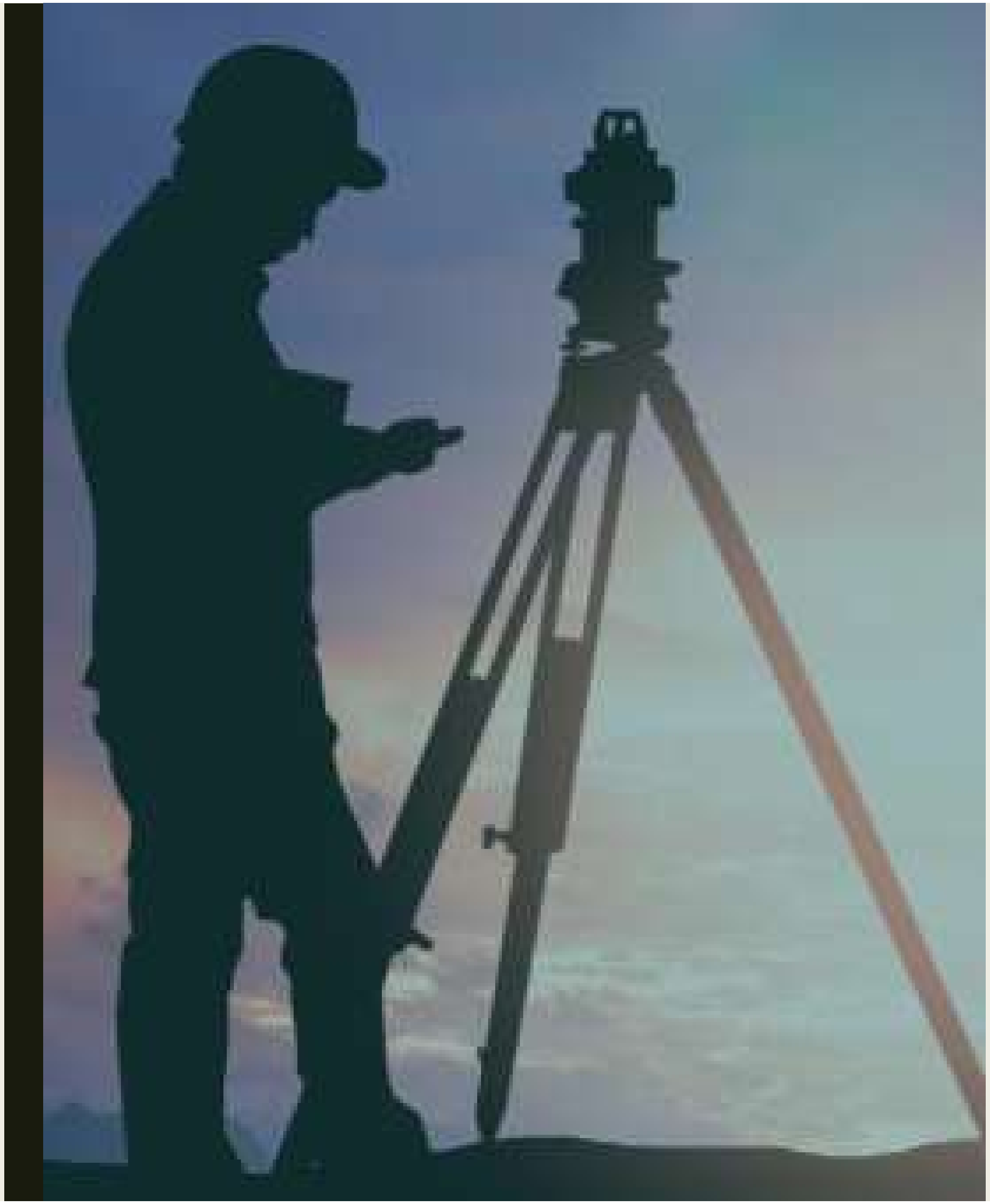


Diaphragm (cross-hairs)



Wild-system telescope with changeable focal length

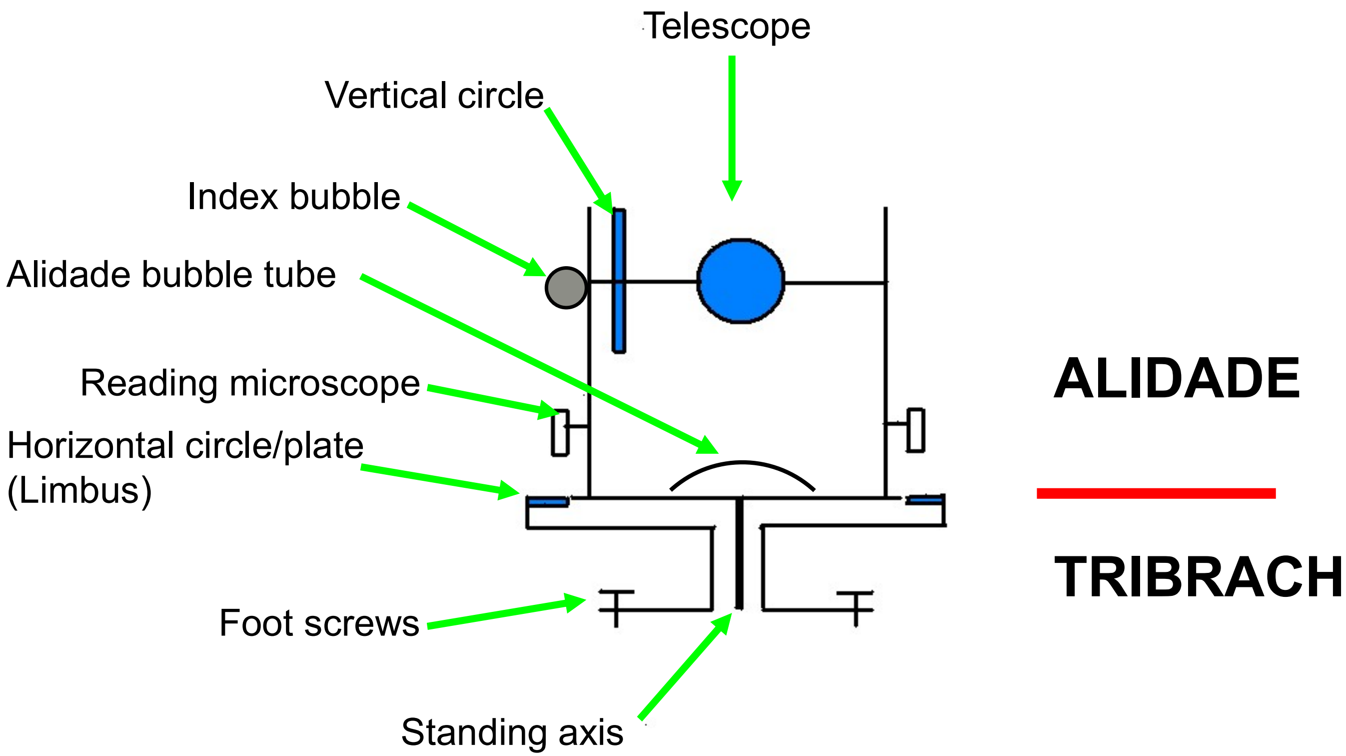




HORIZONTAL MEASURE-MENTS

Angles and distances

Theodolite



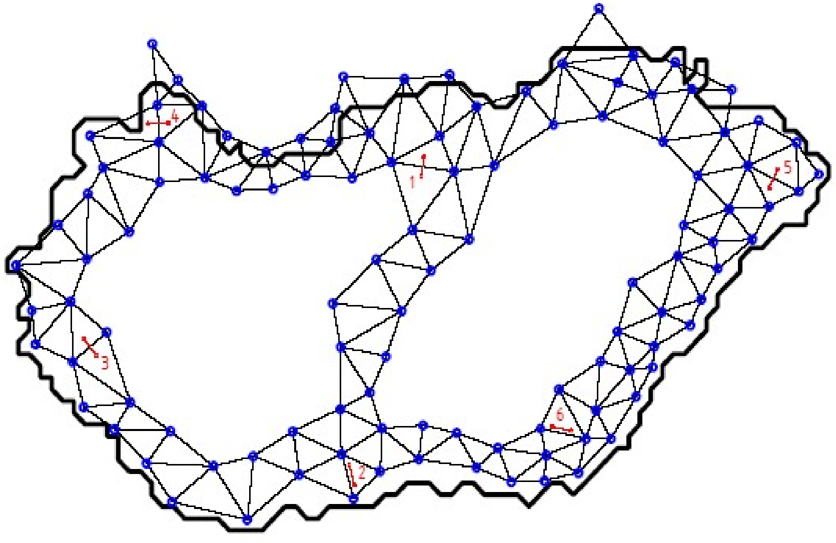
Telescope
Vertical circle
Index bubble
Alidade bubble tube
Reading microscope
Horizontal circle/plate
(Limbus)
Foot screws
Standing axis
ALIDADE
TRIBRACH

Reading microscopes

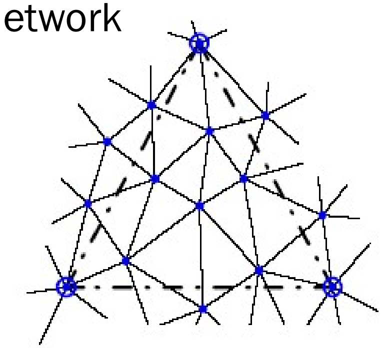
Modern Teodolitos

Horizontal grid-system (EOV)

Hungarian first rank triangulated basepoints



Fictional first rank basepoint network

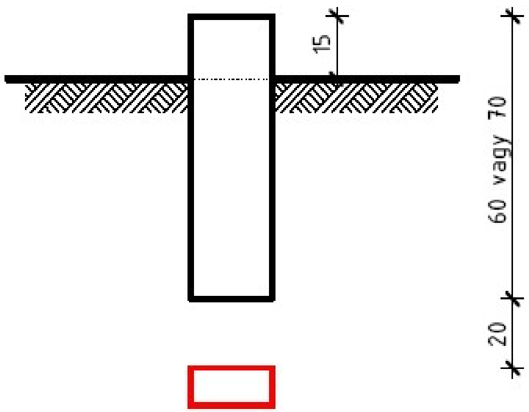


Point stabilisation

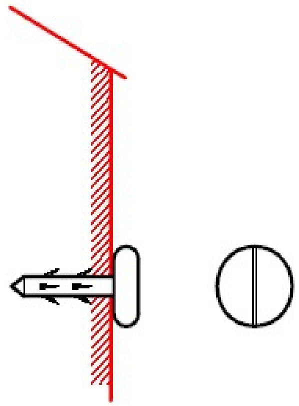
Stone sizes

15 x 15 x 60
20 x 20 x 70
25 x 25 x 60
25 x 25 x 90

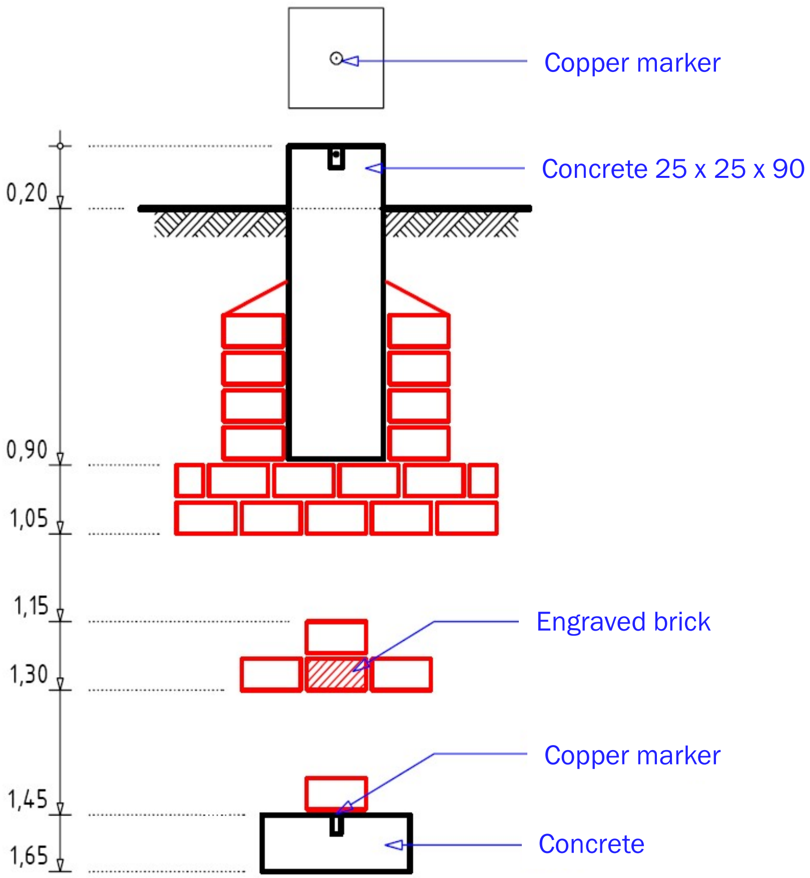
Stabilisation of 4th and 5th ranked points



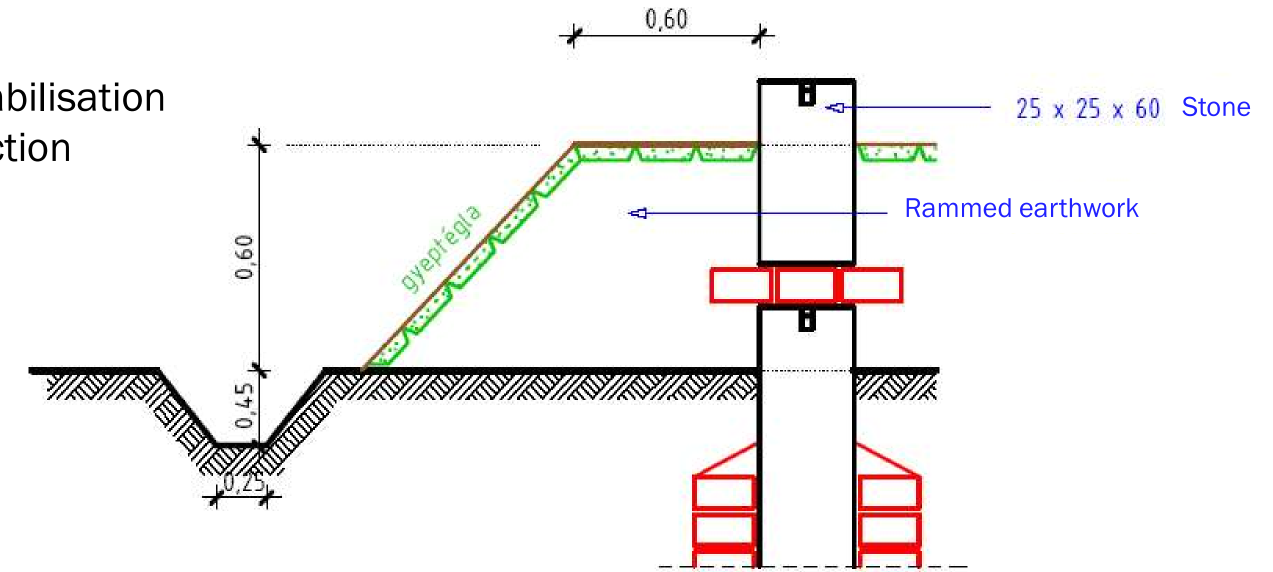
Guard pin



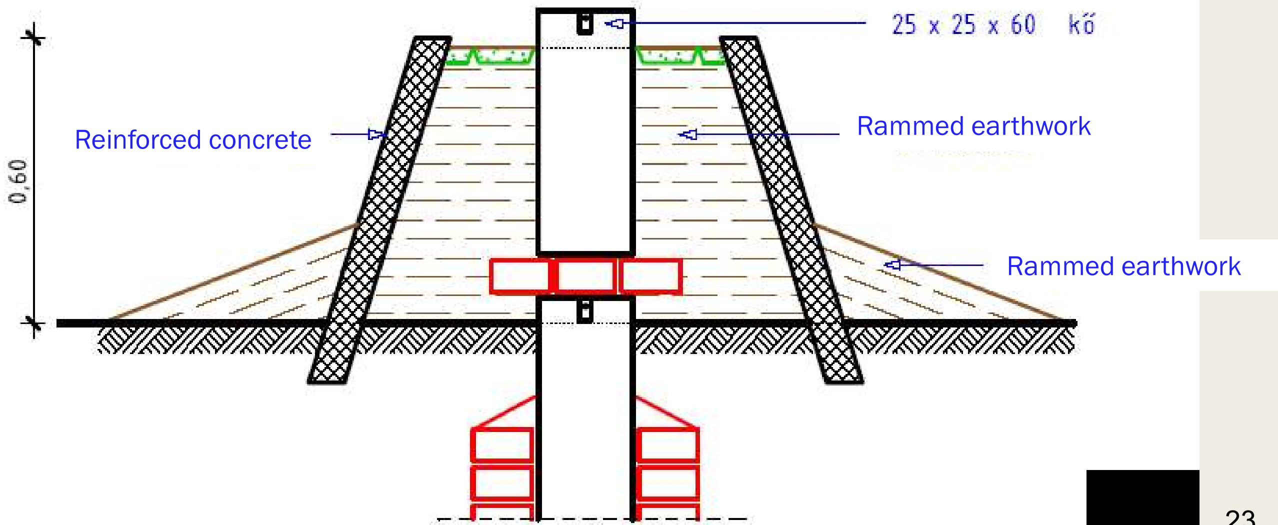
Point stabilisation



Higher order point stabilisation with earthwork protection

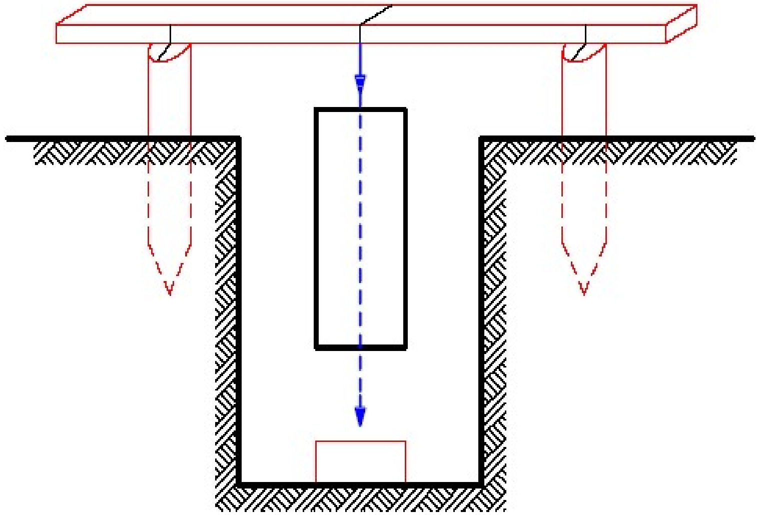


Higher order point stabilisation with reinforced concrete protection

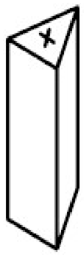


Point stabilisation

Point below surface



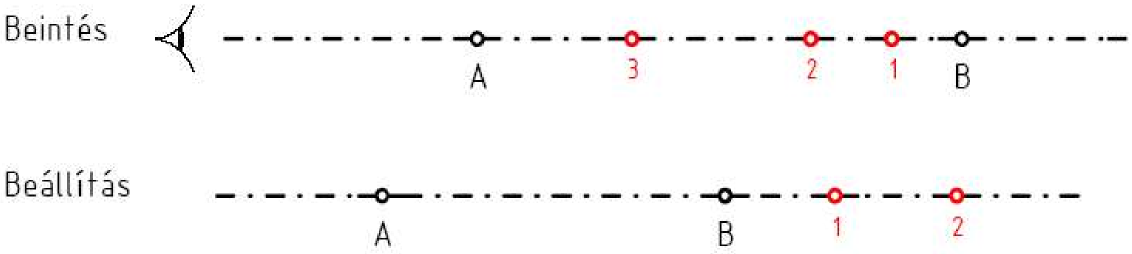
Detail point



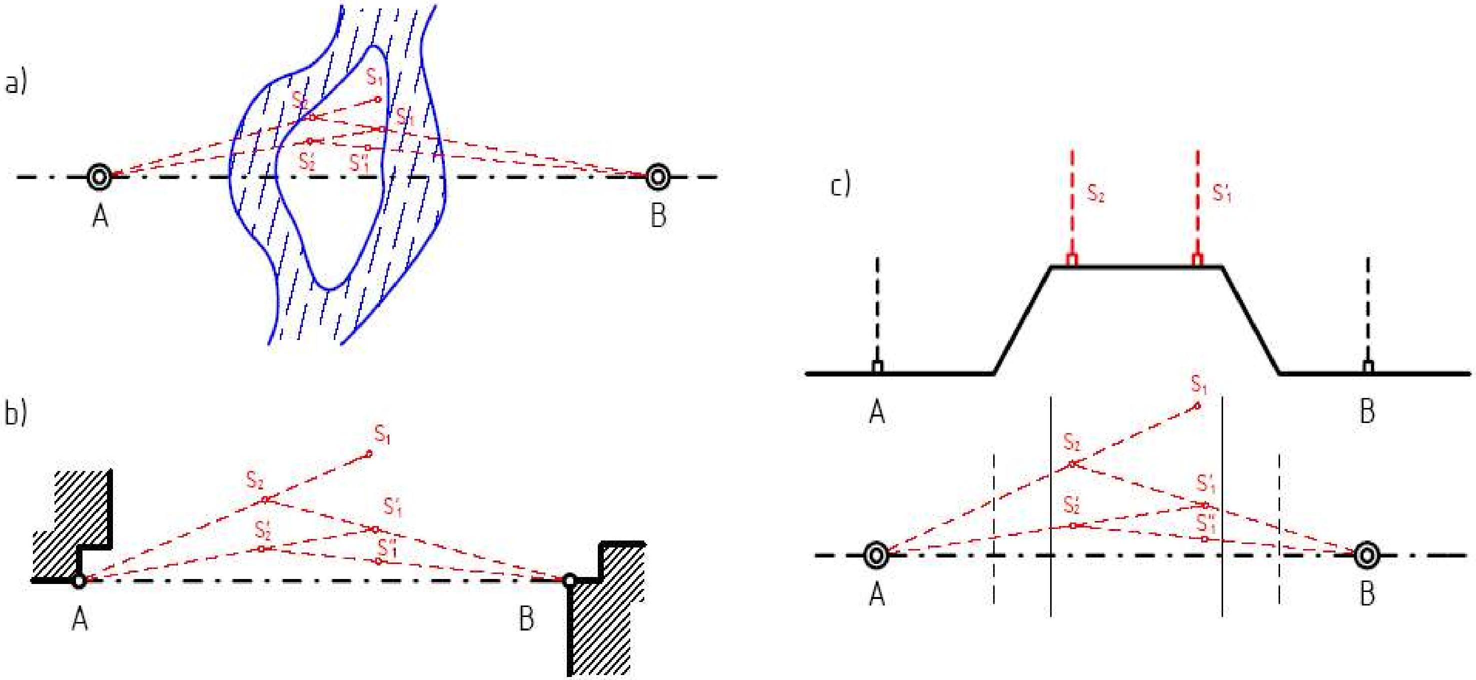
15 x 15 x 50 Concrete

SETTING OUT STRAIGHT LINES

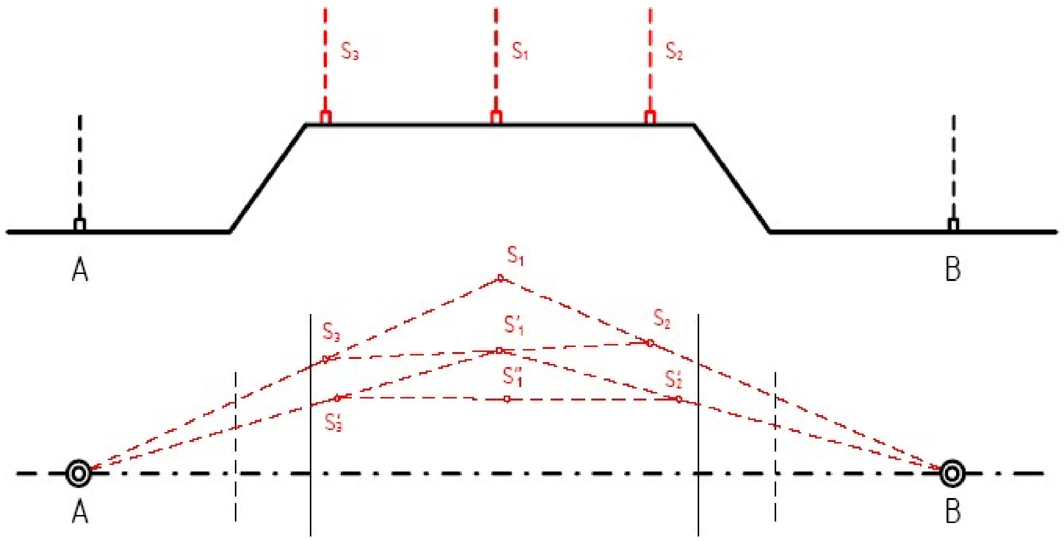
Setting out lines



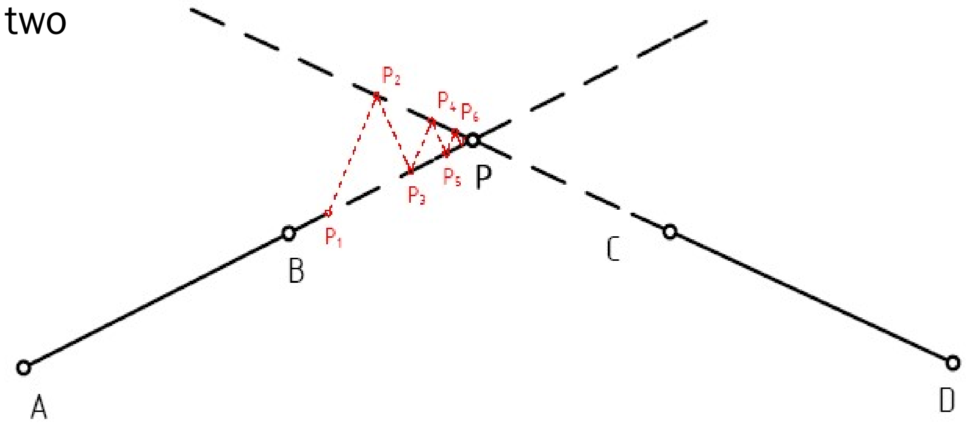
Setting out lines with obstacles

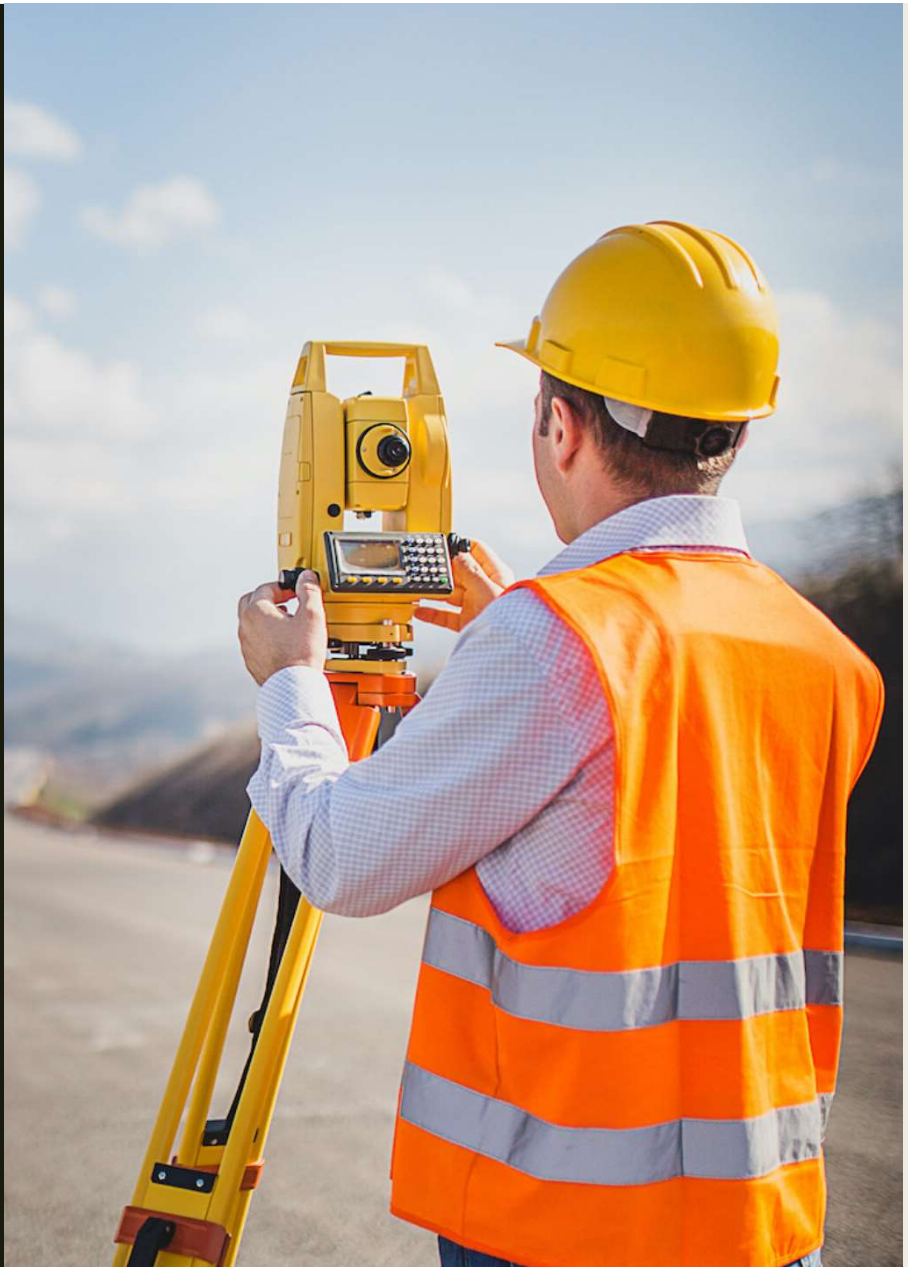


Setting out lines with obstacles



Intersection between two points





Detail point measurement

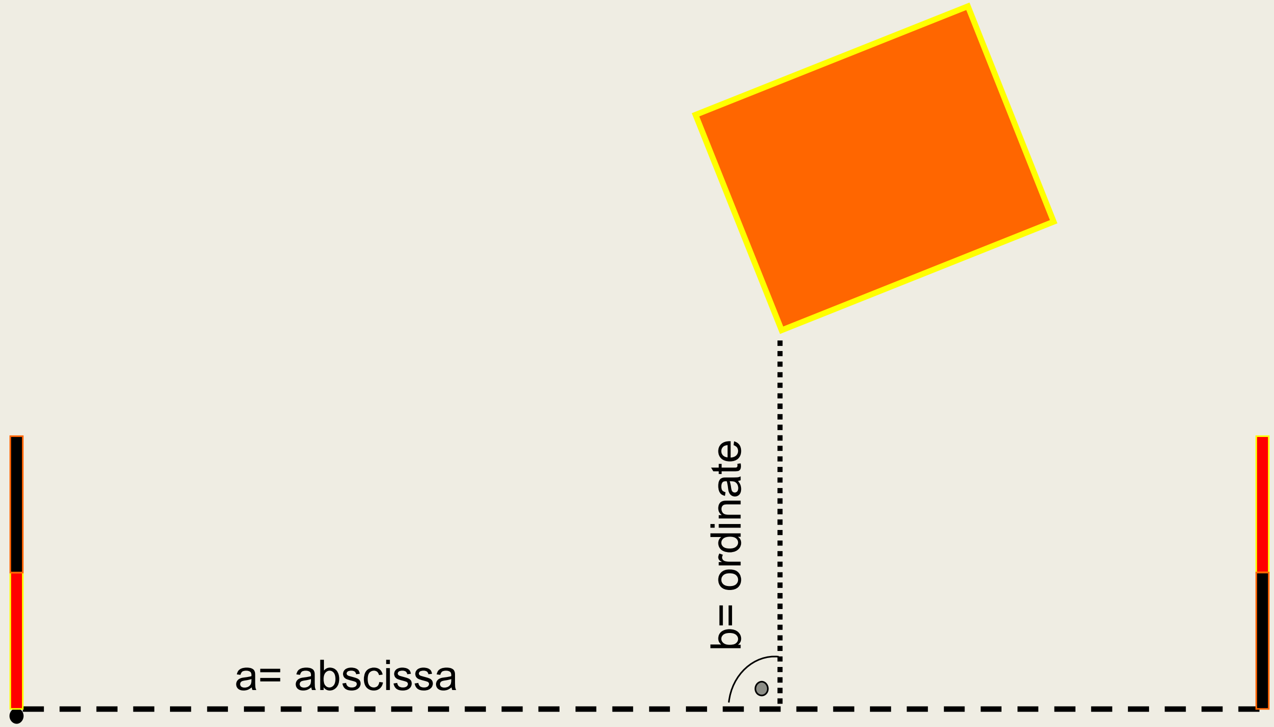
Orthogonal

Tools:
Prism,
Measure tape

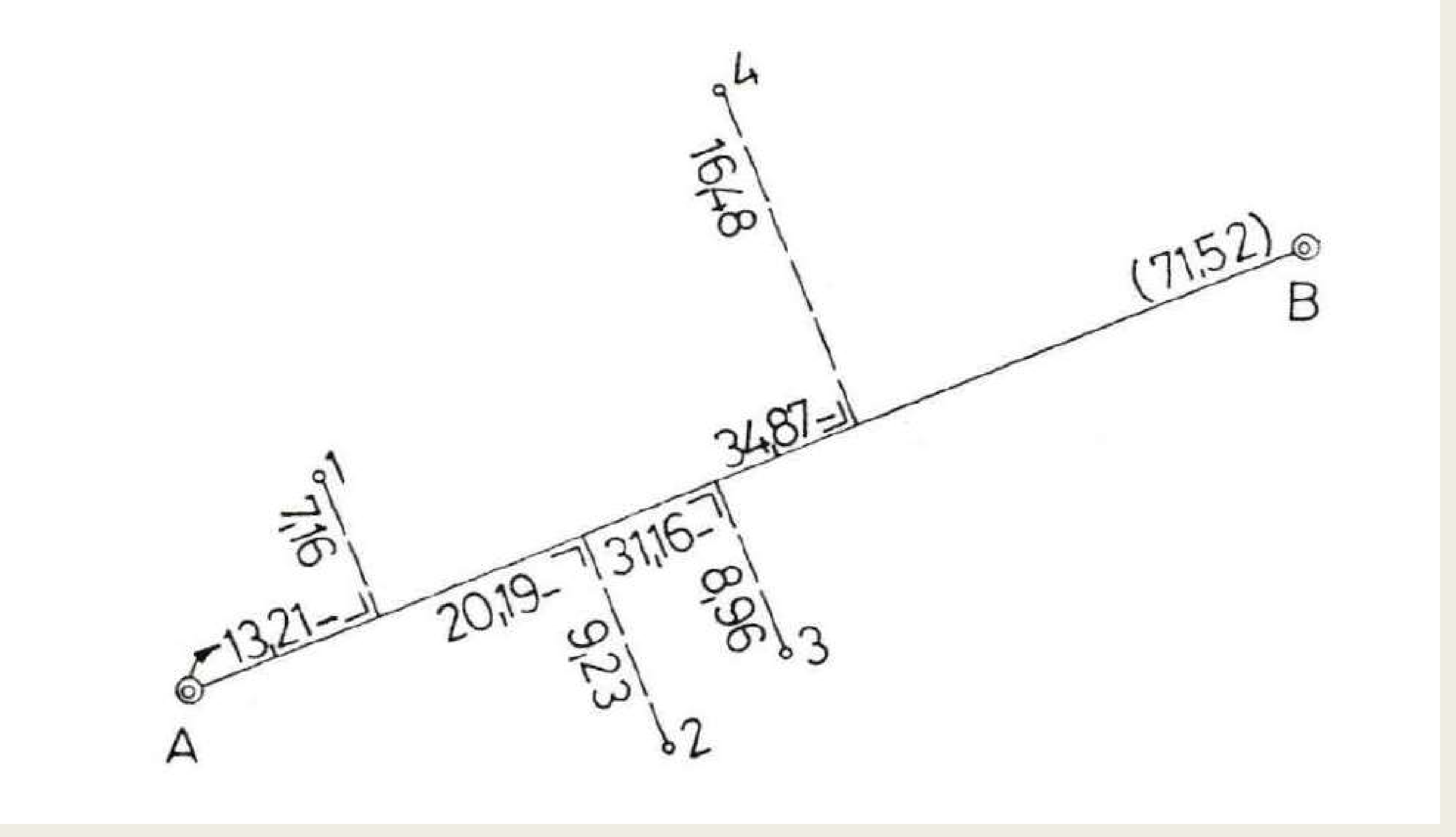
Polar

Tools:
Theodolite,
Measure tape

Orthogonal detailpoint measurement

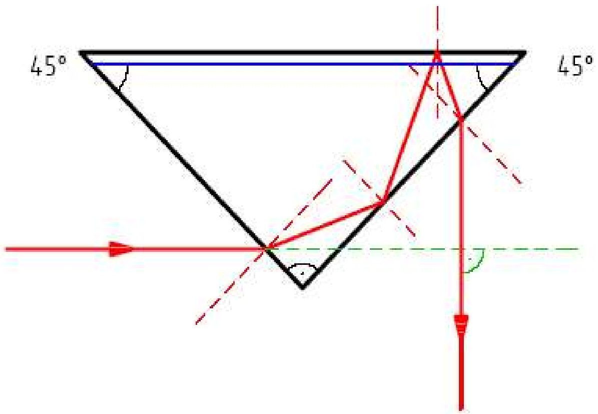


Example drawing

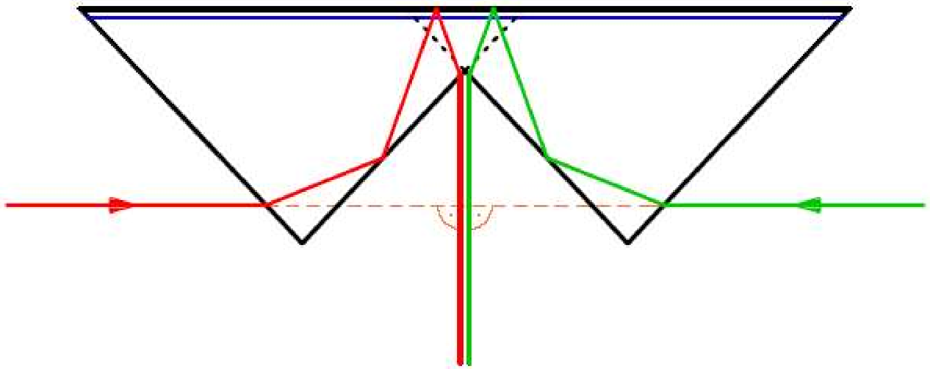


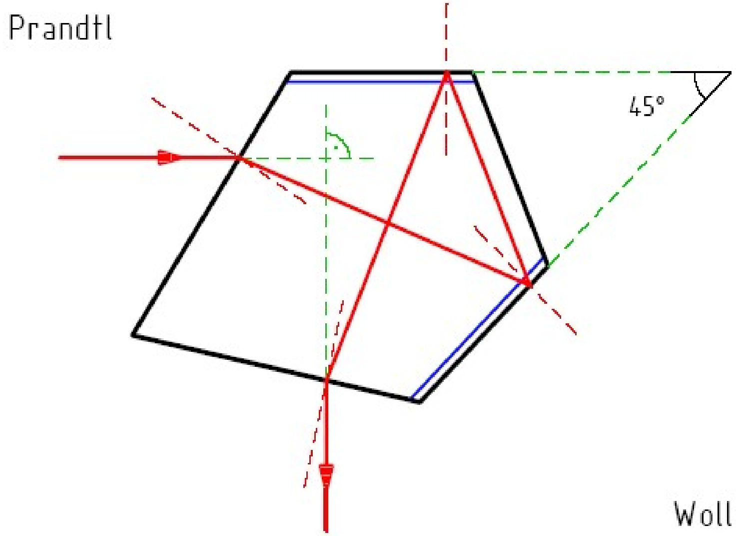
Prisms

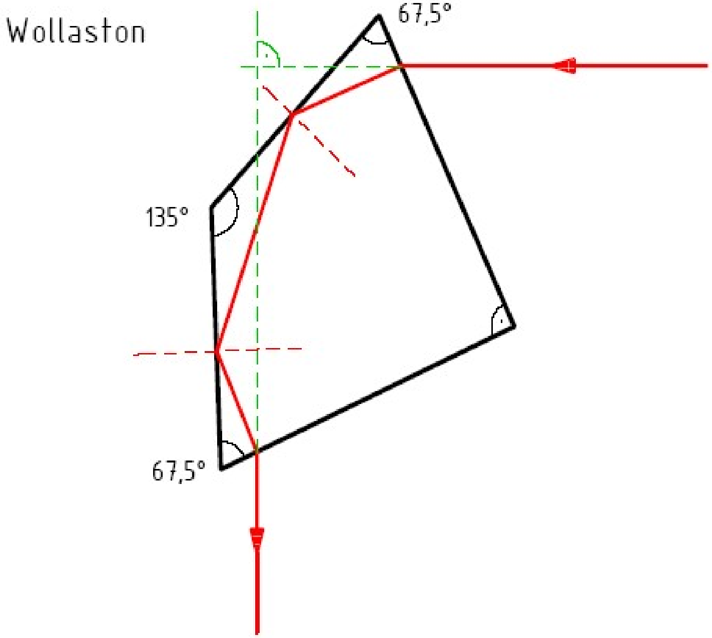
Bauerfeind

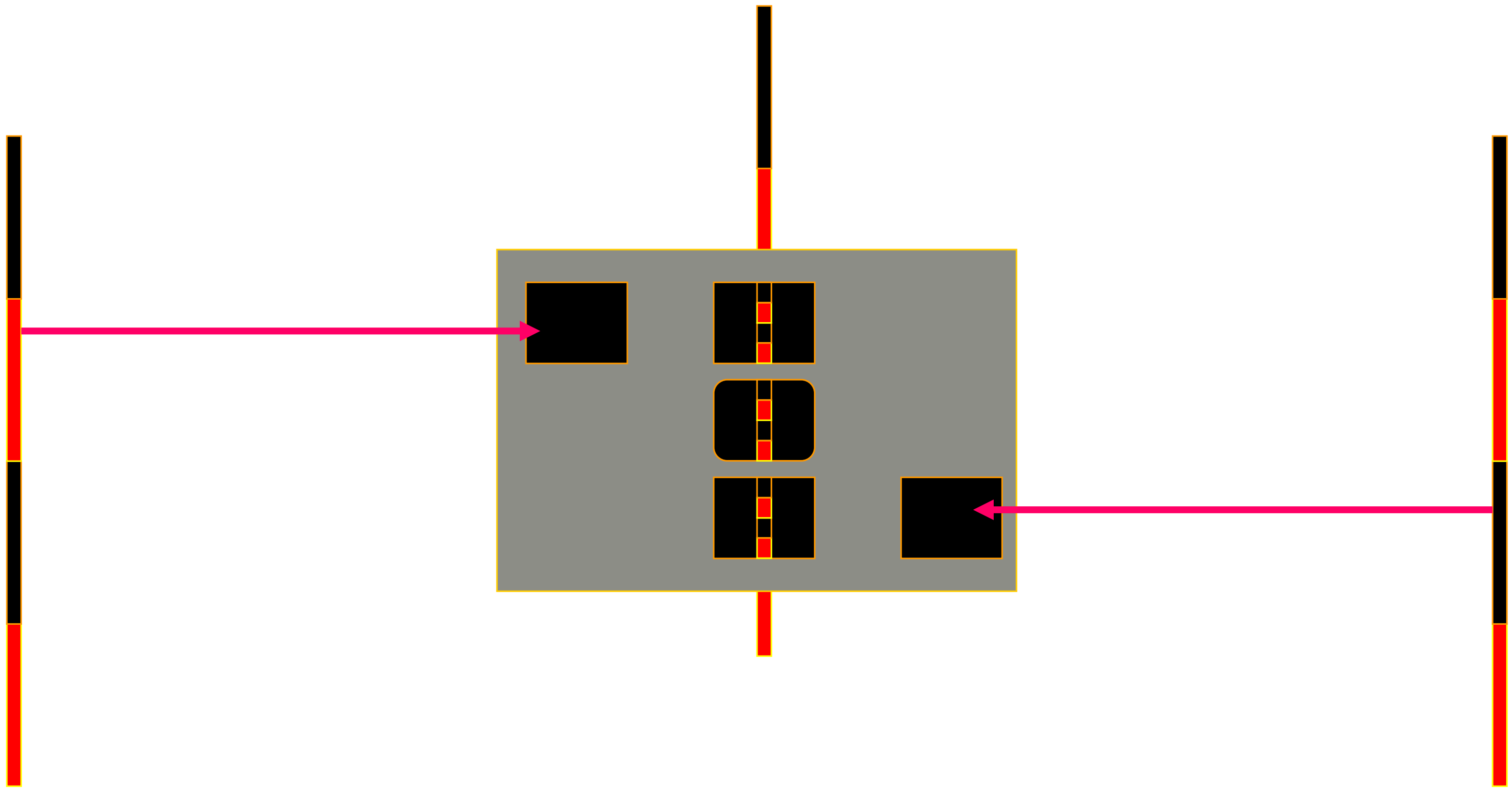


Duplex – double Bauerfeind

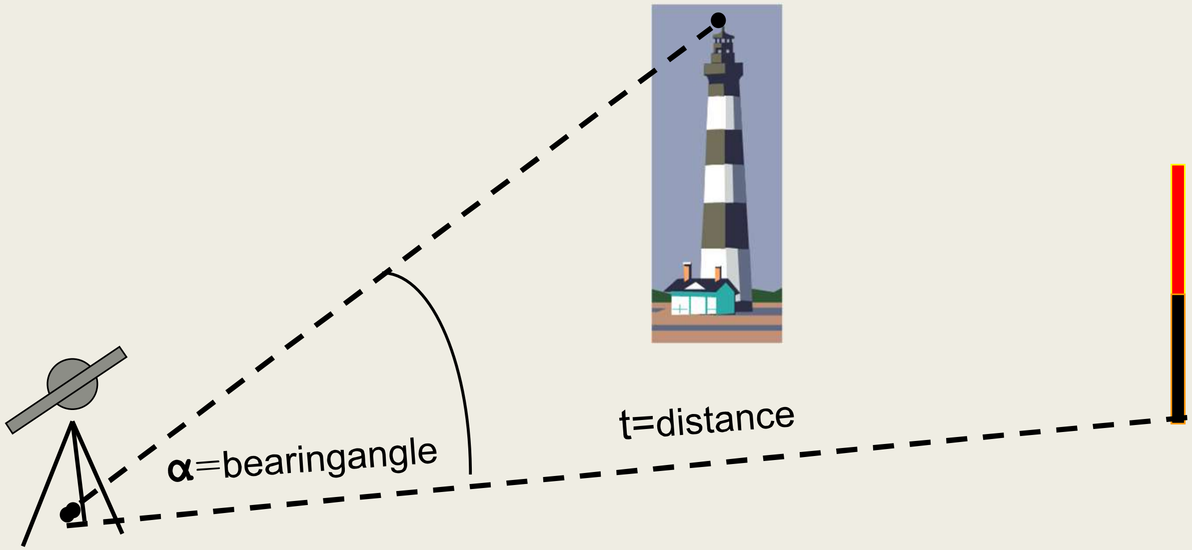



Prandtl
45°


Wollaston
67,5°
135°
67,5°



Polar detailpoint measurement



Surveying I.

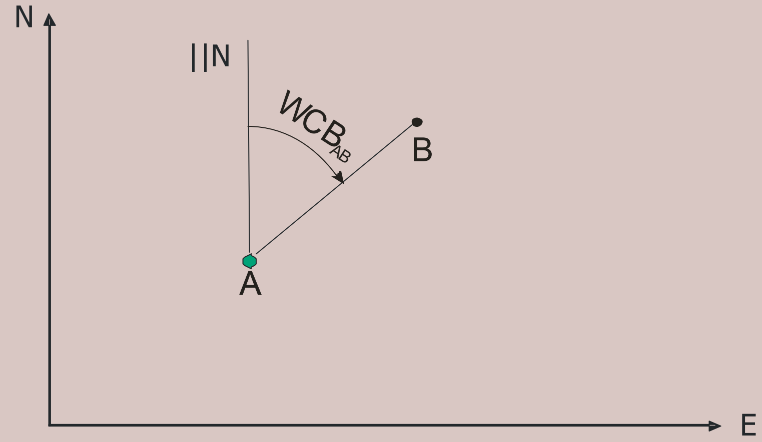
Plane surveying. Fundamental tasks of surveying. Intersections. Orientation.

The coordinate system

Northing axis is the projection of the starting meridian of the projection system, while the Easting axis is defined as the northing axis rotated by 90° clockwise.

The whole circle bearing

How could the direction of a target from the station be defined?



Whole circle bearing: the local north is rotated clockwise to the direction of the target. The angle which is swept is called the whole circle bearing.

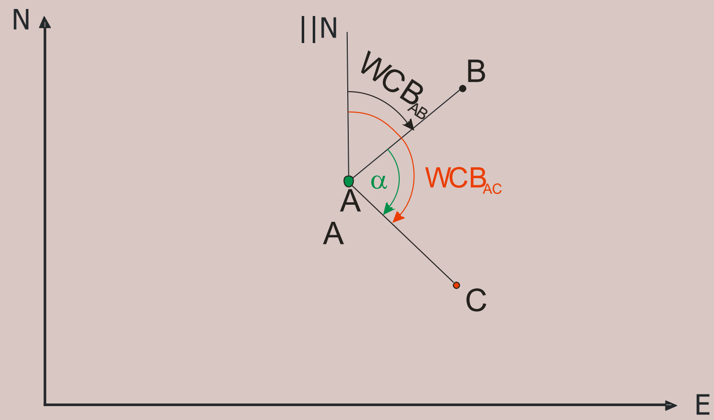
$$0° \leq WCB_{AB} < 360°$$

Transferring Whole Circle Bearings

WCB of reverse direction:

$$WCB_{BA} = WCB_{AB} \pm 180°$$

Transferring WCBs: WCB_{AB} is known, α is measured, how much is WCB_{AC}?

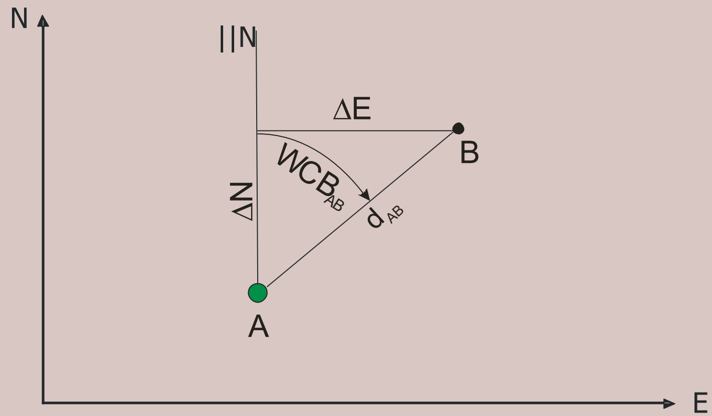


$$WCB_{AC} = WCB_{AB} + \alpha$$

$$or$$

$$WCB_{AB} = WCB_{AC} - \alpha$$

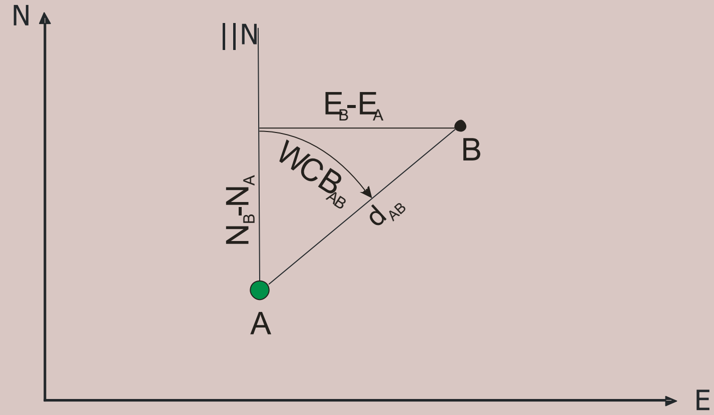
1st fundamental task of surveying



A(E_A, N_A), WCB_{AB} and d_{AB} is known,
B(E_B,N_B)=?

$$\Delta E_{AB} = E_B - E_A = d_{AB} \cdot \sin WCB_{AB}$$
$$\Delta N_{AB} = N_B - N_A = d_{AB} \cdot \cos WCB_{AB}$$
$$\Downarrow$$
$$E_B = E_A + d_{AB} \cdot \sin WCB_{AB},$$
$$N_B = N_A + d_{AB} \cdot \cos WCB_{AB}.$$

2nd fundamental task of surveying



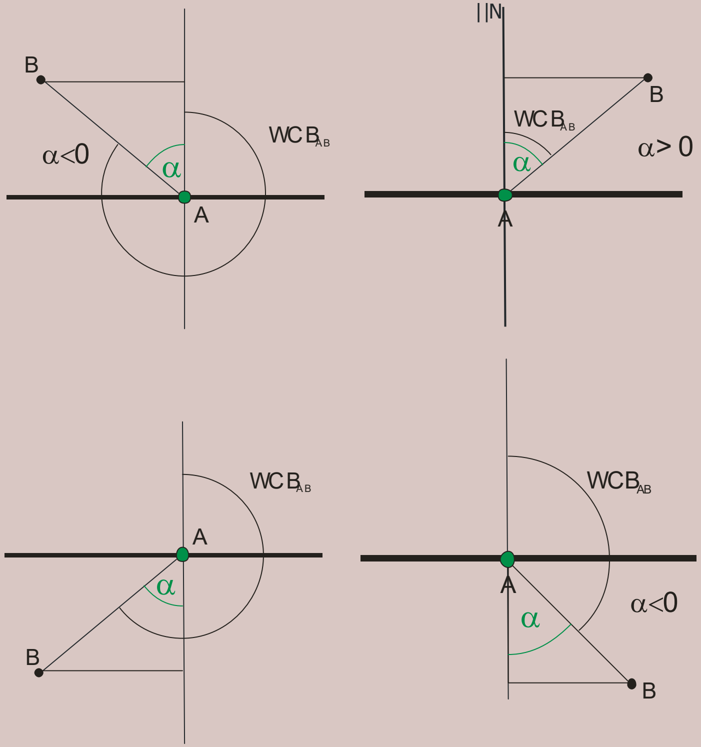
A(E_A, N_A), B(EB,NB) is known,
WCB_{AB}=? and d_{AB}=?

$$d_{AB} = \sqrt{(E_B - E_A)^2 + (N_B - N_A)^2}$$

$$\alpha = \arctan \frac{E_B - E_A}{N_B - N_A},$$

$$WCB_{AB} = \alpha + c$$

2nd fundamental task of surveying



$$d_{AB} = \sqrt{(E_B - E_A)^2 + (N_B - N_A)^2}$$

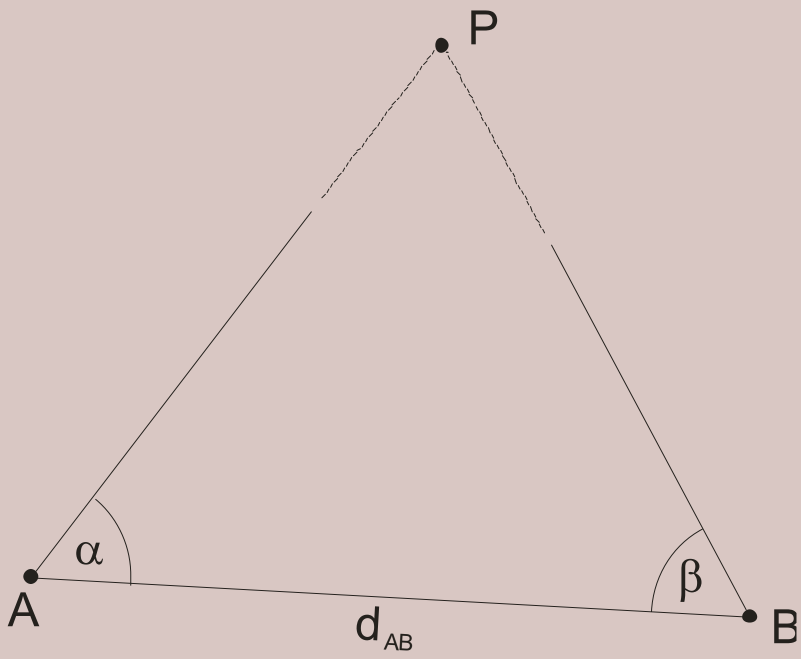
$$\alpha = \arctan \frac{E_B - E_A}{N_B - N_A},$$

$$WCB_{AB} = \alpha + c$$

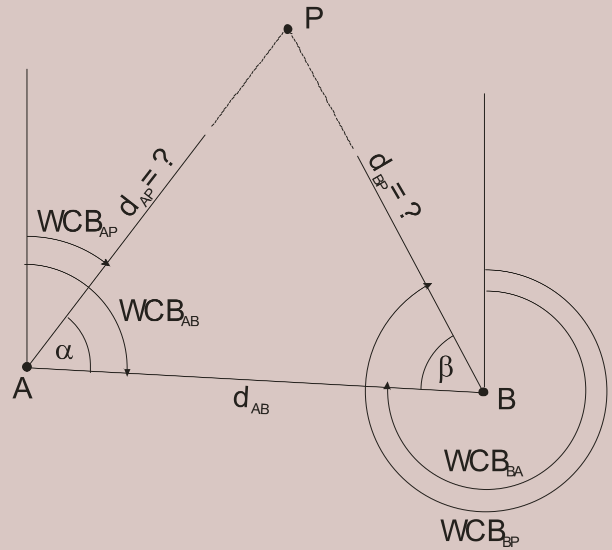
Quadrant	E_B-E_A	N_B-N_A	c
I.	+	+	0
II.	+	-	+180°
III.	-	-	+180°
IV.	-	+	+360°

Intersections

Aim: the coordinates of an unknown point should be computed. Measurements are taken from two different stations to the unknown point, and the so formed triangle should be solved.



Foresection with inner angles



A (E_A,N_A)
B (E_B,N_B) are known
α, β are observed

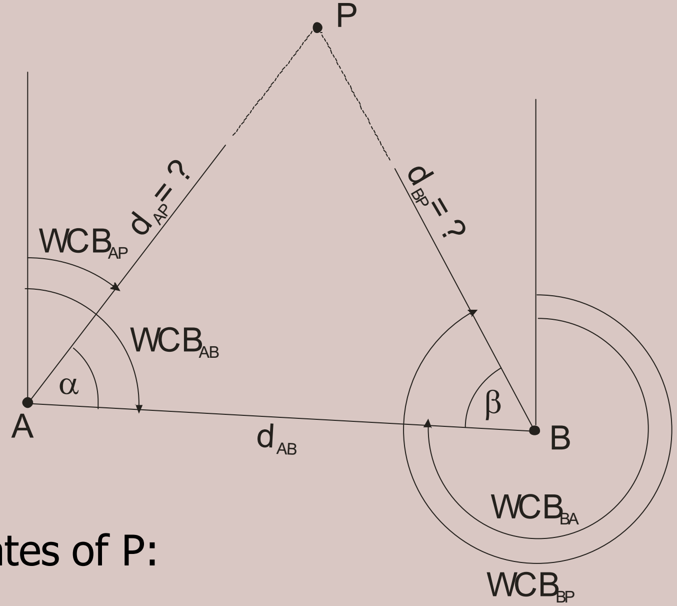
1. Compute WCB_{AB}, d_{AB} using the 2nd fundamental task of surveying.
2. Using the sine theorem compute d_{AP} and d_{BP}!

$$d_{AP} = d_{AB} \frac{\sin\beta}{\sin(\alpha+\beta)} \qquad d_{BP} = d_{AB} \frac{\sin\alpha}{\sin(\alpha+\beta)}$$

3. Compute WCB_{AP} and WCB_{BP}:

$$WCB_{AP} = WCB_{AB} - \alpha \qquad WCB_{BP} = WCB_{BA} + \beta$$

Foresection with inner angles



4. Compute the coordinates of P:

$$\textit{From } A:$$

$$E_P^A = E_A + d_{AP} \sin WCB_{AP} \qquad N_P^A = N_A + d_{AP} \cos WCB_{AP},$$

$$\textit{From } B:$$

$$E_P^B = E_B + d_{BP} \sin WCB_{BP} \qquad N_P^B = N_B + d_{BP} \cos WCB_{BP},$$

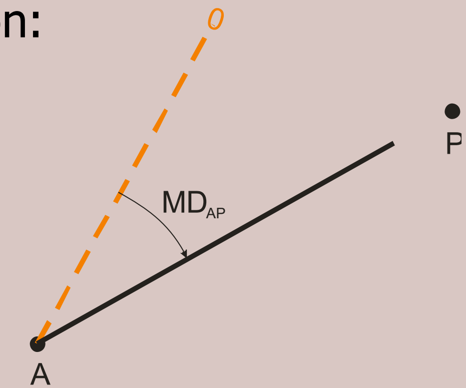
$$\Downarrow$$

$$E_P = \frac{E_P^A + E_P^B}{2} \qquad N_P = \frac{N_P^A + N_P^B}{2}$$

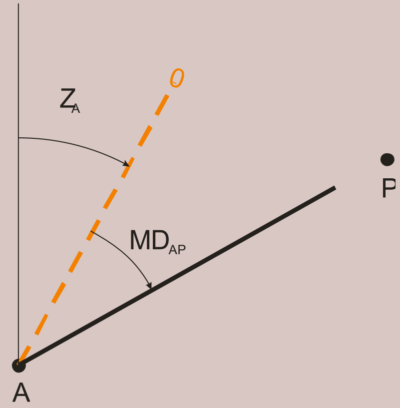
Orientation

How can the WCB be determined from observations?

Recall the definition of mean direction:



All the angular observations refer to the index of the horizontal circle, but they should refer to the Northing instead!



Orientation

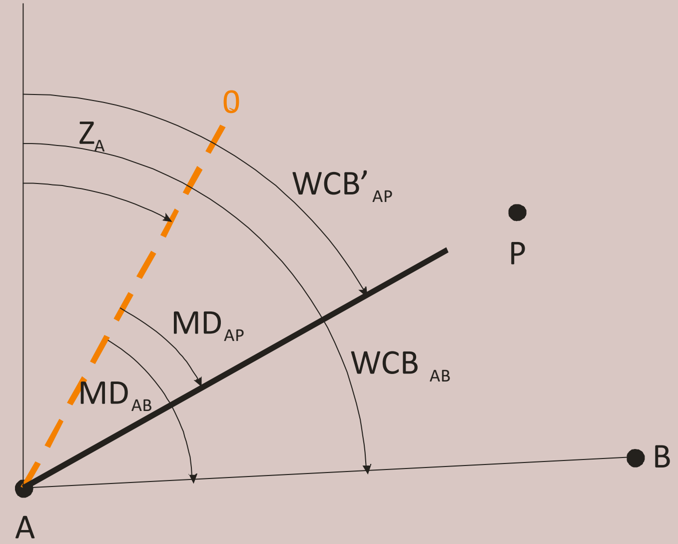
z_A – orientation angle

Orientation

How to find the orientation angle?

A,B are known points, MD_{AP} and MD_{AB} are observed.

Aim: Compute WCB'_{AP}



Compute the orientation angle:

$$z_A = WCB_{AB} - MD_{AB}$$

Computing the WCB'_{AP}:

$$WCB'_{AP} = z_A + MD_{AP}$$

Computing the mean orientation angle

In case of more orientations, as many orientation angles can be computed as many control points are sighted:

$$z_A^B = WCB_{AB} - MD_{AB}$$

$$z_A^C = WCB_{AC} - MD_{AC}$$

$$z_A^D = WCB_{AD} - MD_{AD}$$

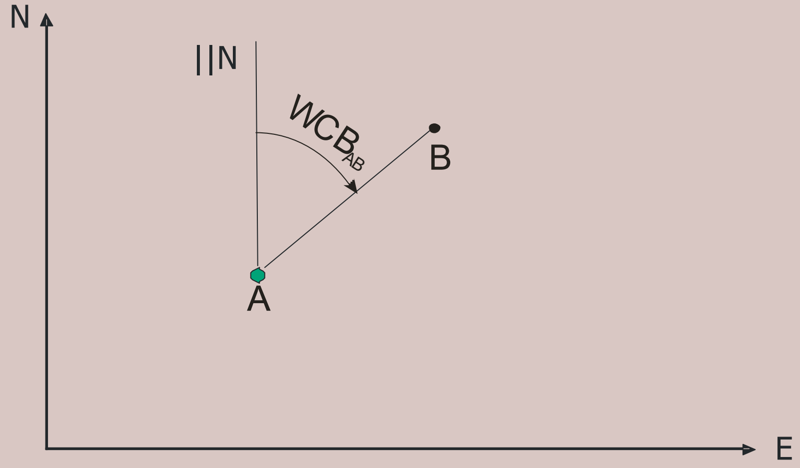
z_A^B, z_A^C and z_A^D are usually slightly different due observation and coordinate error.

However, the orientation angle is constant for a station and a set of observations.

Mean orientation angle:

$$z_A = \frac{z_A^B \cdot d_{AB} + z_A^C \cdot d_{AC} + z_A^D \cdot d_{AD}}{d_{AB} + d_{AC} + d_{AD}}$$

WCB vs provisional WCB

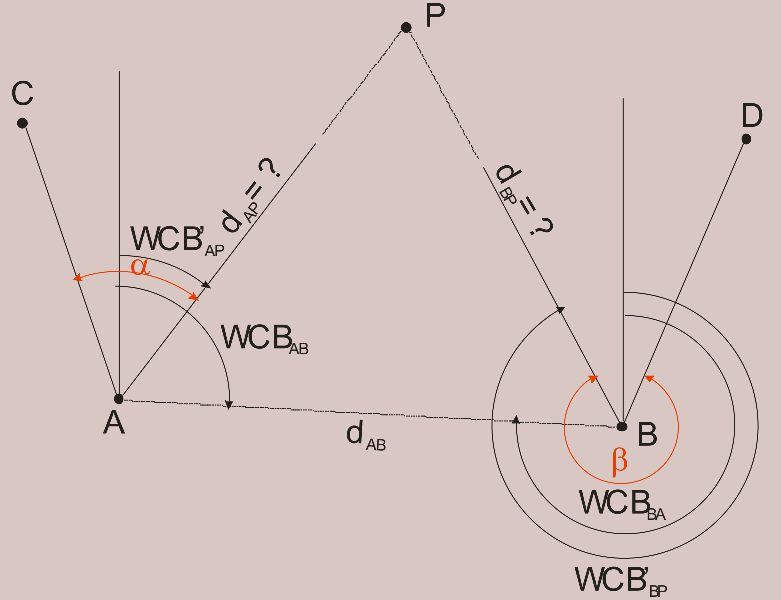


Whole circle bearing (WCB_{AB}): computed from coordinates, between two points, which coordinates are known.

Provisional whole circle bearing (WCB'_{AB}): an angular quantity, which is similar to the whole circle bearing. However it is computed from observations, by summing up the (mean) orientation angle and the mean direction.

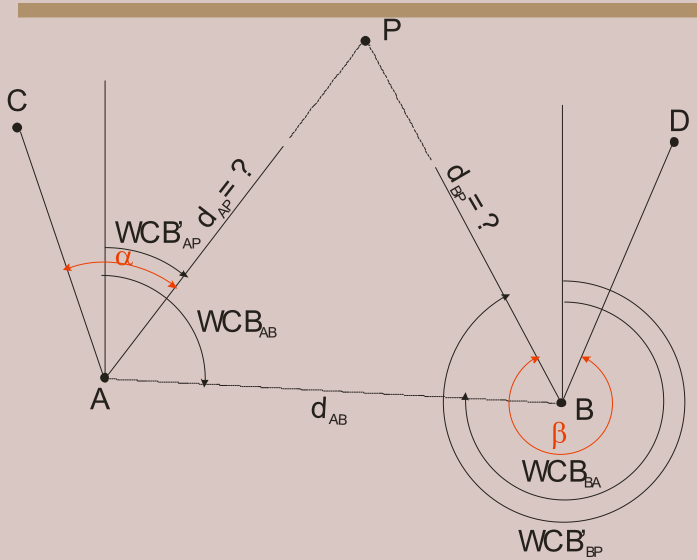
Foresection with WCBs

What happens, when B is not observable from A?



A,B,C and D are known points, α and β are measured.

Foresection with WCBs

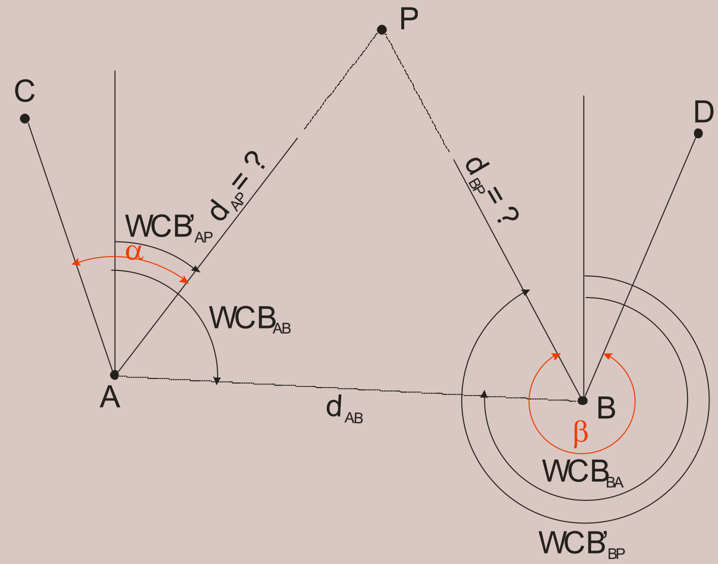


$$WCB'_{AP} = WCB_{AC} + \alpha$$
$$WCB'_{BP} = WCB_{BD} + \beta$$

The equations of the lines AP and BP:

$$N_1 = N_A + \left(E - E_A\right) \cdot \cot WCB_{AP}$$
$$N_2 = N_B + \left(E - E_B\right) \cdot \cot WCB_{BP}$$

Foresection with WCBs



Let's compute the intersection of the lines AP and BP:

$$N_1 = N_2$$

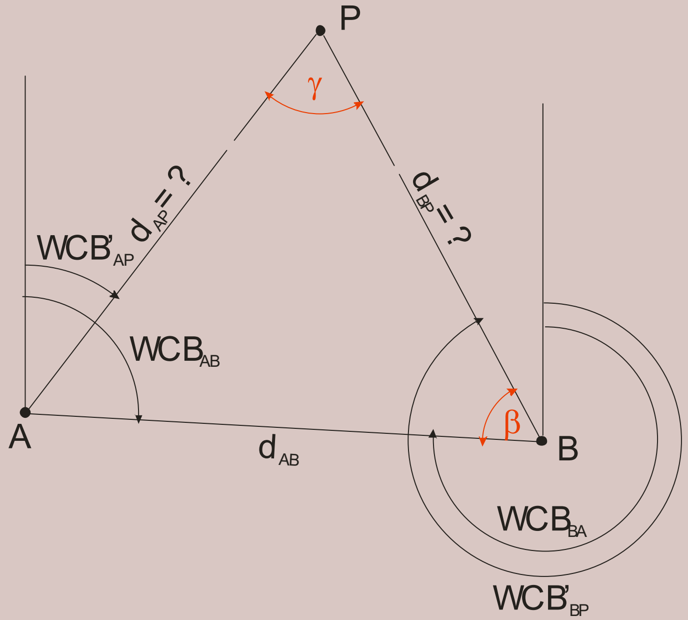
$$E(\cot WCB_{AP} - \cot WCB_{BP}) = N_B - N_A + E_A \cot WCB_{AP} - E_B \cot WCB_{BP}$$

$$E_P = \frac{N_B - N_A + E_A \cot WCB_{AP} - E_B \cot WCB_{BP}}{\cot WCB_{AP} - \cot WCB_{BP}}$$

$$N_P = N_A + (E_P - E_A)\cot WCB_{AP}$$

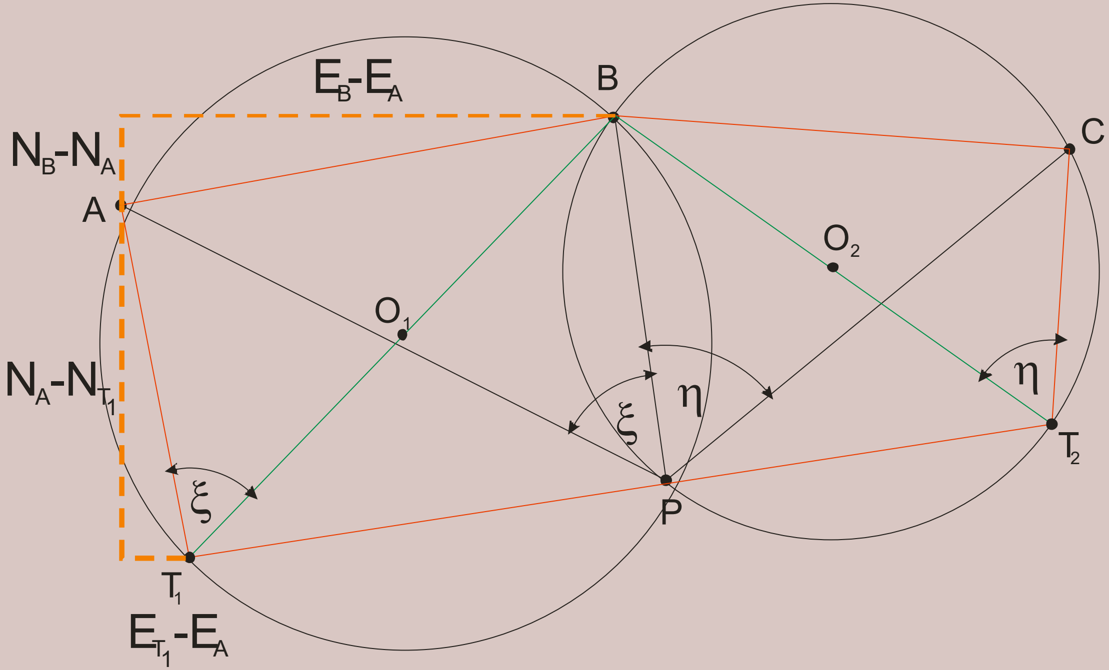
Different types of intersections

How can we use intersections, when A or B is not suitable for setting up the instrument:



α can be computed by $\alpha=180°-\gamma-\beta$. => Foresection.

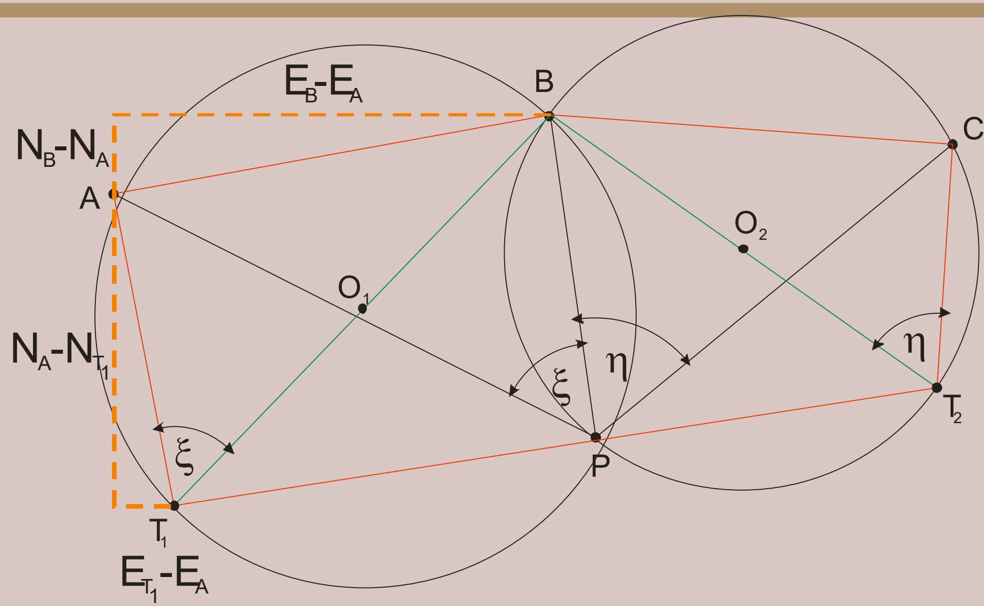
Resection



A, B, C are known control points
ξ and η are observed angles

Aim: compute the coordinates of P (the station)

Resection



Compute the coordinates of T_1 and T_2!

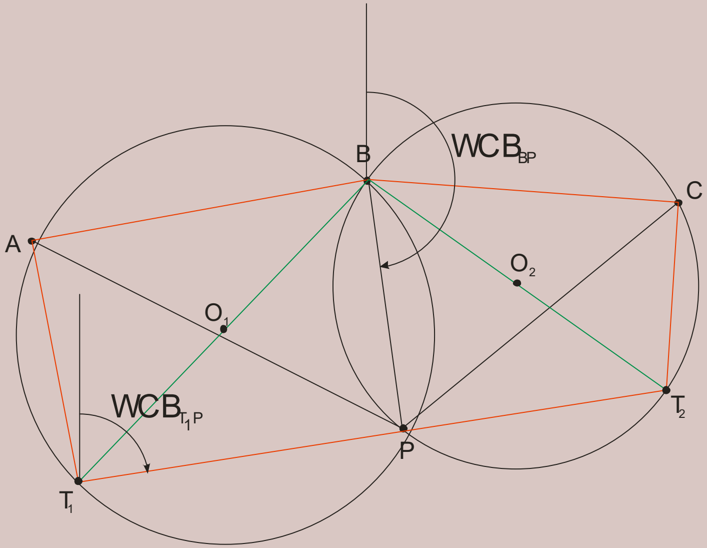
$$\frac{E_B - E_A}{N_A - N_{T_1}} = \frac{N_B - N_A}{E_{T_1} - E_A} = \cot \xi$$

$$\Downarrow$$

$$N_{T_1} = \frac{E_B - E_A - N_A \cot \xi}{\cot \xi},$$

$$E_{T_1} = \frac{N_B - N_A + E_A \cot \xi}{\cot \xi}.$$

Resection



Since T_1, P and T_2 are on a straight line:

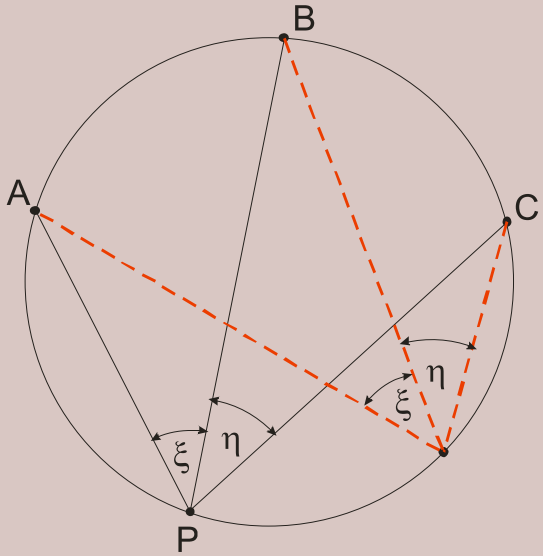
$$WCB_{T_1P} = WCB_{T_1T_2}$$

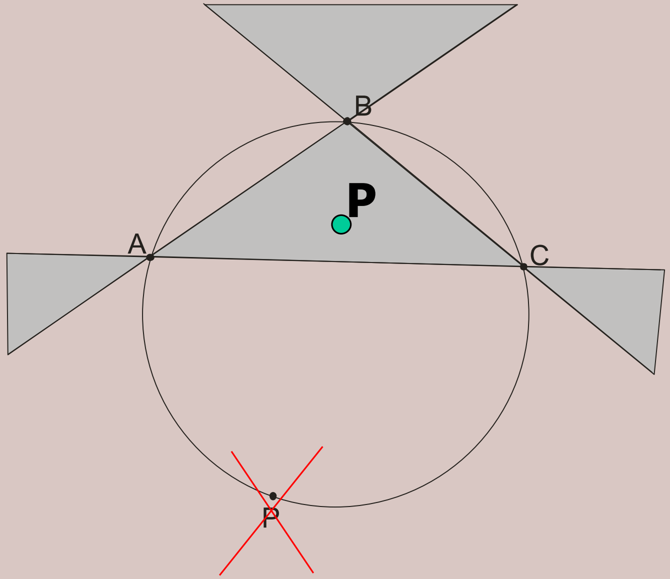
$$WCB_{BP} = WCB_{T_1T_2} + 90°$$

Foresection with WCBs

Resection – the dangerous circle

What happens, if all the four points are on one circumscribed circle?

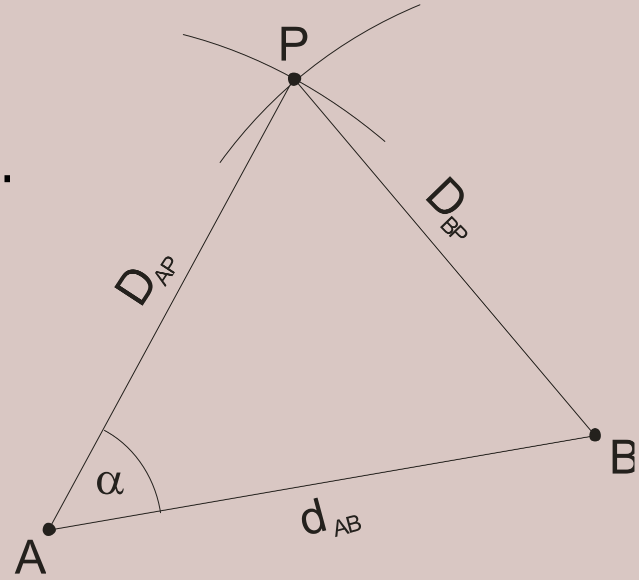




Arcsection

A, B are known control points,
D_{AP} and D_{BP} are measured.

Aim: compute the coordinates of P!



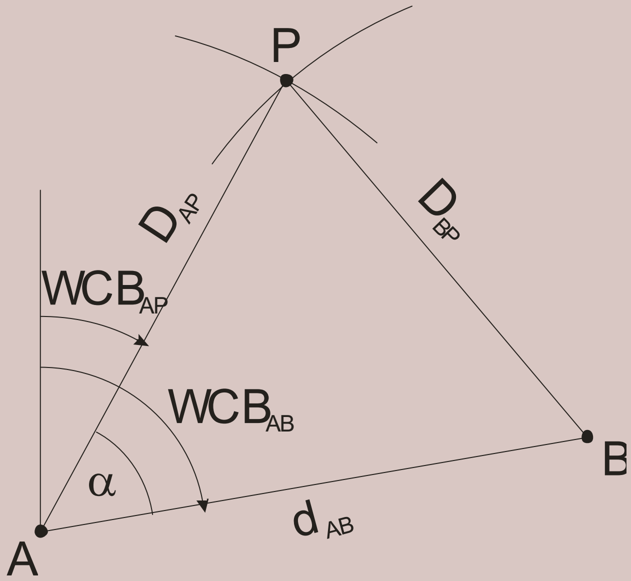
Using the cosine theorem, compute the angle α:

$$D_{BP}^2 = D_{AP}^2 + d_{AB}^2 - 2D_{AP}d_{AB}\cos\alpha$$

$$\Downarrow$$

$$\alpha = \arccos\frac{D_{AP}^2 + d_{AB}^2 - D_{BP}^2}{2D_{AP}d_{AB}}.$$

Arcsection



Compute WCB_{AB} from the coordinates of A and B,

$$WCB_{AP} = WCB_{AB} - \alpha$$

⇩

1st fundamental task of surveying

Thank You for Your Attention!

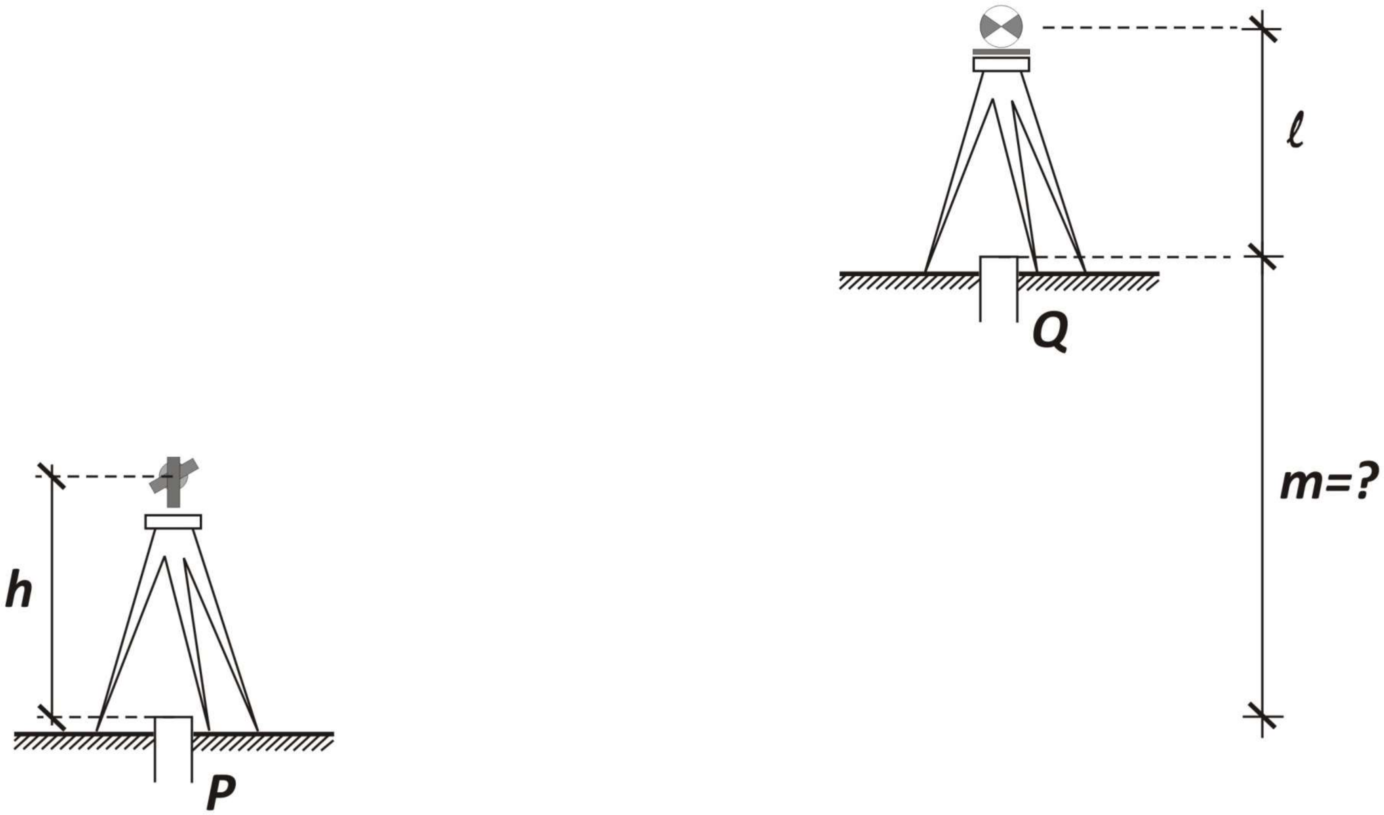
Surveying I. (BSc)

Trigonometric heighting.
Distance measurements, corrections and reductions

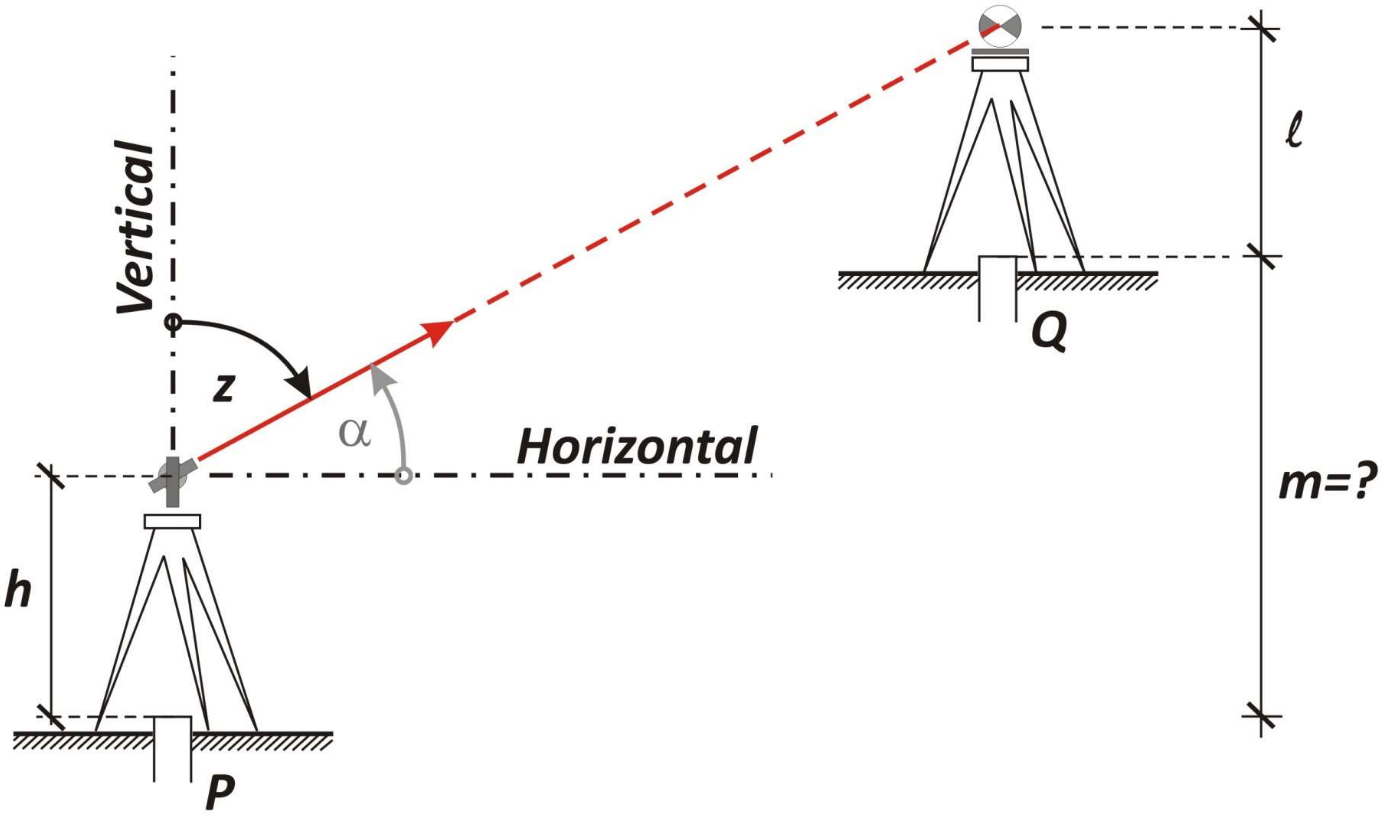
How could the height of skyscrapers be measured?

The principle of trigonometric heighting

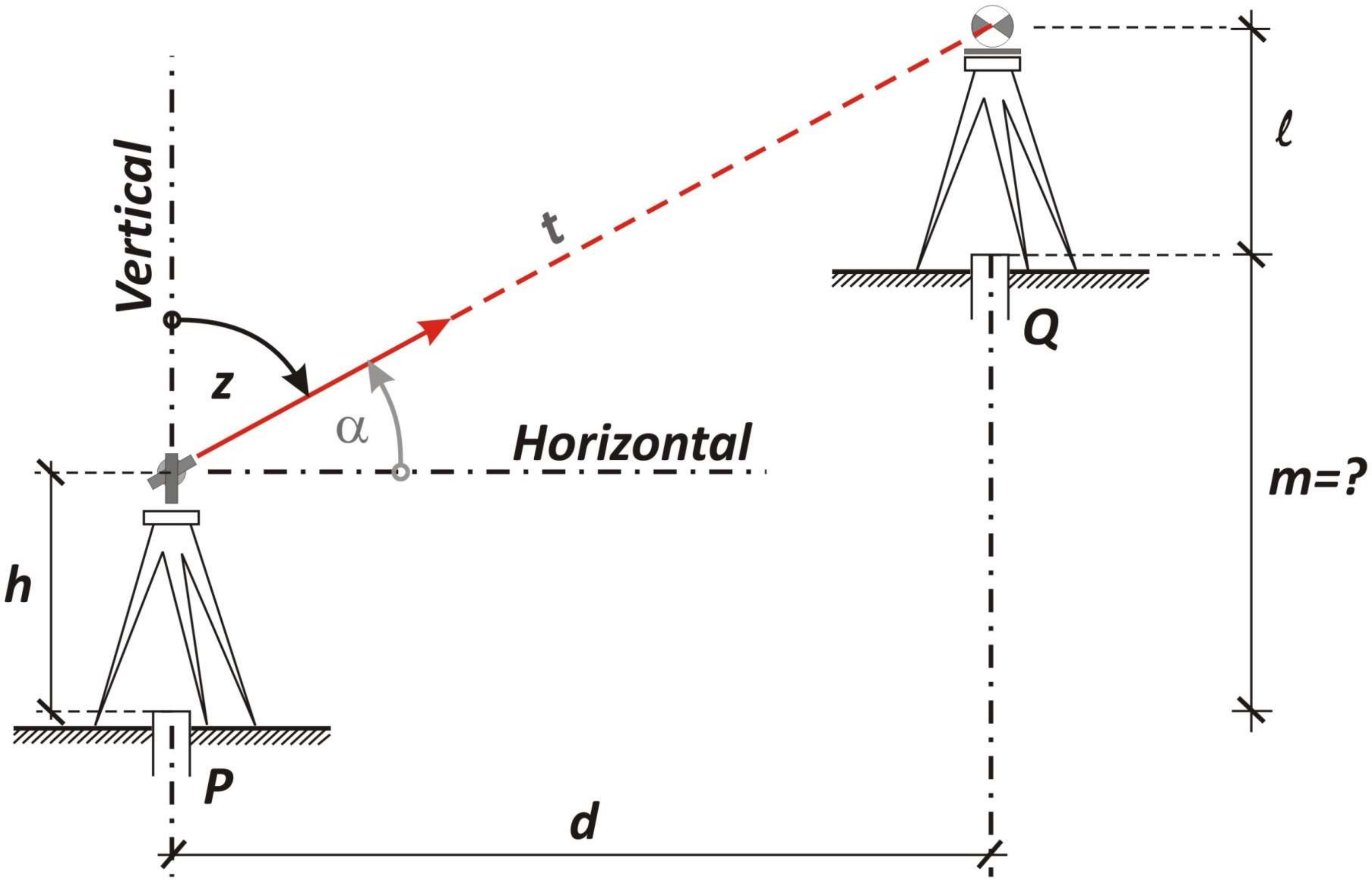
The principle of trigonometric heighting



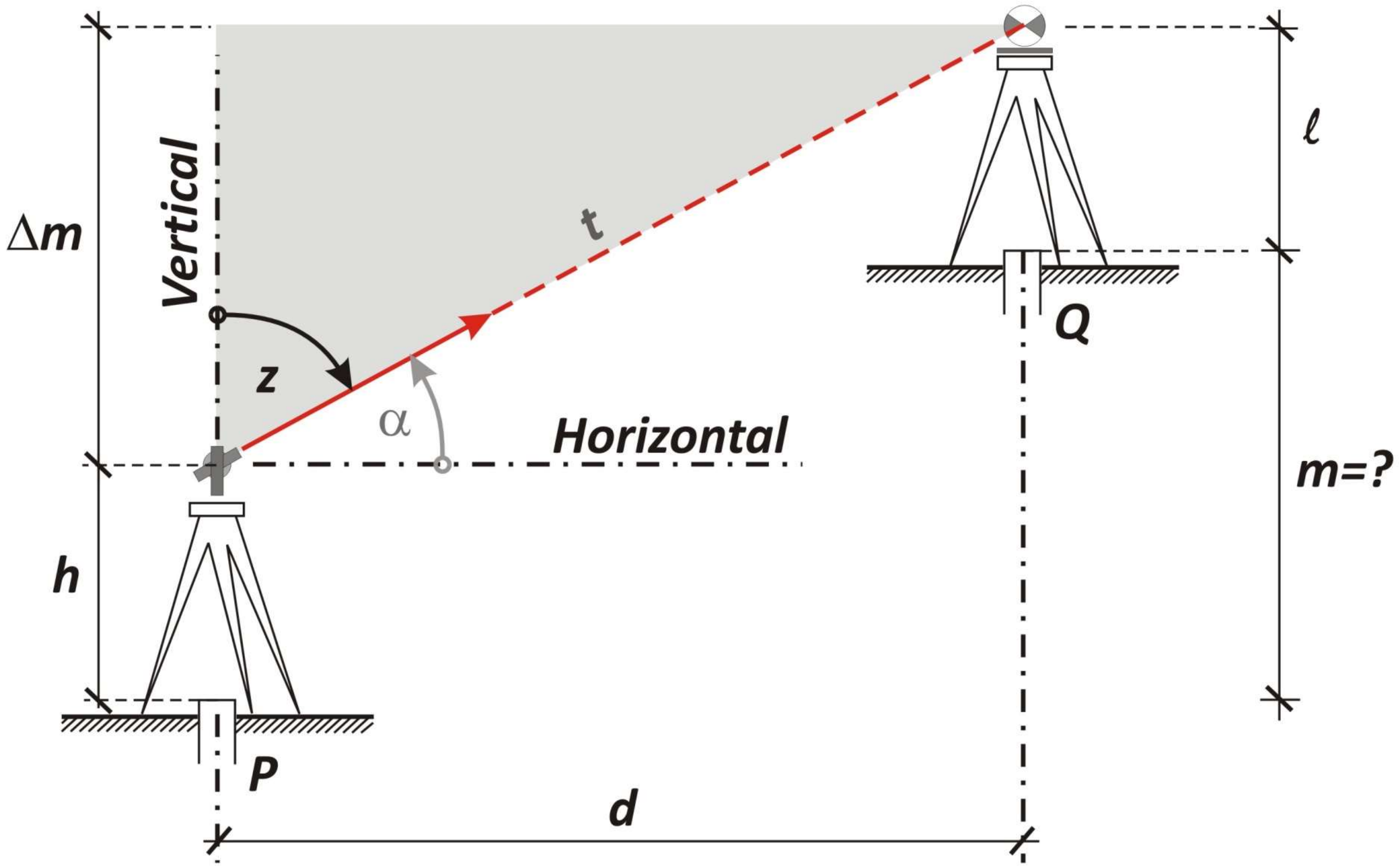
The principle of trigonometric heighting



The principle of trigonometric heighting

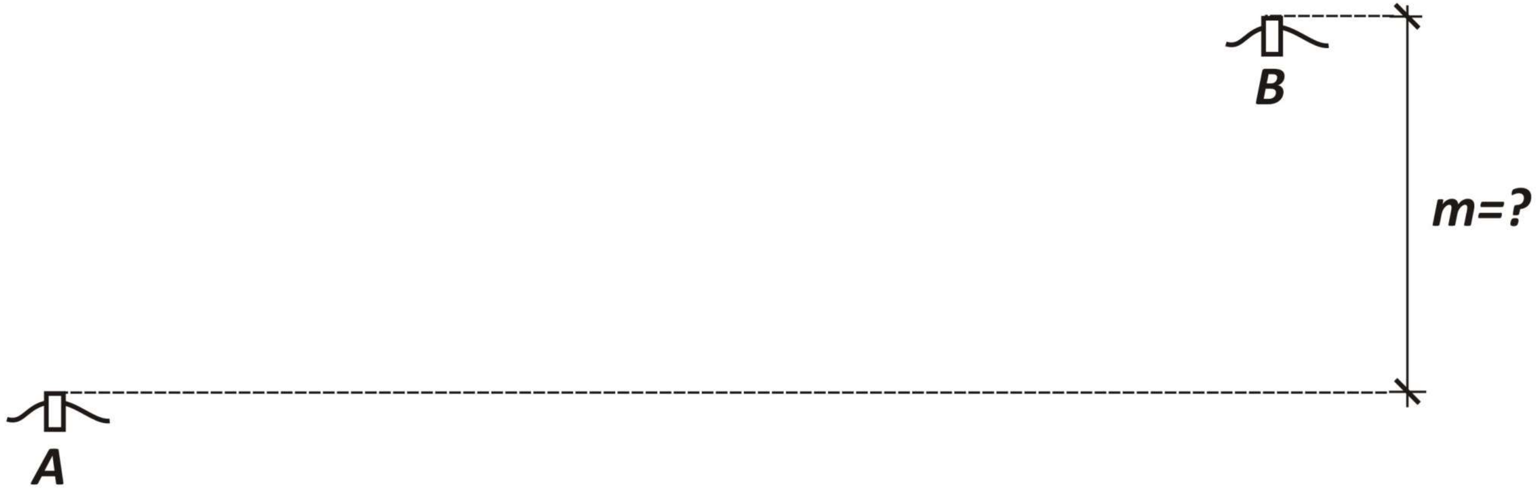


The principle of trigonometric heighting

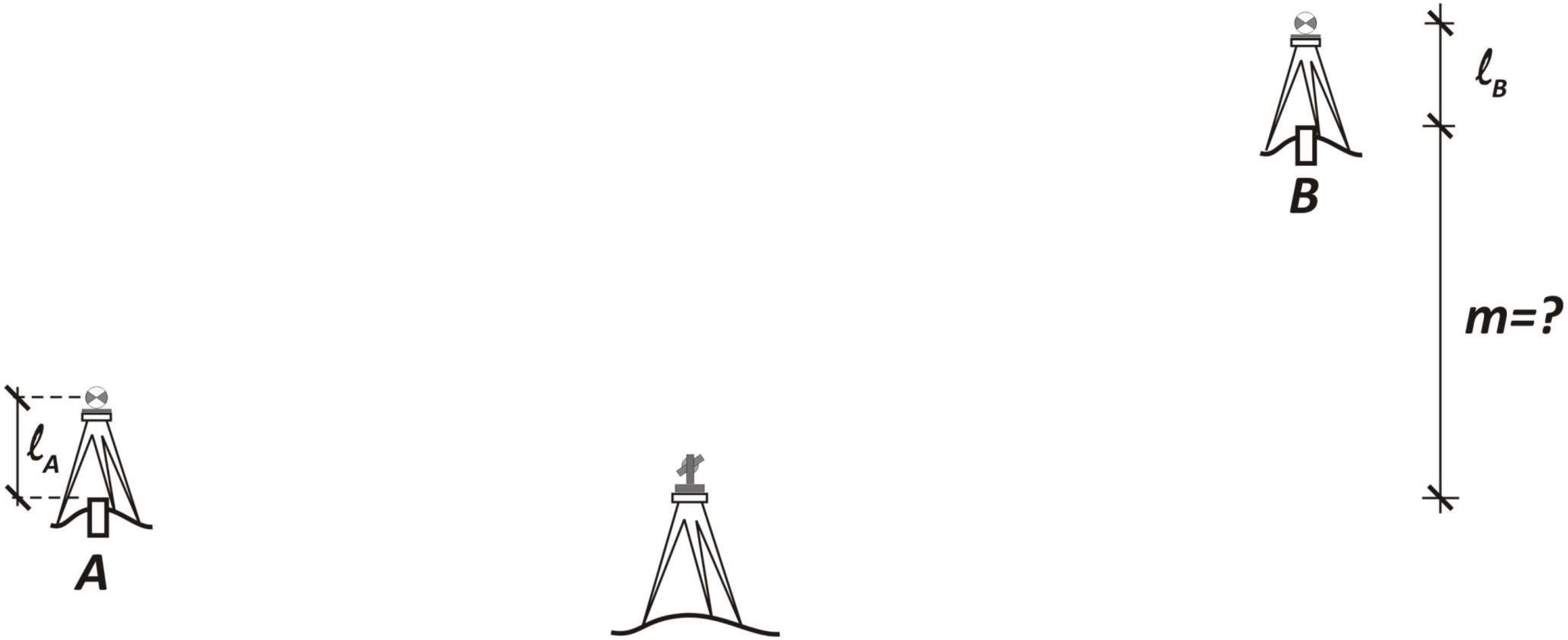


$$m = h + \Delta m - \ell = h - \ell + d \cot z$$

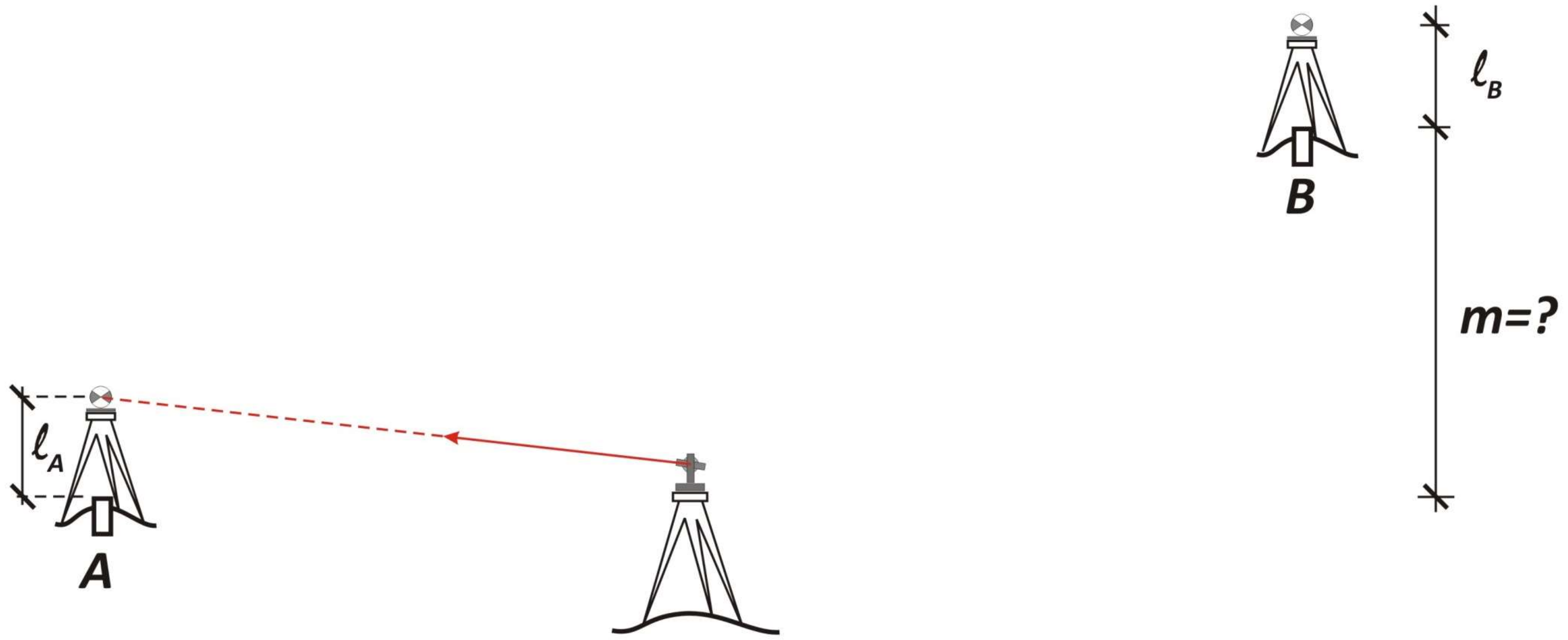
Trigonometric levelling



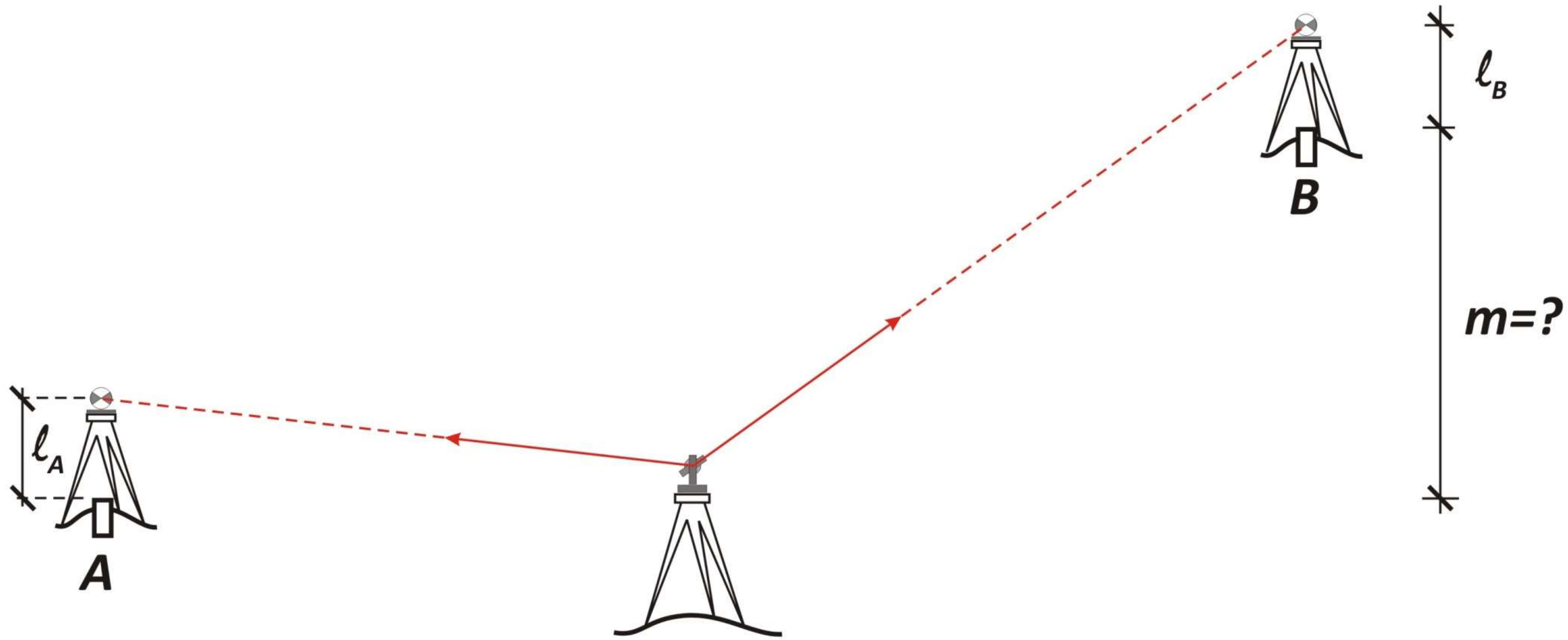
Trigonometric levelling



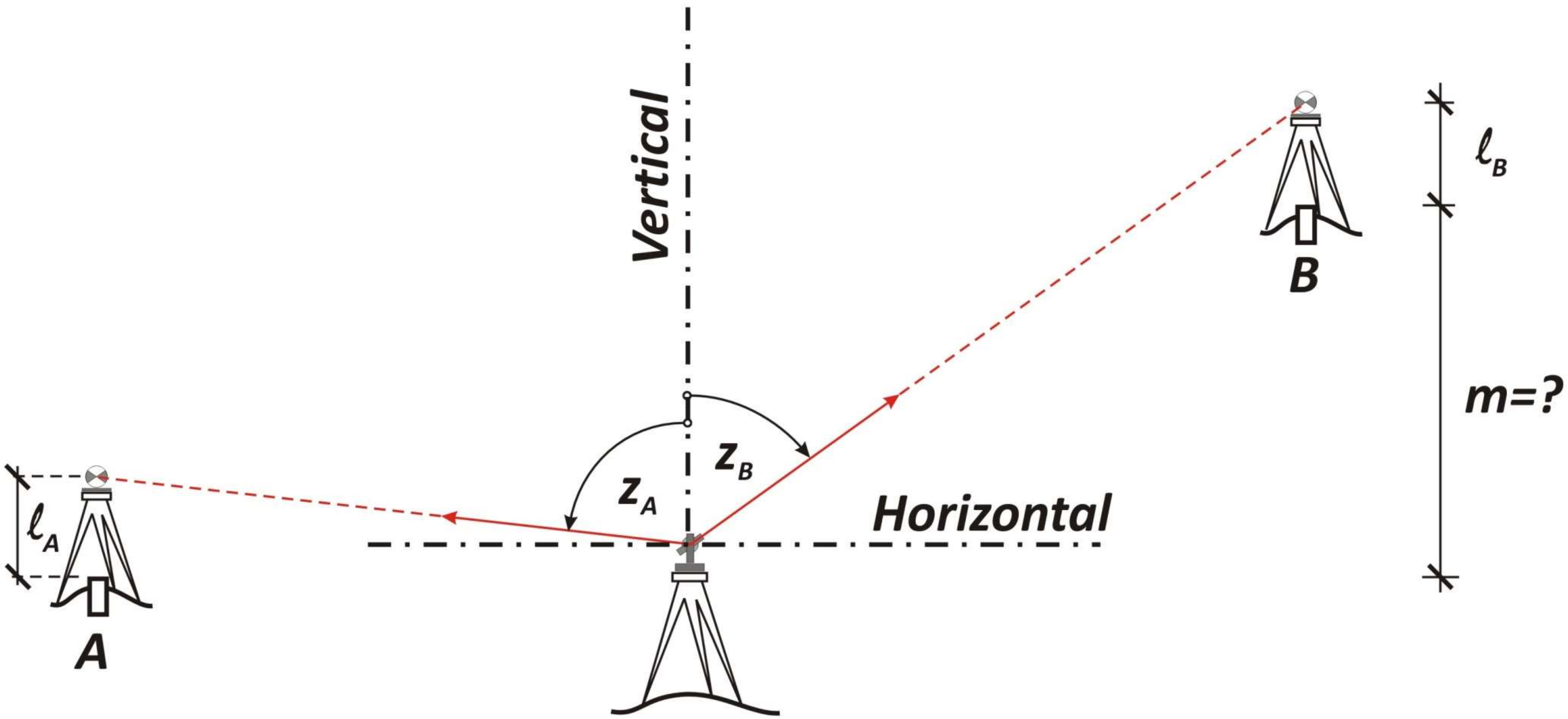
Trigonometric levelling



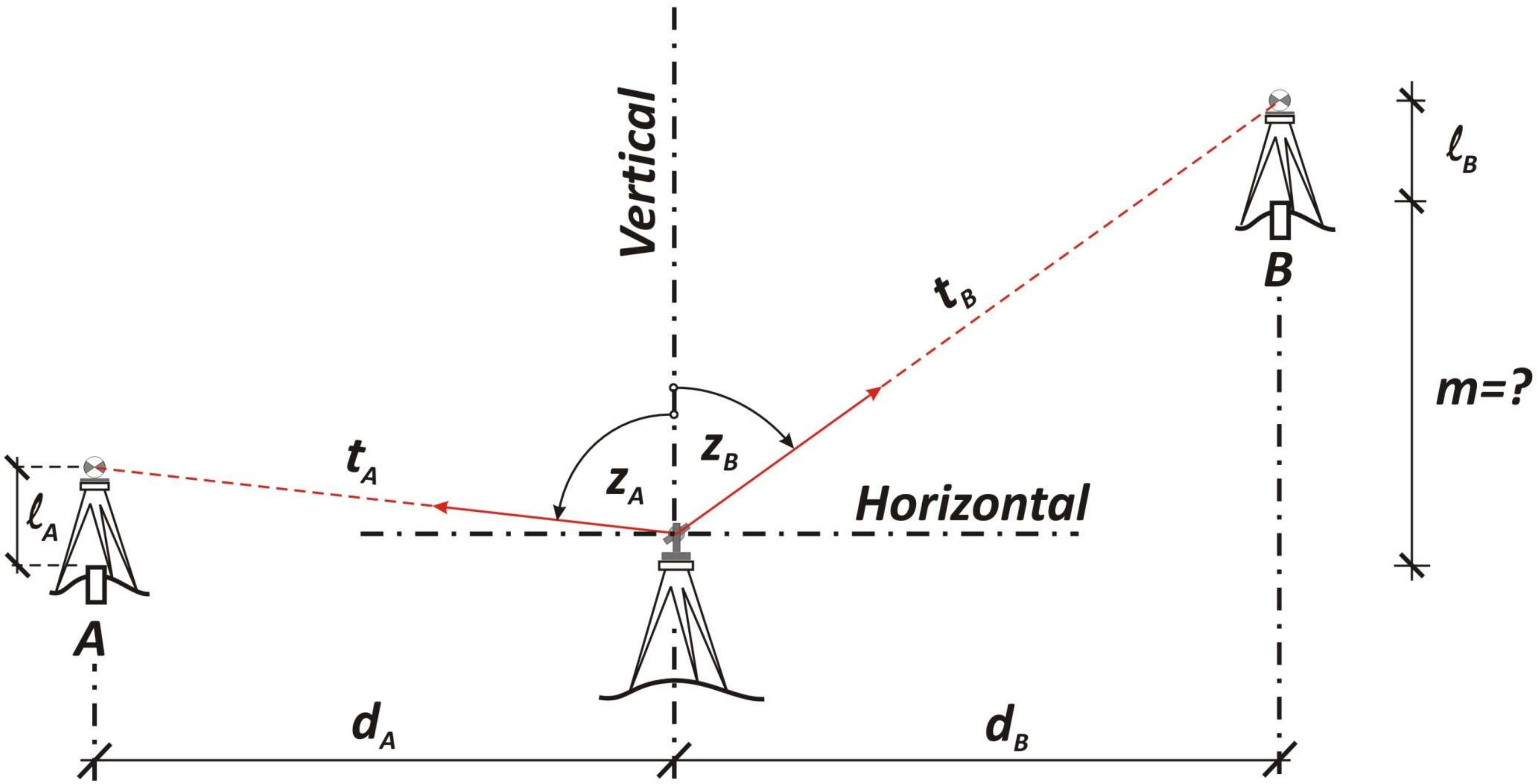
Trigonometric levelling



Trigonometric levelling

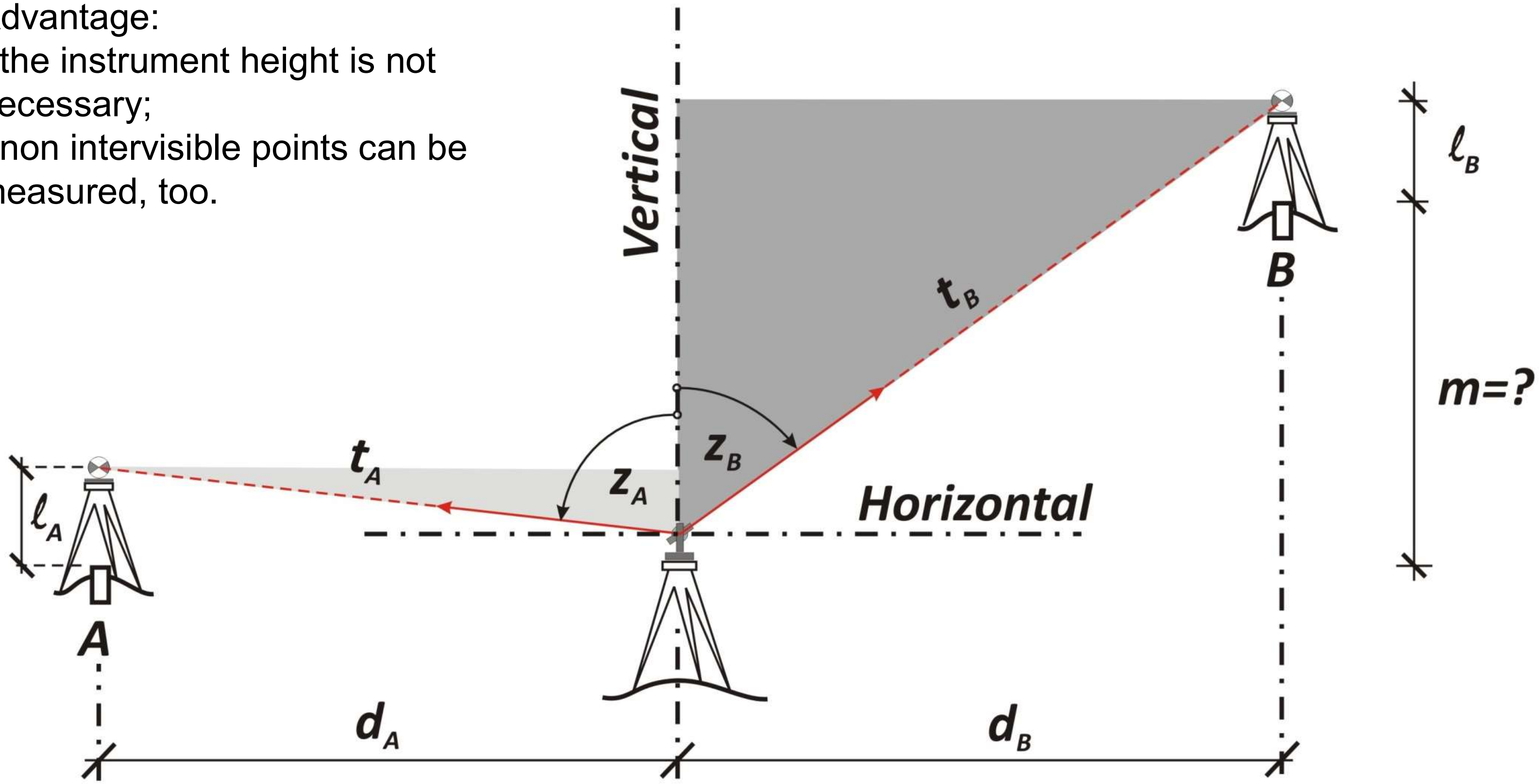


Trigonometric levelling



Trigonometric levelling

Advantage:
- the instrument height is not necessary;
- non intervisible points can be measured, too.



$$m=\left(d_B\cot z_B-\ell_B\right)-\left(d_A\cot z_A-\ell_A\right)=$$
$$=\left(t_B\cos z_B-\ell_B\right)-\left(t_A\cos z_A-\ell_A\right)$$

Trigonometric heighting

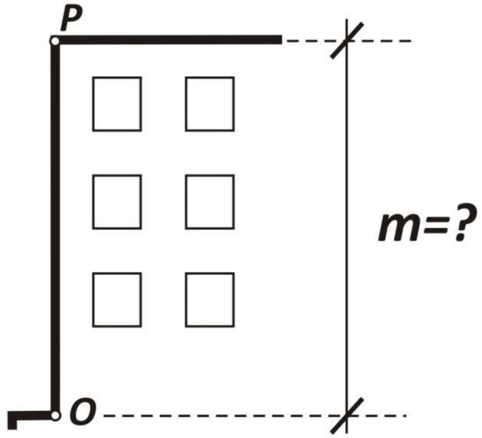
Advantages compared to optical levelling:

- **A large elevation difference can be measured over short distances;**
- **The elevation difference of distant points can be measured (mountain peaks);**
- **The elevation of inaccessible points can be measured (towers, chimneys, etc.)**

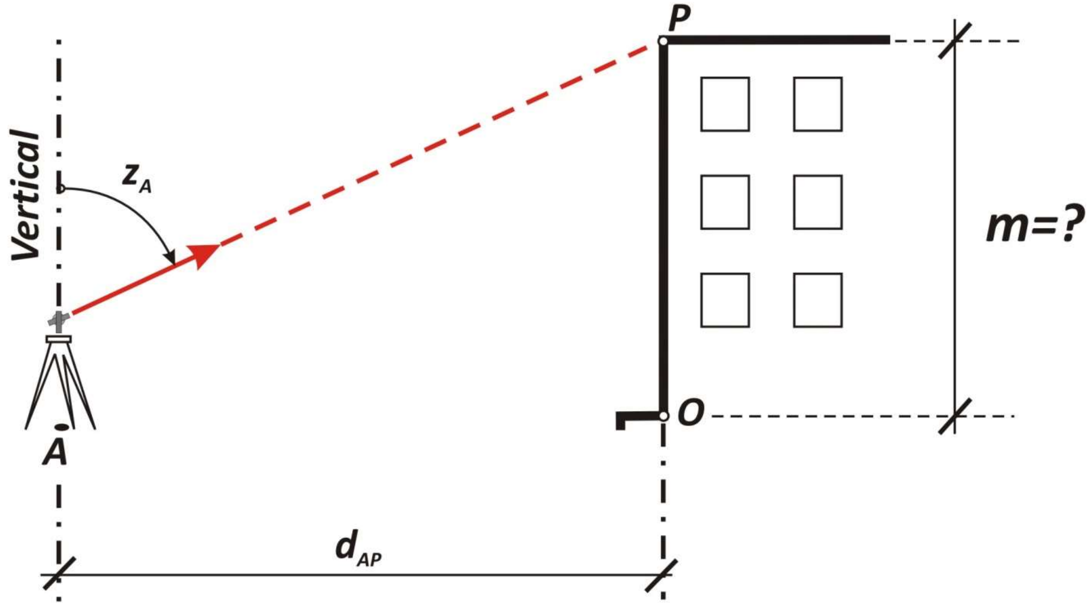
Disadvantages compared to optical levelling:

- **The accuracy of the measured elevation difference is usually lower.**
- **The distance between the points must be known (or measured) in order to compute the elevation difference**

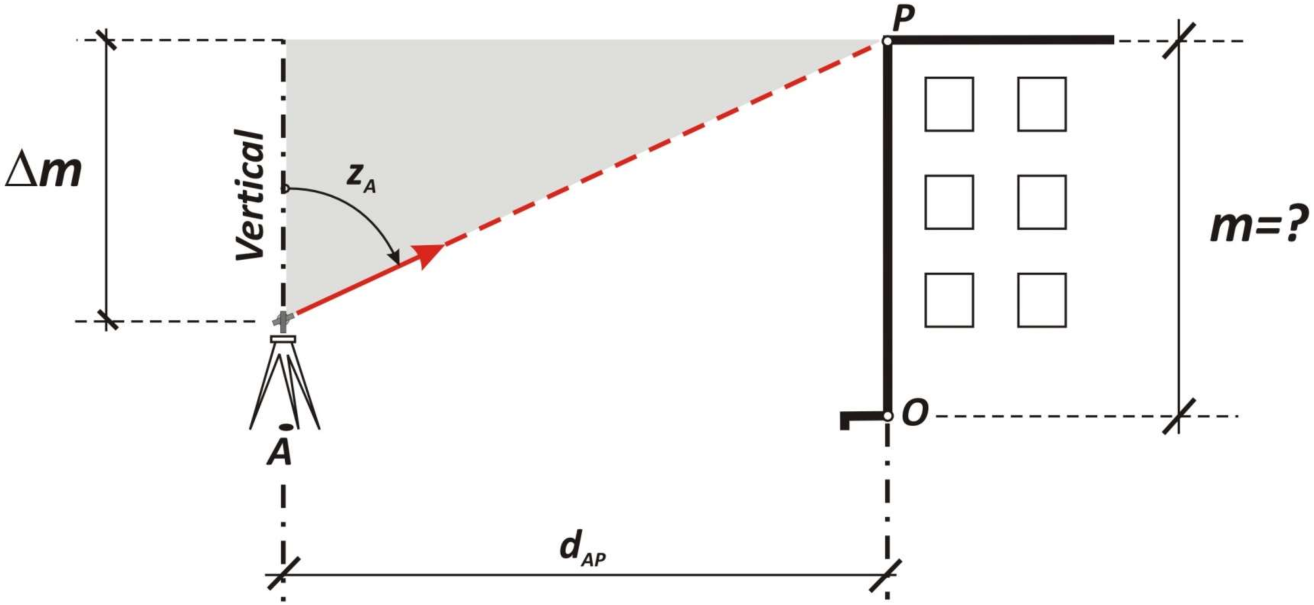
The determination of the heights of buildings



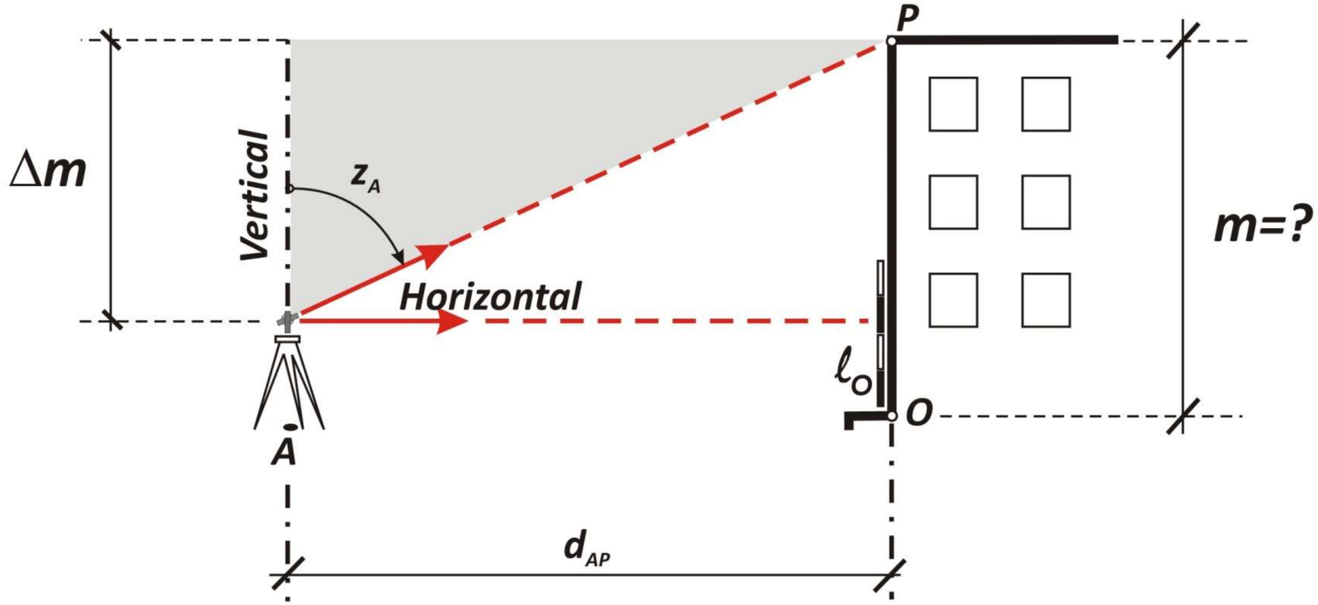
The determination of the heights of buildings



The determination of the heights of buildings



The determination of the heights of buildings



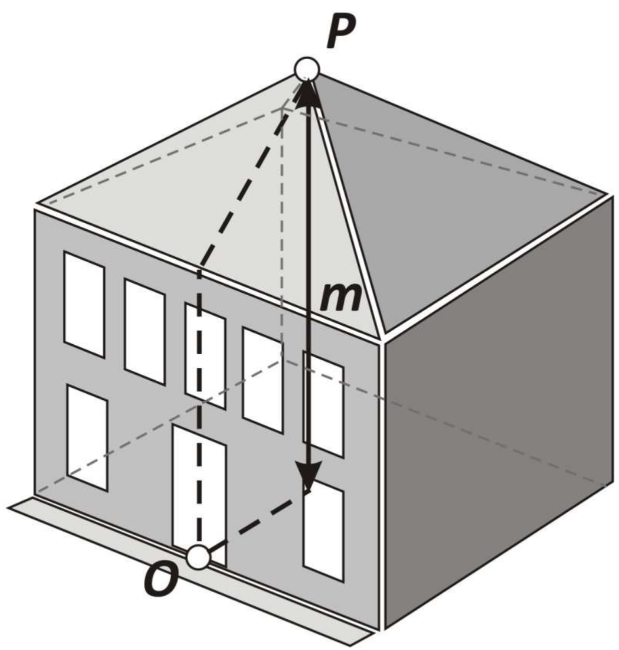
The horizontal distance is observable, therefore:

$$\Delta m = d_{AP} \cot z_A$$

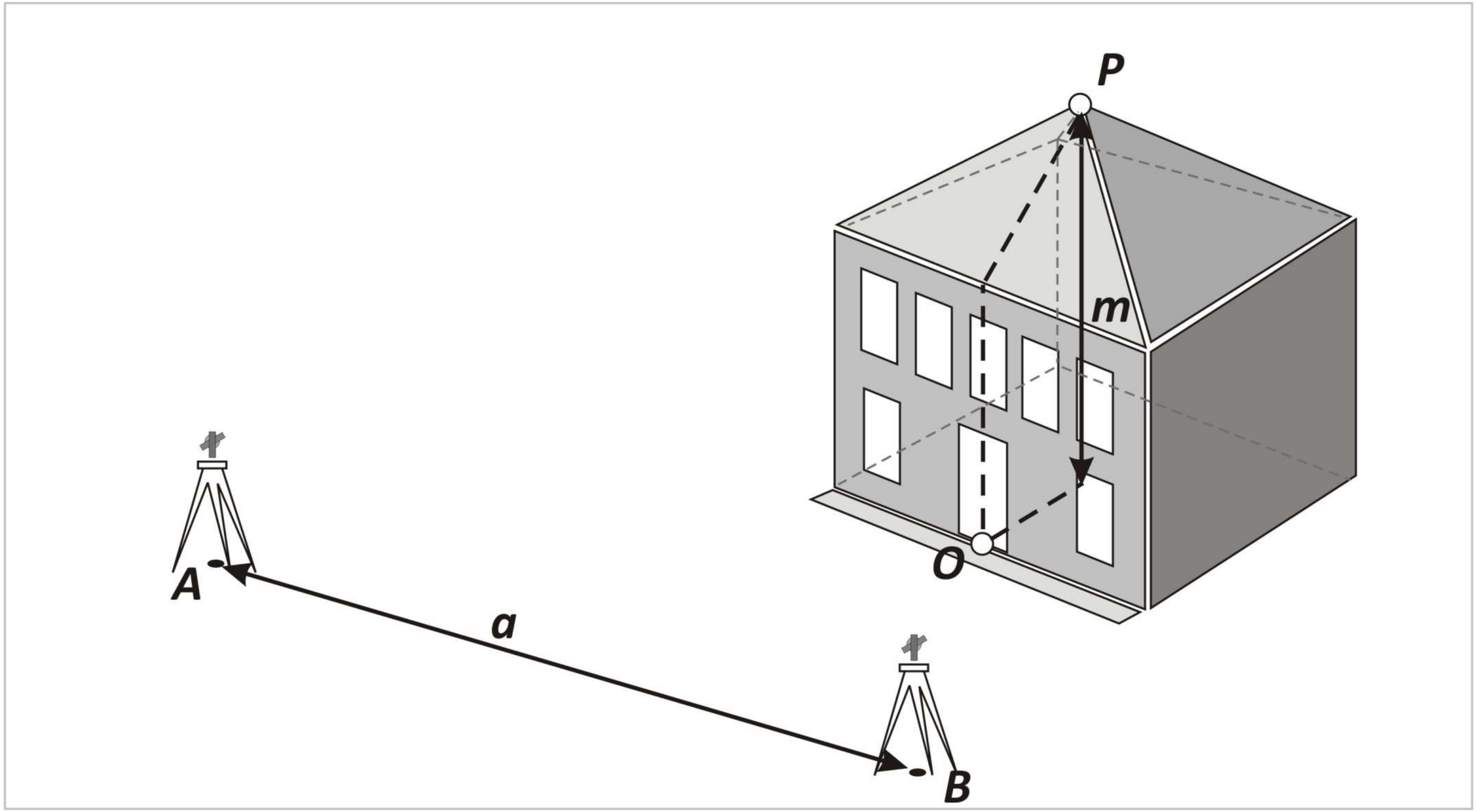
$$m = l_O + d_{AP} \cot z_A$$

Determination of the height of buildings

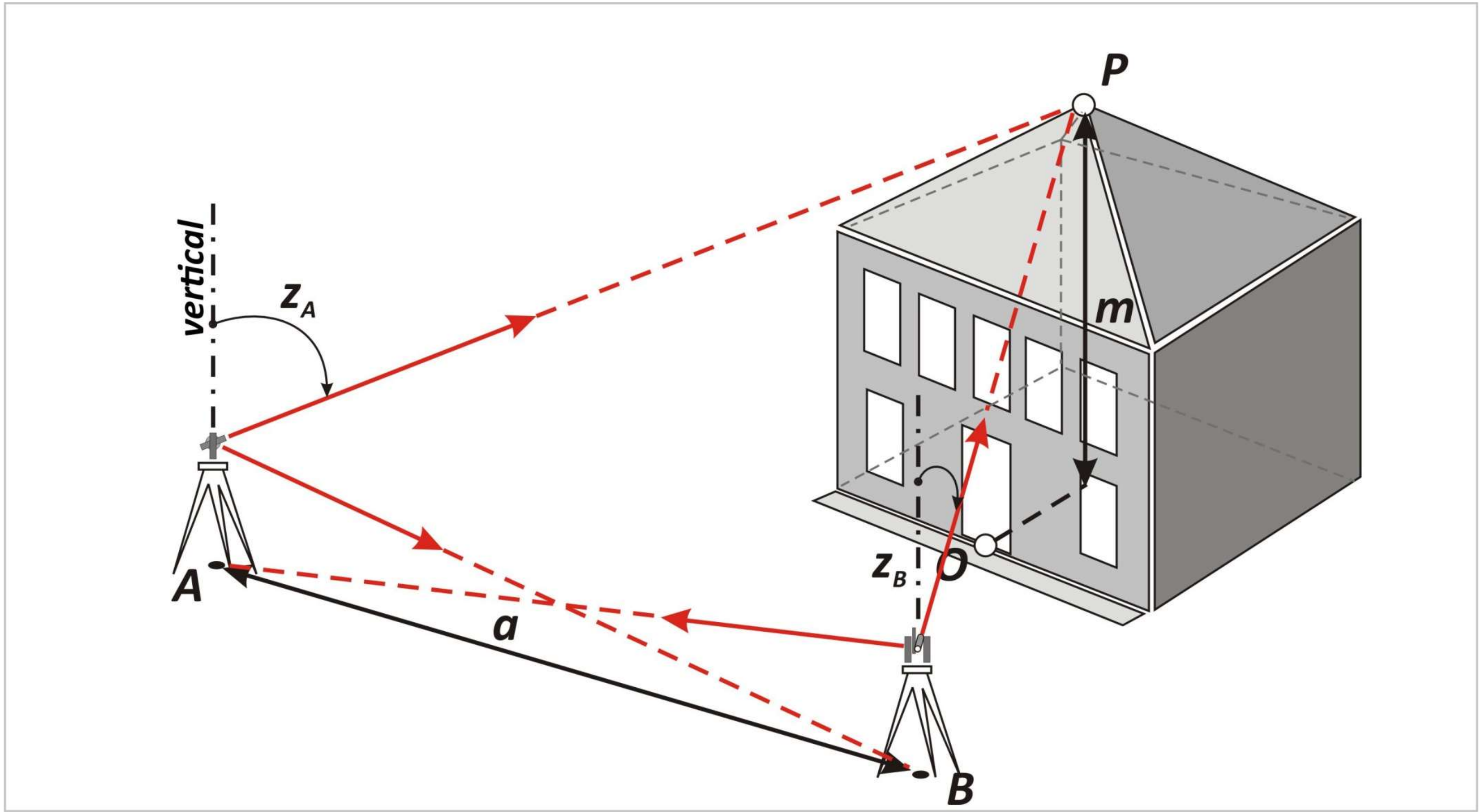
The distance is not observable.



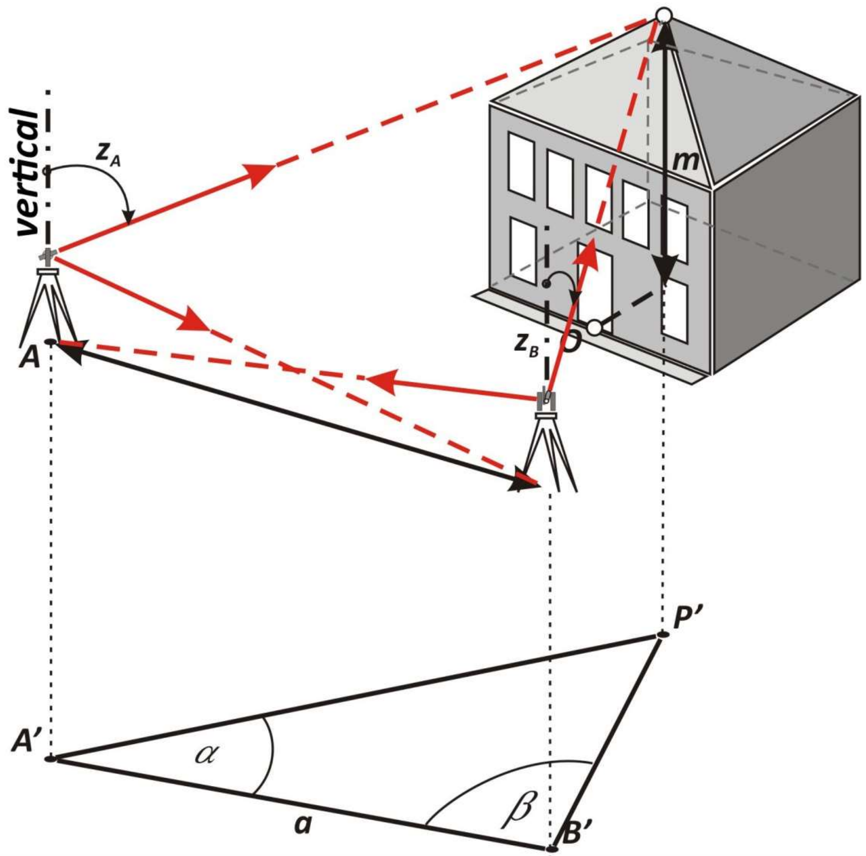
Determination of the height of buildings



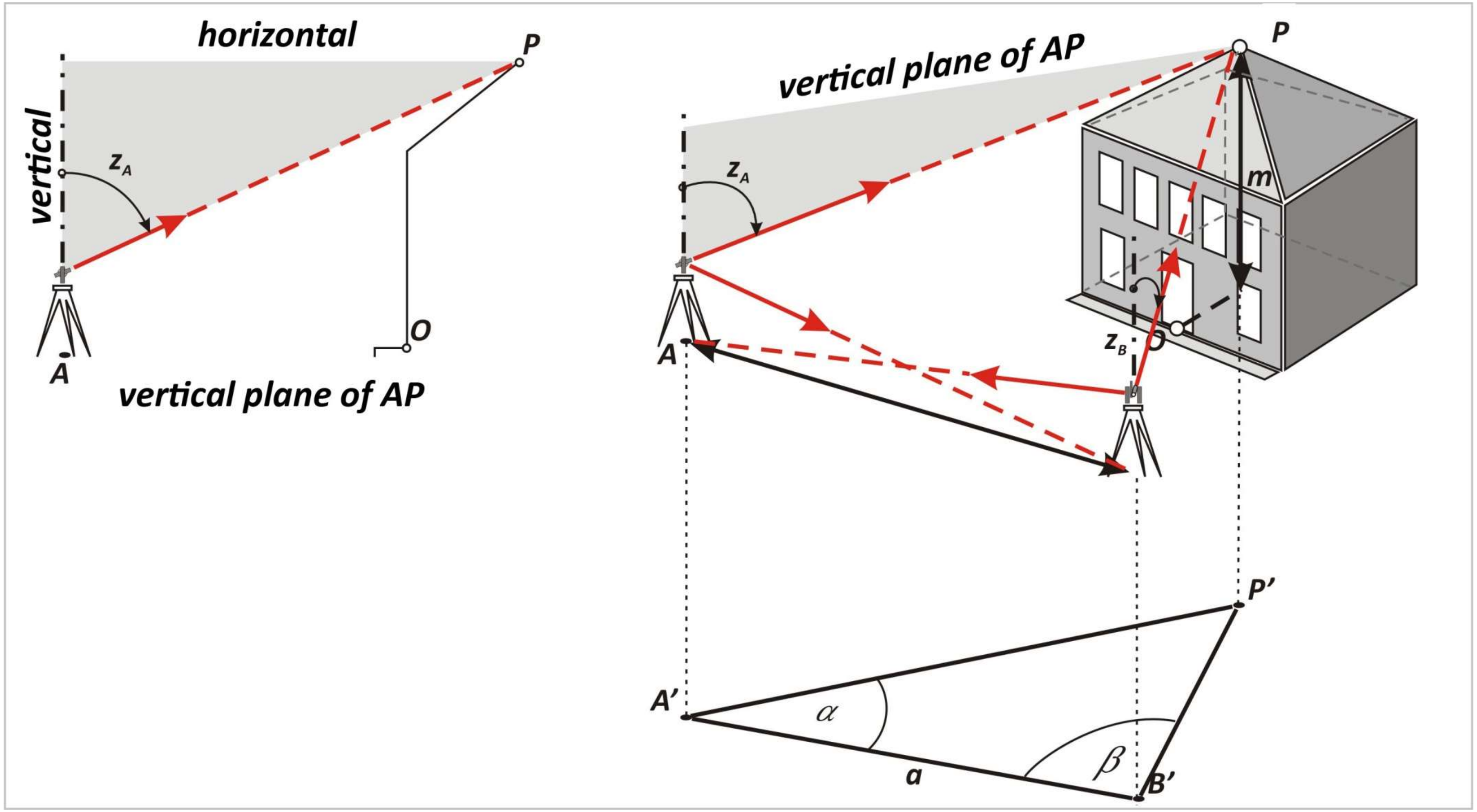
Determination of the height of buildings



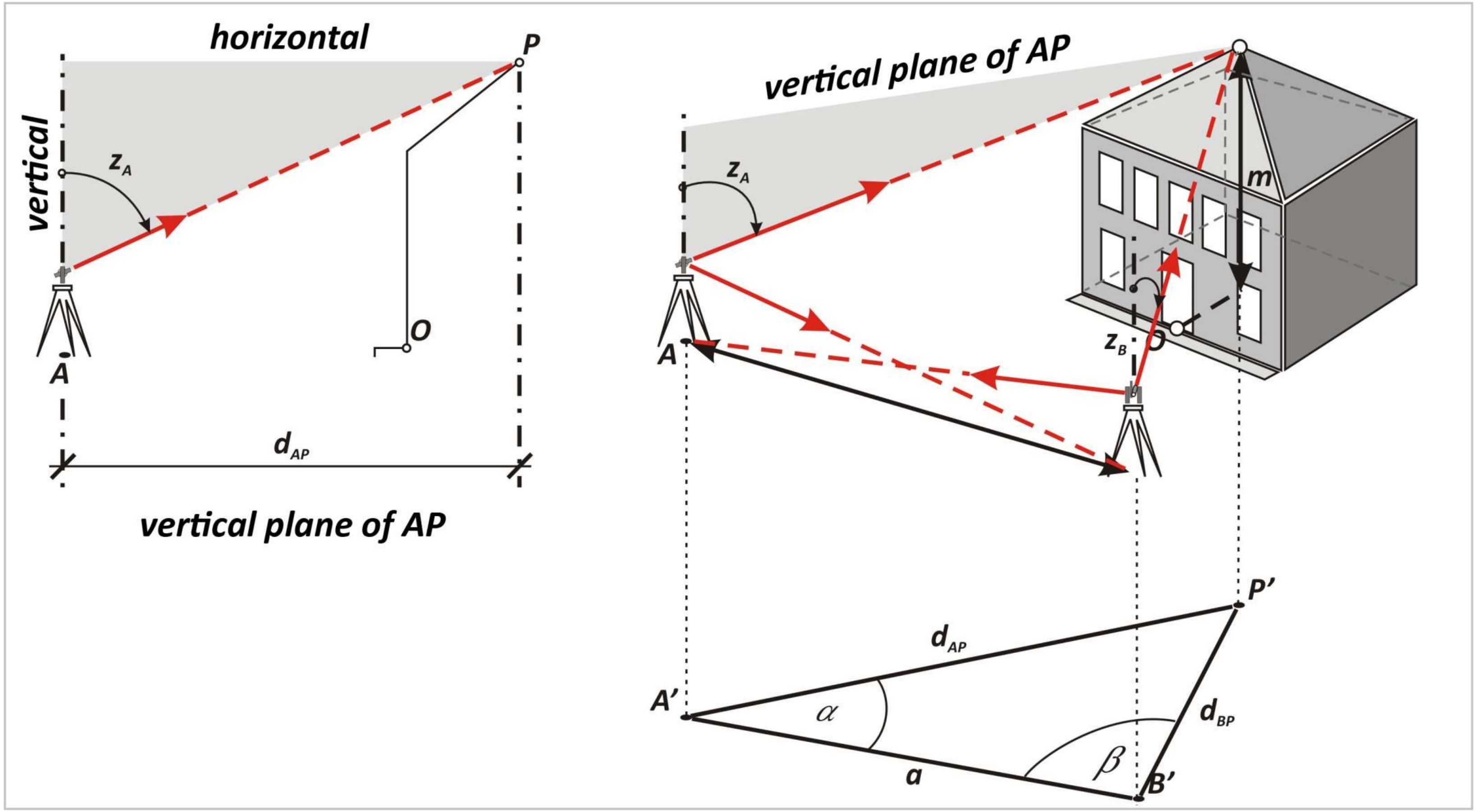
Determination of the height of buildings



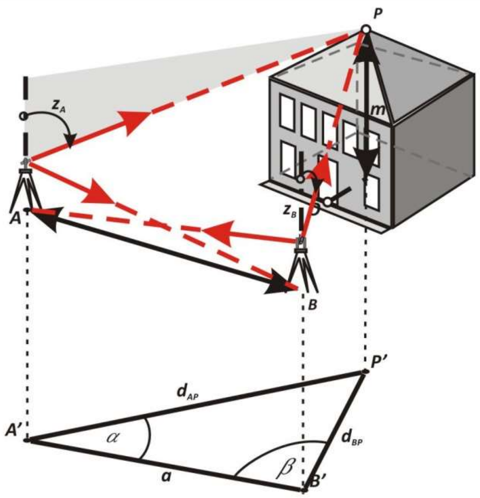
Determination of the height of buildings

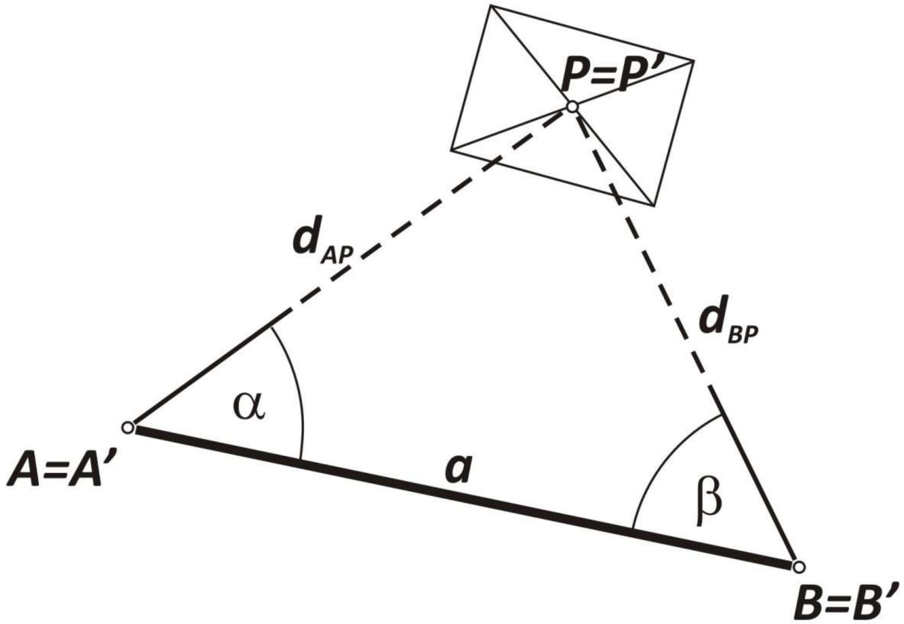


Determination of the height of buildings



Determination of the height of buildings



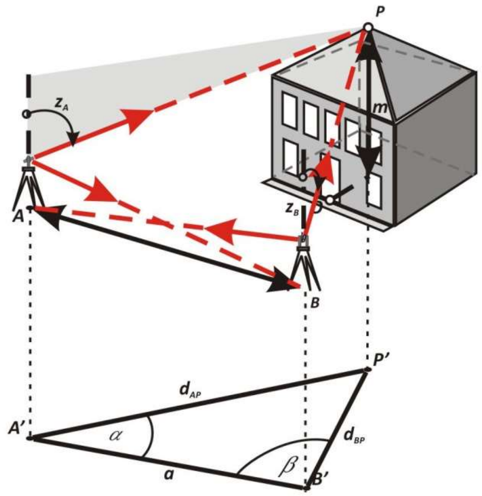


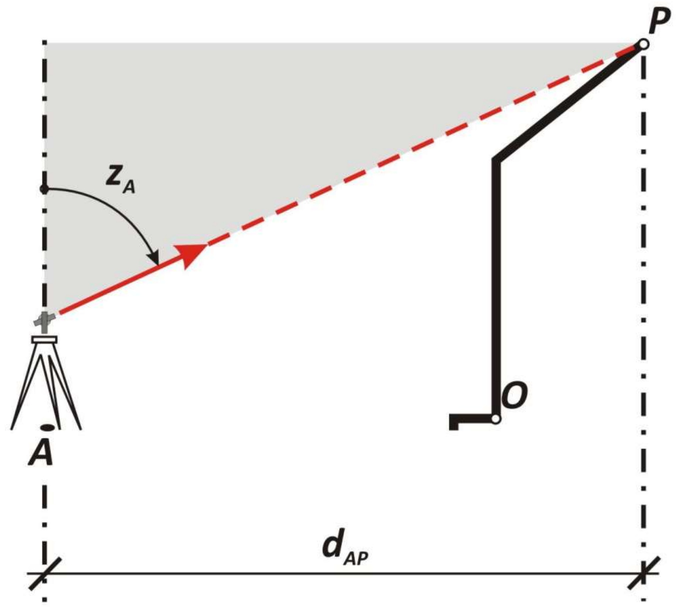
Using the sine-theorem:

$$\frac{d_{AP}}{\sin\beta} = \frac{a}{\sin(180-\alpha-\beta)} \Rightarrow d_{AP} = a\frac{\sin\beta}{\sin(\alpha+\beta)}$$

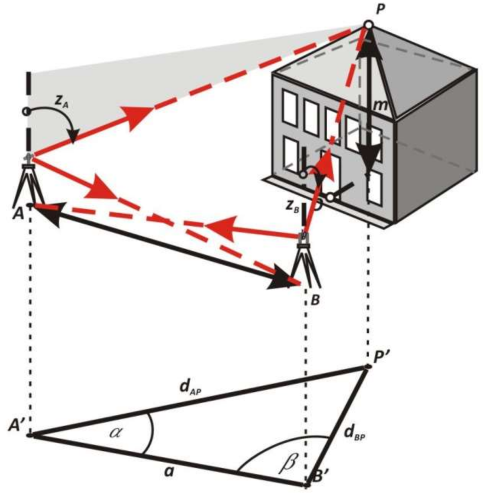
$$\frac{d_{BP}}{\sin\alpha} = \frac{a}{\sin(180-\alpha-\beta)} \Rightarrow d_{BP} = a\frac{\sin\alpha}{\sin(\alpha+\beta)}$$

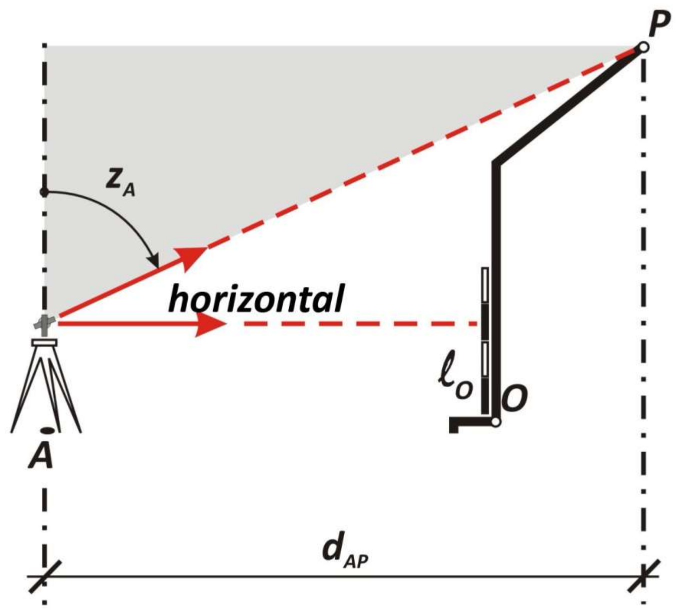
Determination of the height of buildings





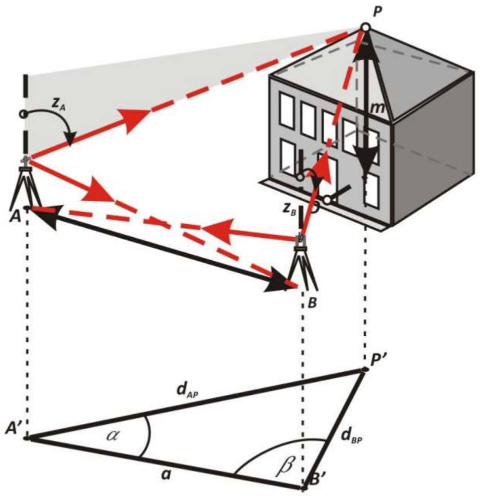
Determination of the height of buildings

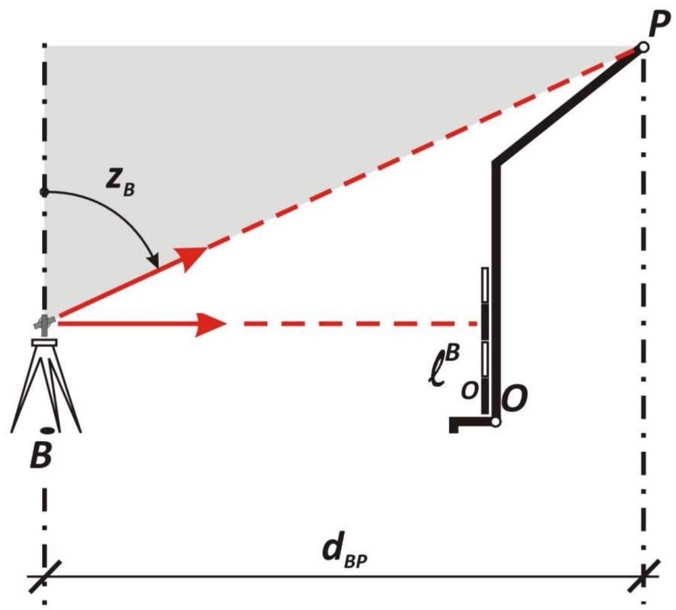




$$m^A = l_O + d_{AP} \cot z_A$$

Determination of the height of buildings





Using the observations in pont B:

$$m^B = l_O^B + d_{BP} \cot z_B$$

$$m = \frac{\left(m^A + m^B\right)}{2}$$

Surveying I.

Tacheometry

Principle of tacheometry

Tacheometry

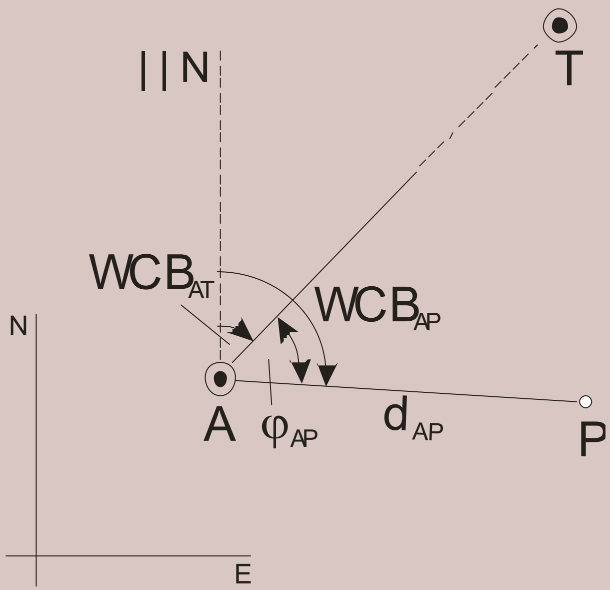
„Fast measurement" – measurement of horizontal and vertical coordinates of detail points in one step.

Principle of tacheometry

The horizontal position of the detail point is computed using the polar coordinates (WCB & d_h), while the elevation is measured using trigonometric heighting.

Principle of tacheometry

Horizontal coordinates:



- (N_A, E_A) and (N_T, E_T) are known;
- φ_{AP}, d_{AP} is measured.

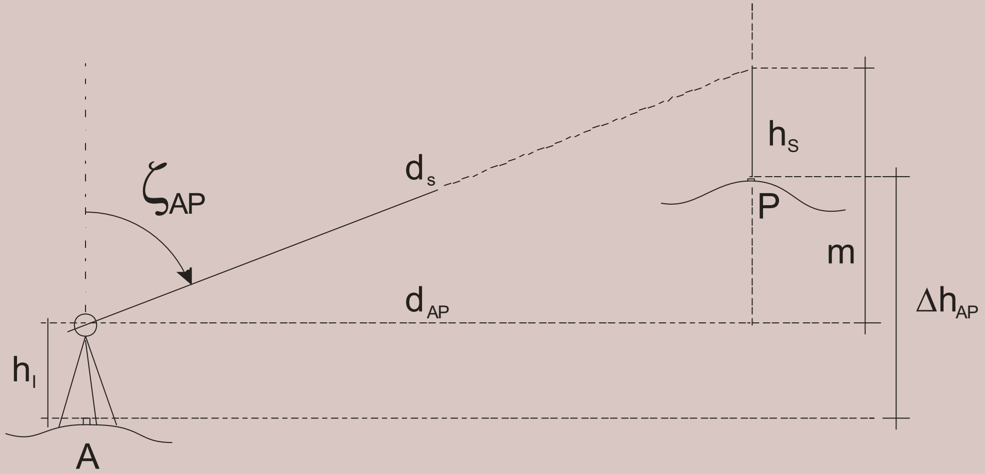
Exercise: compute the coordinates of **P**

Solution:

- WCB_{AT} is computed (2nd fundamental task of surveying;
- WCB_{AP} is computed by transfering the WCB from AT to AP ($WCB_{AP}=WCB_{AT}+\varphi_{AP}$);
- the horizontal coordinates of P are computed by the 1st fundamental task of surveying

Principle of tacheometry

Vertical coordinates:



h_I – instrument height **h_S – signal height** **ζ_{AP} – zenith angle** **d_S – slope distance**	**Measured**

Δh_{AP}=?

$$\Delta h_{AP}=h_I+d_S\cos\zeta_{AP}-h_S$$

Measuring the slope distance

Older instruments: use the optical method (stadia lines) to measure the distance. The maximal range is 150-200m, and the accuracy 15-20cm.

Latest instruments: EDMs are used to measure the slope distance. The maximal range is usually 2-3 km, accuracy is 1-2 cm.

Electronic tacheometers (Total Stations)

Important features:

- automated distance measurements and angular observations;

- the observations can be corrected for the effect of systematic error, and reduced to the MSL;

- the data can be recorded for later use;

- observation software enables the instrument to compute coordinates and stake out.

Operation of Total Stations

• Centering and leveling the instrument by the operator

• observing the slope distance (d_s), correcting the effect of the reflector constant, the frequency error and the meteorological correction;

• the horizontal (Hz) and vertical (V) angles are read, and the effects of the collimation and index error are accounted for;

• the horizontal distance (d_h) and the elevation difference is (Δh) is computed (instrument and signal height must be entered previously);

• the data set (d_s, Hz, V) or (Hz, d_h, Δh) is logged.

Important software of Total Stations

1. **Free station establishment**
   The station coordinates are computed using angular and distance observations to known points (resection, arc-section and their combination). In most cases the orientation is also done.

2. **Determination of the elevation of the station**
   by trigonometric heighting to known stations.

3. **Orientation of the horizontal circle**
   by taking horizontal angle observations to known stations.

4. **Computation of rectangular coordinates (N,E)**
   using the polar coordinates (provisional WCB and horizontal distance)

Important software of Total Stations

5. **Tie distance**
   The horizontal distance between two measured detail points can be computed using their coordinates.

6. **Remote object**
   by measuring the horizontal distance to the vertical of a remote object, and the zenith angle.

Detail surveys using tacheometry

Preparation

- densification of control network;
- finding suitable places for free station establishment.

Detail survey

- detail points of:
  - buildings;
  - linear objects (e.g. electric poles);
  - rectangular buildings;
  - arcs;
  - topography.

Detail surveys using tacheometry

Identifying the detail points

- drawing a sketch of the area, and marking the detail points on it with ID numbers;
- recording the coordinates or observations with the same ID numbers;
- ensure that the two numberings are identical;

Mapping the survey

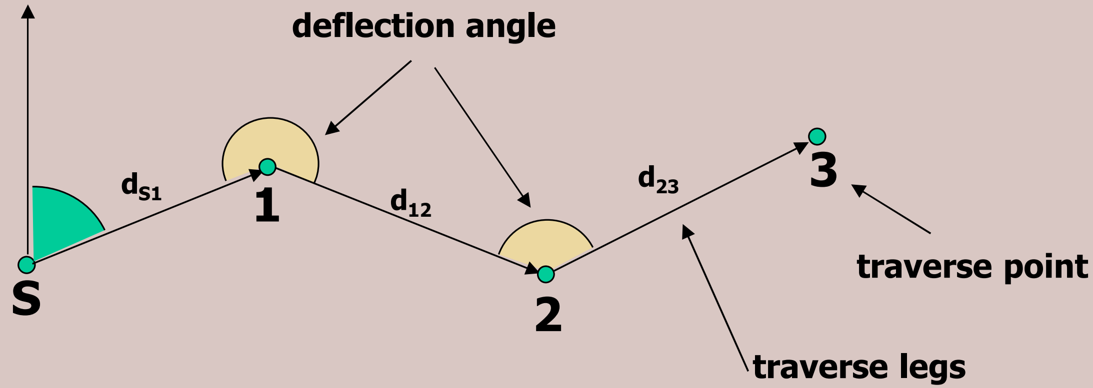
- marking the positions of the detail points in a given scale;
- the elevation of topographic points should be written on the map;
- contour lines are interpolated between the measured topographic points.

Thank You for Your Attention!

Surveying I.

Traversing

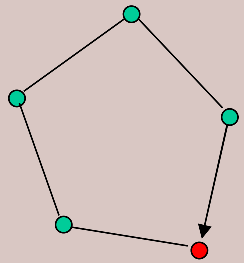
Principle of Traversing



- Determine the WCB of the first leg;
- measure the length of the first leg;
- compute the coordinates of the traverse point No. 1, using the 1st fundamental task of surveying;
- measure the deflection angle at point 1;
- compute the WCB of the second leg;
- continue with step 2.

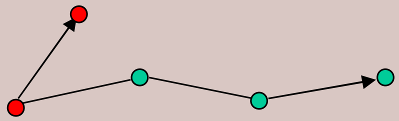
Types of traverse lines

Closed Loop

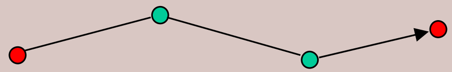


Unclosed

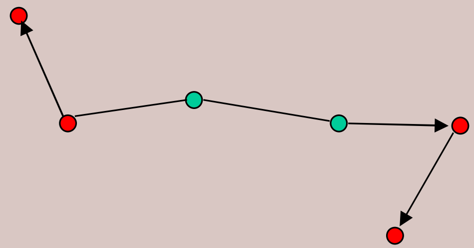
- **Free traverse**



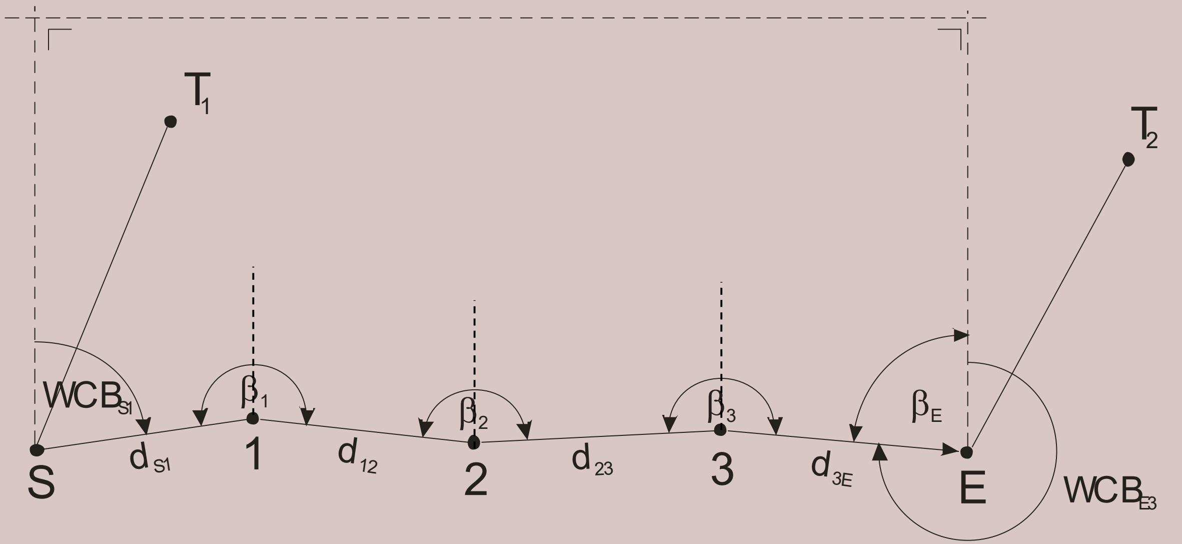
- **Inserted traverse**



- **Closed line traverse**



Computation of the closed line traverse



Controlling the angular observations:

- sum of the inner angles

$$WCB_{S1} + \beta_1 + \beta_2 + \beta_3 + \beta_E + 90° + 90°$$

- theory

$$[(n+2)-2] \cdot 180°$$

Computation of the closed line traverse

Angular misclosure:

$$\Delta\beta = n \cdot 180° - \left(WCB_{S1} + \beta_1 + \beta_2 + \beta_3 + \beta_E + 90° + 90°\right)$$

$$\Downarrow$$

$$\Delta\beta = (n-1)\cdot 180° - \left(\sum_{i=0}^{n-1} \beta_i\right),$$

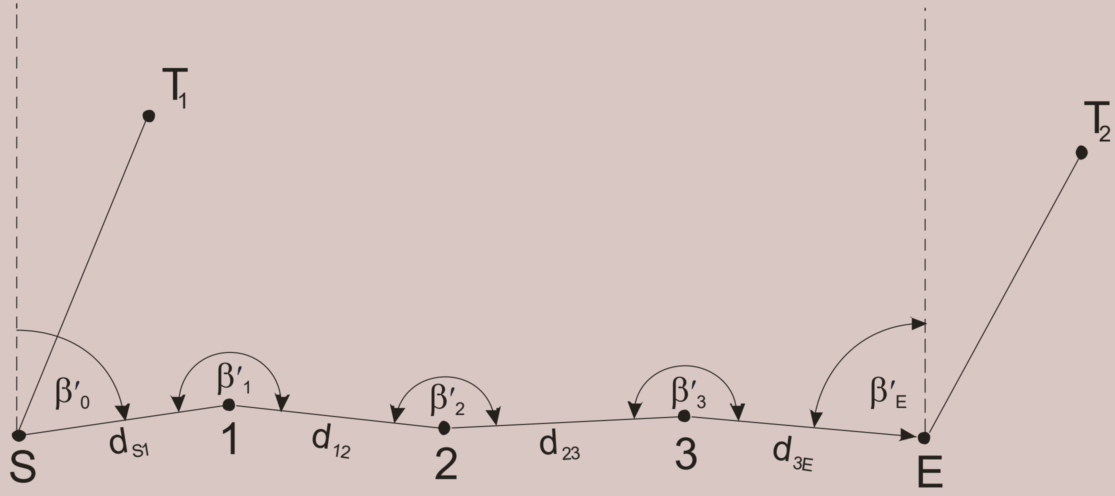
$$where \quad \beta_0 = WCB_{S1}$$

How to correct for the angular error?

The accuracy of the angular observations can supposed to be at the same level, therefore the same correction should be applied to each observed angle (n).

$$v\beta = \frac{\Delta\beta}{n} \qquad \beta_i' = \beta_i + v\beta$$

Computation of the closed line traverse



Controlling the distance observations:

• the computed coordinate differences between S and E should be equal to the known coordinate differences

Computation of the closed line traverse

Compute the provisional WCB of the traverse legs:

$$WCB_{i,i+1} = WCB_{i-1,i} + \beta_i \mp 180°$$

Easting and Northing coordinate differences:

$$\Delta E_{i,i+1} = d_{i,i+1} \cdot \sin WCB_{i,i+1},$$
$$\Delta N_{i,i+1} = d_{i,i+1} \cdot \cos WCB_{i,i+1}.$$

The coordinate misclosure:

$$\Delta\Delta E = \left(E_E - E_S\right) - \sum_{i=0}^{n-2} d_{i,i+1} \cdot \sin WCB_{i,i+1}$$

$$\Delta\Delta N = \left(N_E - N_S\right) - \sum_{i=0}^{n-2} d_{i,i+1} \cdot \cos WCB_{i,i+1}$$

The linear misclosure:

$$\Delta L = \sqrt{\Delta\Delta E^2 + \Delta\Delta N^2}$$

Computation of the closed line traverse

How to correct for the coordinate misclosure?

- coordinate error is caused by the distance observations;
- the accuracy of distance observations is proportional with the distance.

Corrections of the computed coordinate differences:

$$v\Delta E_{i,i+1} = \frac{d_{i,i+1} \cdot \Delta\Delta E}{\sum_{i=0}^{n-2} d_{i,i+1}},$$

$$v\Delta N_{i,i+1} = \frac{d_{i,i+1} \cdot \Delta\Delta N}{\sum_{i=0}^{n-2} d_{i,i+1}}.$$

Computation of the closed line traverse

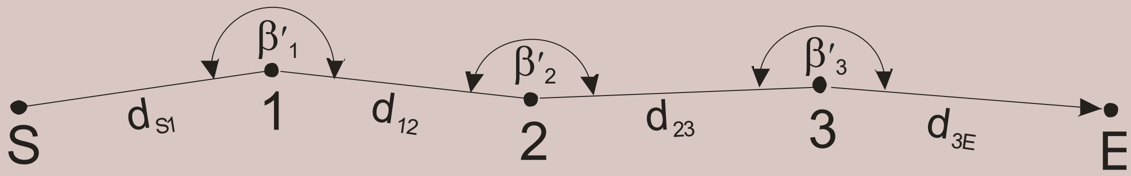
Computing the corrected coordinate differences:

$$\Delta E'_{i,i+1} = \Delta E_{i,i+1} + v\Delta E_{i,i+1},$$
$$\Delta N'_{i,i+1} = \Delta N_{i,i+1} + v\Delta N_{i,i+1}.$$

Computing the final coordinates:

$$E_{i+1} = E_i + \Delta E'_{i,i+1},$$
$$N_{i+1} = N_i + \Delta N'_{i,i+1}.$$

Computation of the inserted traverse

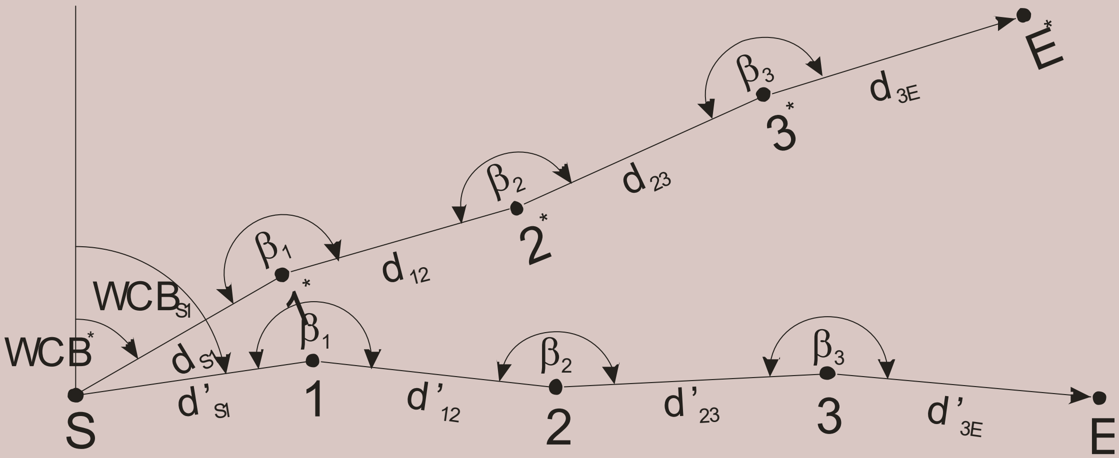


S and E are known, the distances and the deflection angles are measured.

No corrections for the angles (due to the lack of orientations at the endpoints).

Corrections to the distance observations can be computed due to the given endpoints.

Computation of the inserted traverse



The coordinates are computed as a free traverse by using an abritrary starting WCB (WCB*).

Computation of the inserted traverse

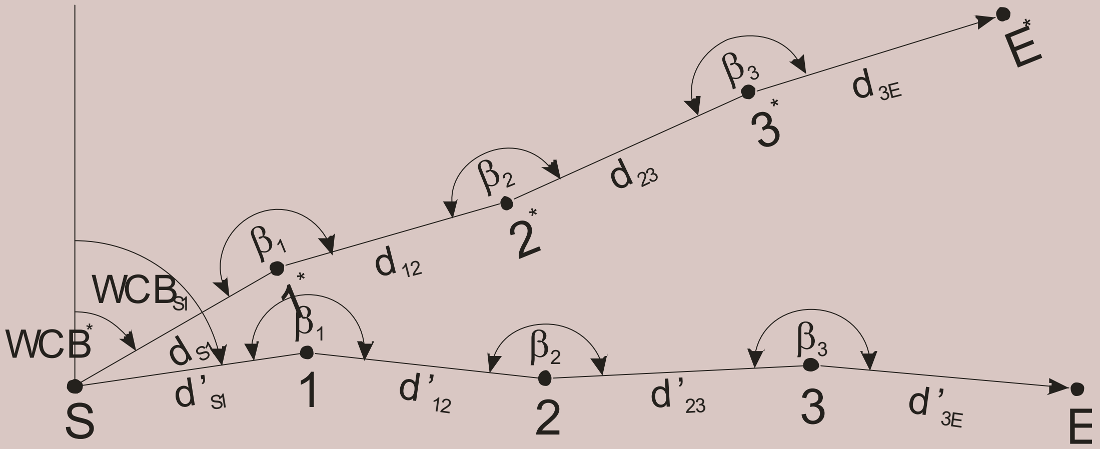
Computing the correction to the starting WCB:

$$\Delta WCB = WCB_{SE} - WCB_{SE^*}$$

Computing the correction to the length of the traverse legs (scale factor):

$$m = \frac{d_{SE}}{d_{SE^*}}$$

Computation of the inserted traverse



Computing the coordinates as a free traverse using the following values:

$$WCB_{S1} = WCB^{*} + \Delta WCB,$$

$$d'_{i,i+1} = m \cdot d_{i,i+1}.$$

Localizing blunders in the observations

Distance observations

Compute the WCB of the linear misclosure. The blunder is made most likely on the traverse leg, which has a similar provisional WCB.

Angular observations

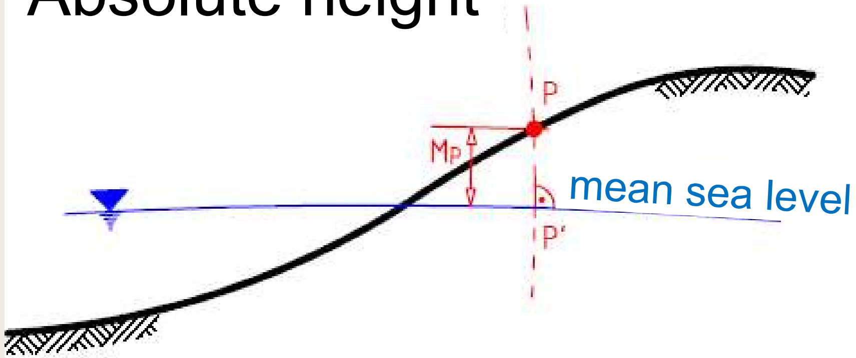
If only one blunder occurs in the observations, it can be localized in case of a closed line traverse.

Compute the traverse as a free traverse in the direction of S->E and E->S as well. The blunder is made at the station, which has similar coordinates in both solutions.

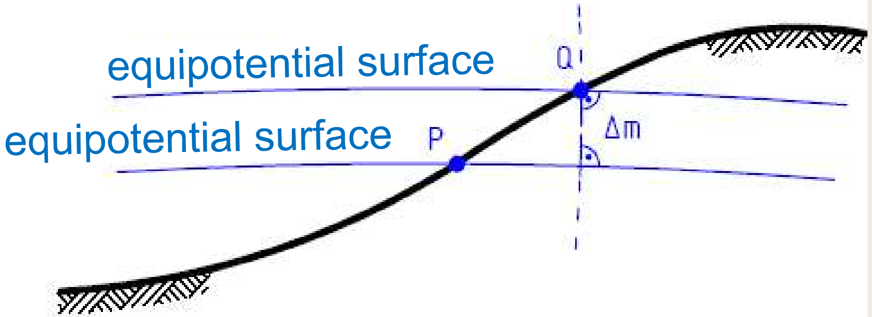
Thank You for Your Attention!

DETERMINATION OF HEIGHTS

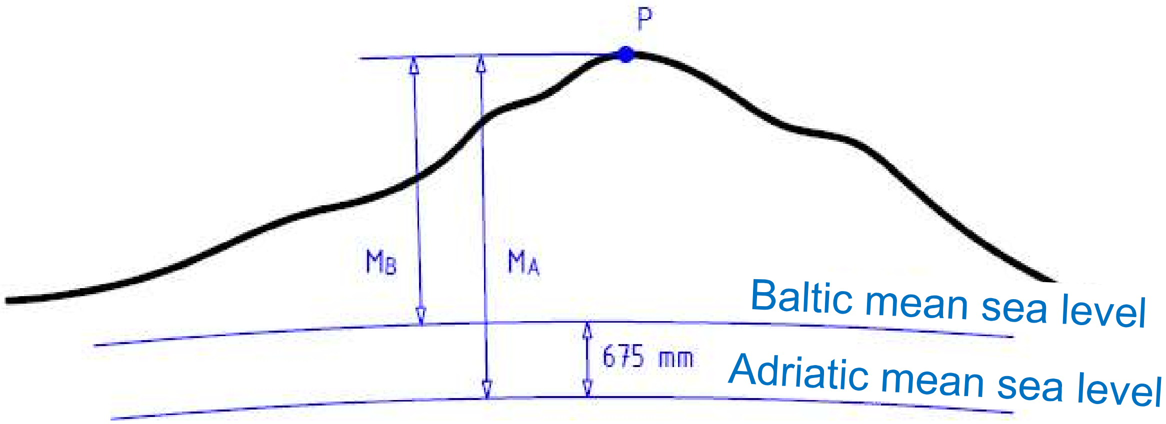
Absolute height



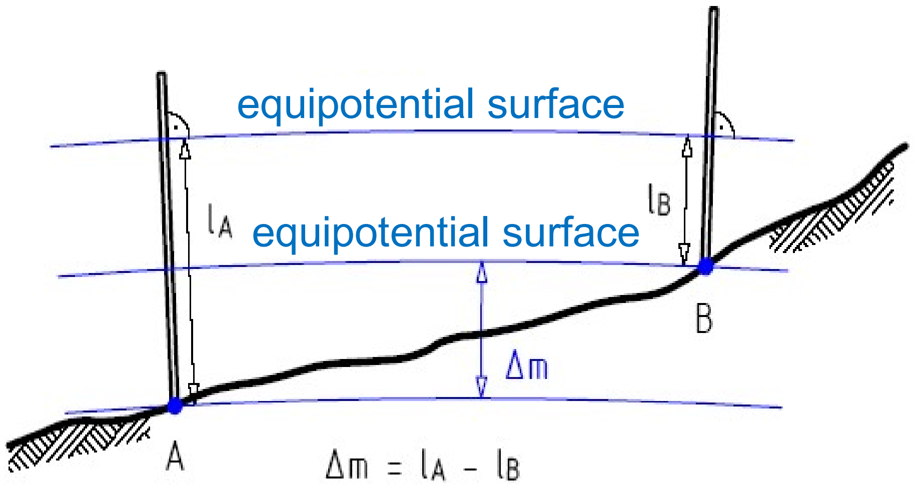
Relative height

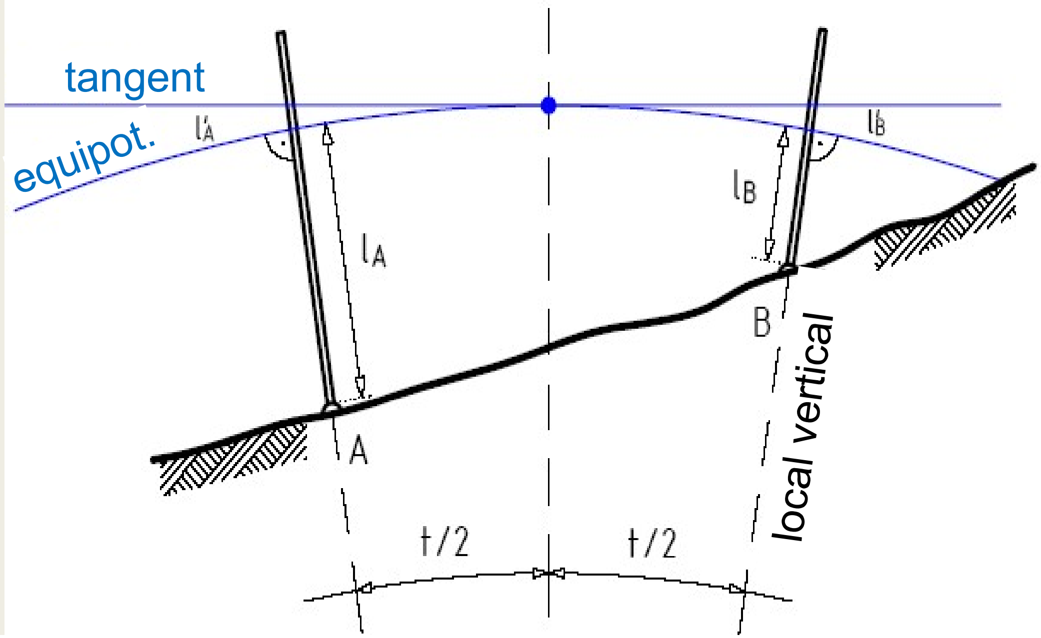


Adriatic and Baltic height



Theory of levelling





$$\Delta m = (l_A + l'_A) - (l_B + l'_B)$$

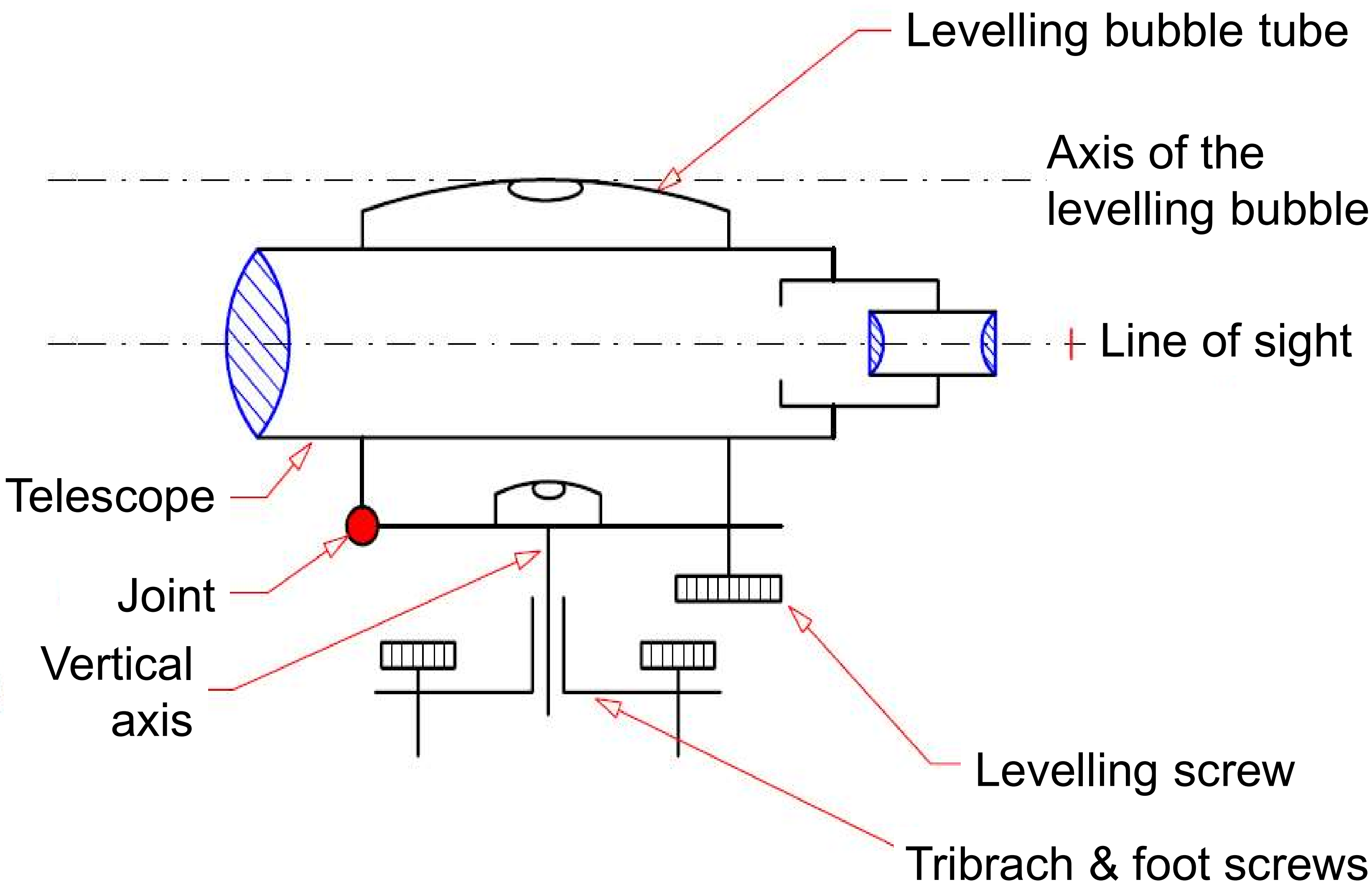
if the level stands same distance from the levelling rods then

$$l'_A = l'_B$$

thus

$$\Delta m = l_A + l'_A - l_B - l'_B = l_A - l_B$$

Tilting level (levelling instrument)

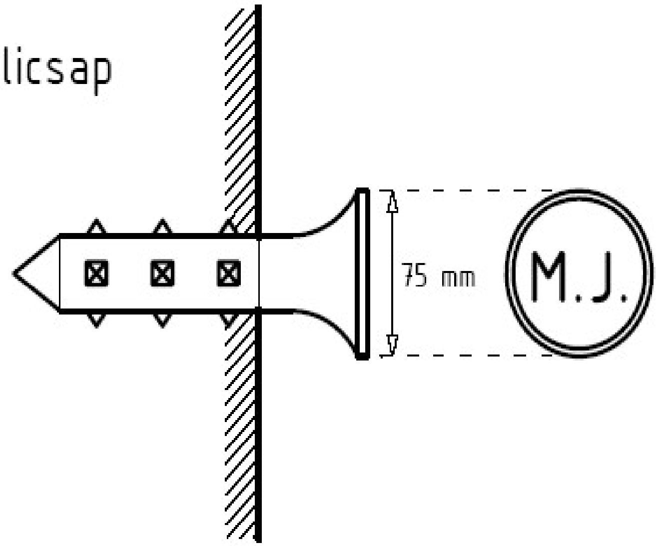


Rules of leveling

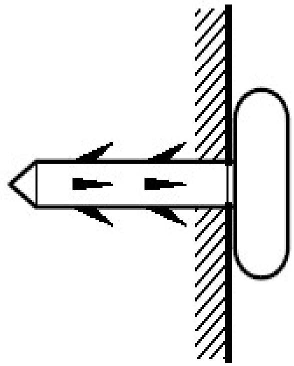
Automatic levelling instrumet

Magassági alappontok

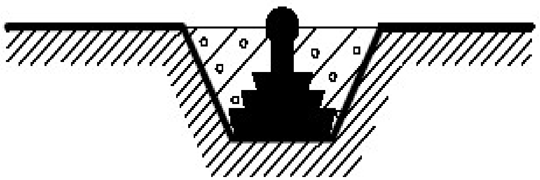
Falicsap



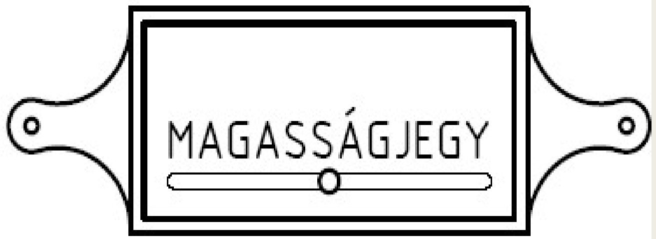
Falitárcsa



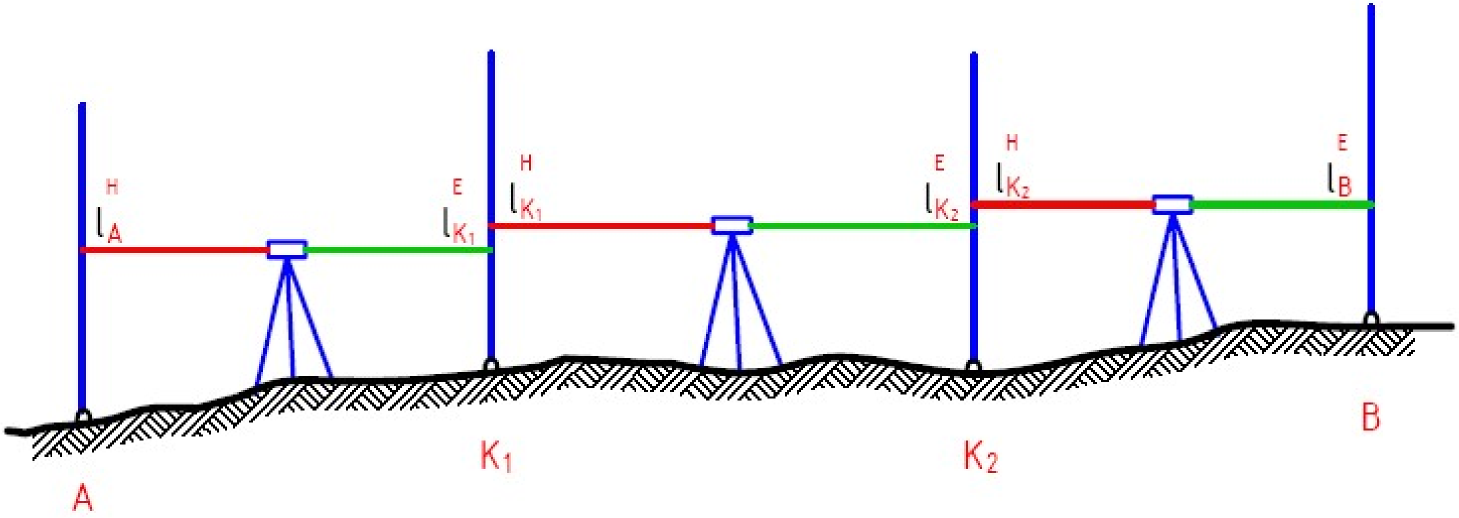
Szintezési gomb



Falitábla



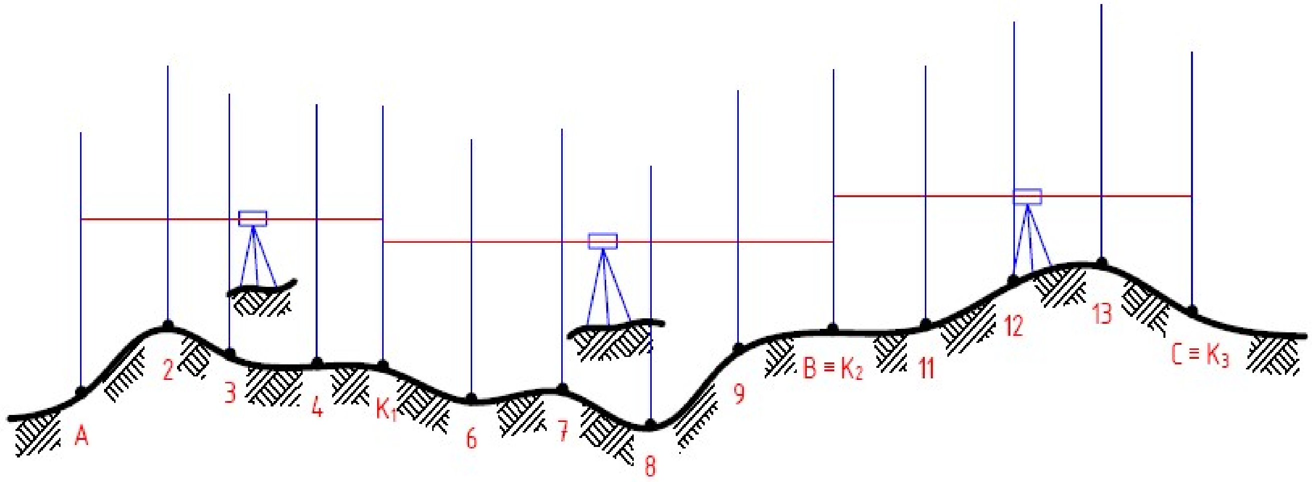
Line levelling



Line levelling measurement log

Point ID	Distance	Reading		Height difference	
		Backsight	Foresight	Rise	Fall
A		0516			1302
K_1	60×		1818		
K_1		0822		0360	
K_2	60×		0462		
K_2		1804		1285	
B	58×		0529		
Sum:		3142		1645	1302
Height difference:		0343		0343	

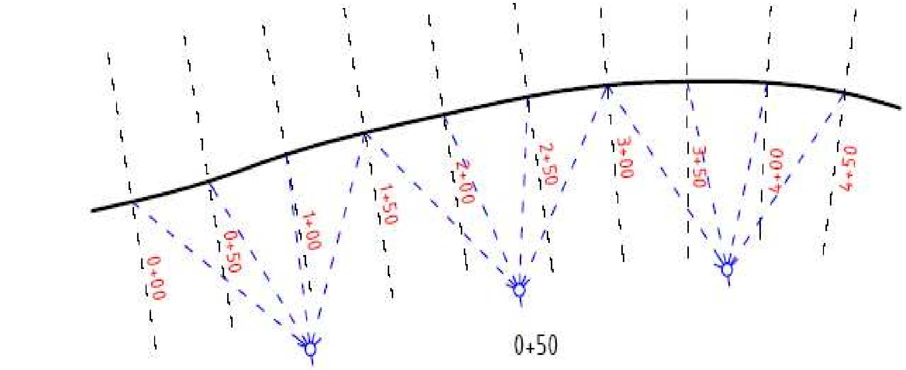
Profile levelling

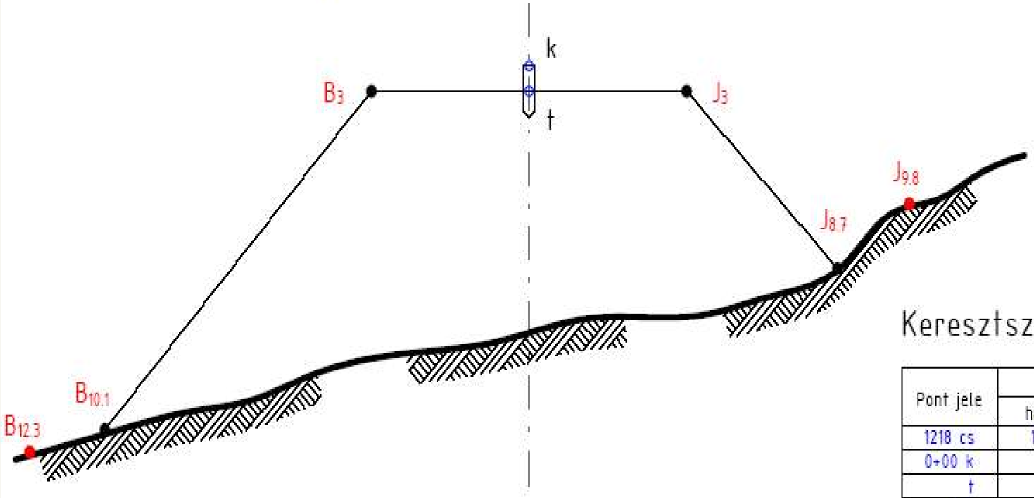


Hosszszelvény jegyzőkönyv

Pont jele	Táv.	Lécleolvasások			Magasság	
	(m)	hátra	közép	előre	látsík	pont
A	0,0	2345			52,345	50,000
2	26,8		0660			51,68
3	60,5		1250			51,10
4	124,8		1530			51,82
K_1				1545		50,800
K_1		0331			51,131	
6	190,0		1880			49,25
7	220,5		1430			49,70
8	265,6		2880			48,25
9	303,4		0250			50,88
B ≡ K_2	324,82			0111		51,020
K_2	0,0	1216			52,236	
11	38,0		2080			50,16
12	110,0		0630			51,61
13	140,8		0260			51,98
B ≡ K_3	164,43			1435		50,801
	[h]	3892	[e]	3091		
		Δ =	0801		Δ =	0801

Cross-section levelling

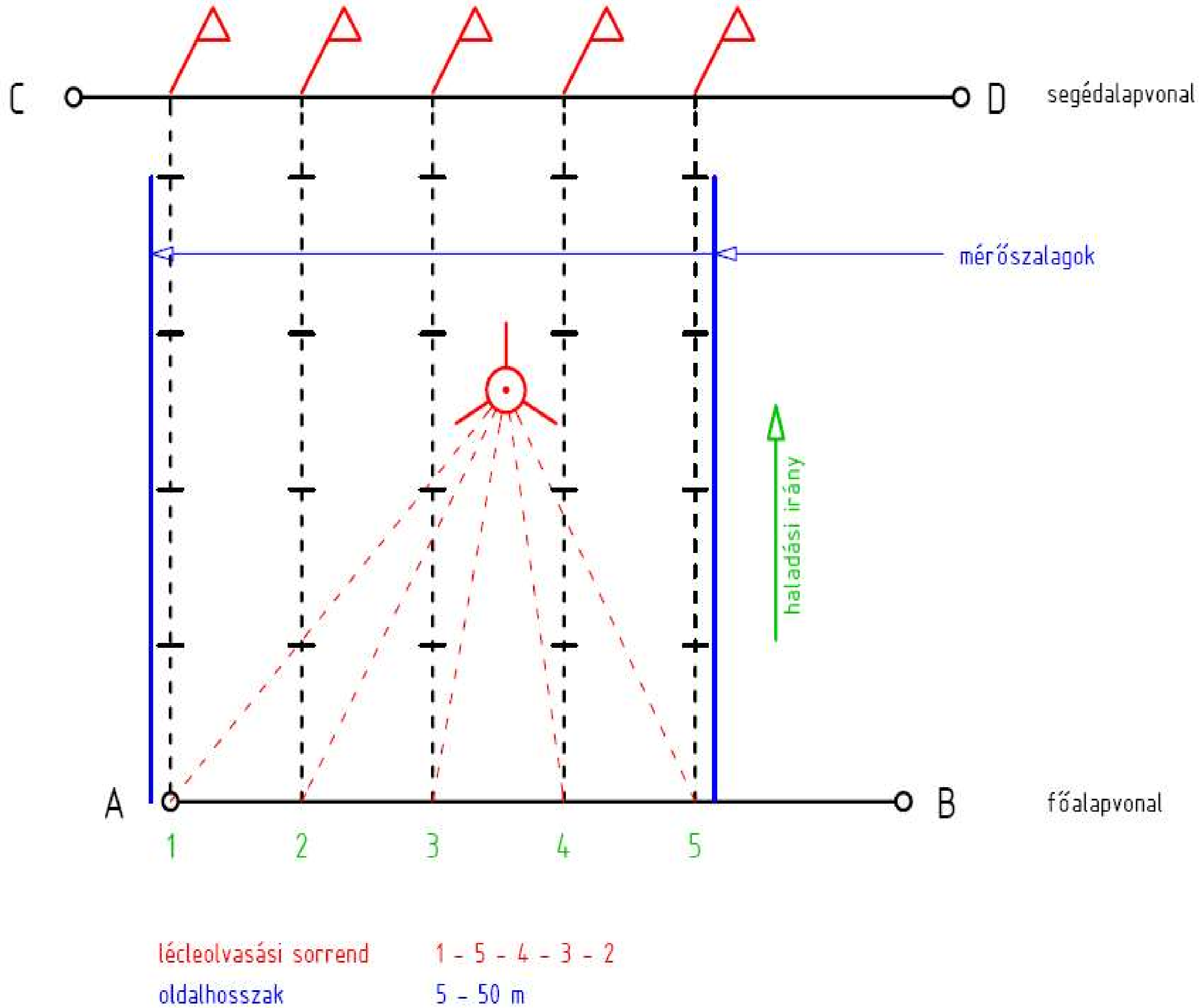




Keresztszelvény jegyzőkönyv

Pont jele	Lécleolvasások			Magasság	
	hátra	közép	előre	látsík	pont
1218 cs	1481			163,608	162,127
0+00 k		1522			162,086
t		1550			162,050
J_3		1590			162,010
$J_{8.7}$		1770			161,830
$J_{9.8}$		1710			163,890
B_3		1580			162,020
$B_{10.1}$		2450			161,150
$B_{12.3}$		2490			161,110
0+50 k		1542			162,162
t		1590			162,010
:	:	:	:	:	:
:	:	:	:	:	:
:	:	:	:	:	:

Area levelling



Területszintezési jegyzőkönyv

kezdő magasság 8. cövek: 150,000 m

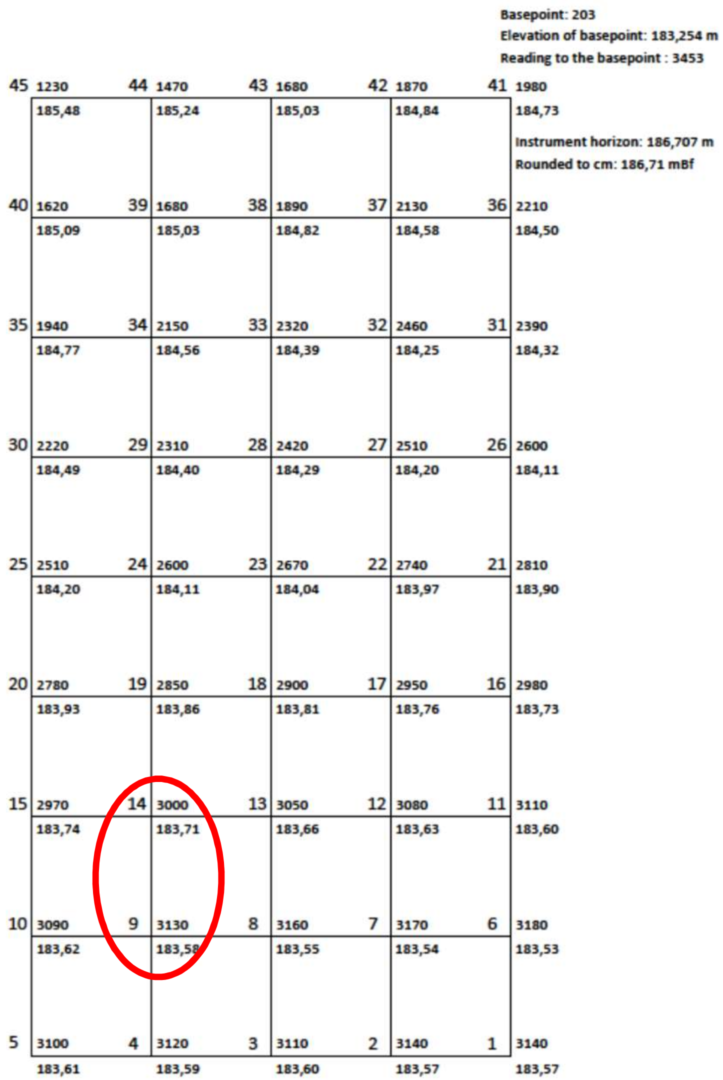
lécleolvasás: 1,367 m

látsík: 151,367 m

151,37 m

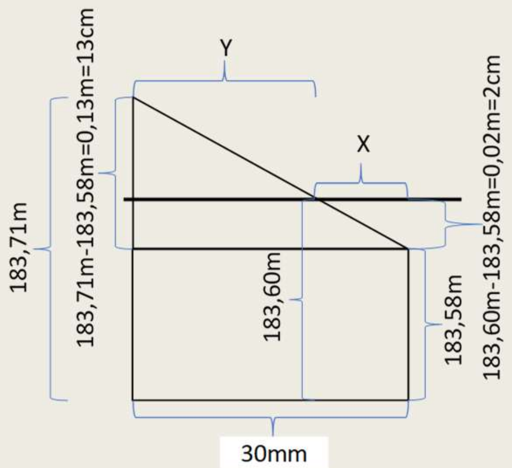
3 19	2 73	2 55	2 35	2 50
148 18	148 64	148 82	149 02	148 87
3 00	2 65	2 18	2 13	2 08
148 37	148 78	149 19	149 24	149 29
2 78	2 43	1 94	1 98	1 78
148 59	148 94	149 43	149 39	149 59
2 59	2 06	1 76	1 59	1 64
148 78	149 31	149 61	149 78	149 73
2 32	1 91	1 45	1 26	1 32
149 05	149 46	149 92	150 11	150 05
2 27	1 82	1 25	1 03	0 99
149 10	149 55	150 12	150 34	150 38
1 89	1 51	0 93	0 64	0 67
149 48	149 86	150 44	150 73	150 70
1 55	1 21	0 75	0 49	0 50
149 82	150 16	150 62	150 88	150 87
1 06	0 85	0 52	0 32	0 37
150 31	150 52	150 85	151 05	151 00

8. cövek



Lineáris interpoláció példa területszintezésből szintvonalas térkép készítésére

Linear interpolation example for creating a contourline map from area (grid) leveling



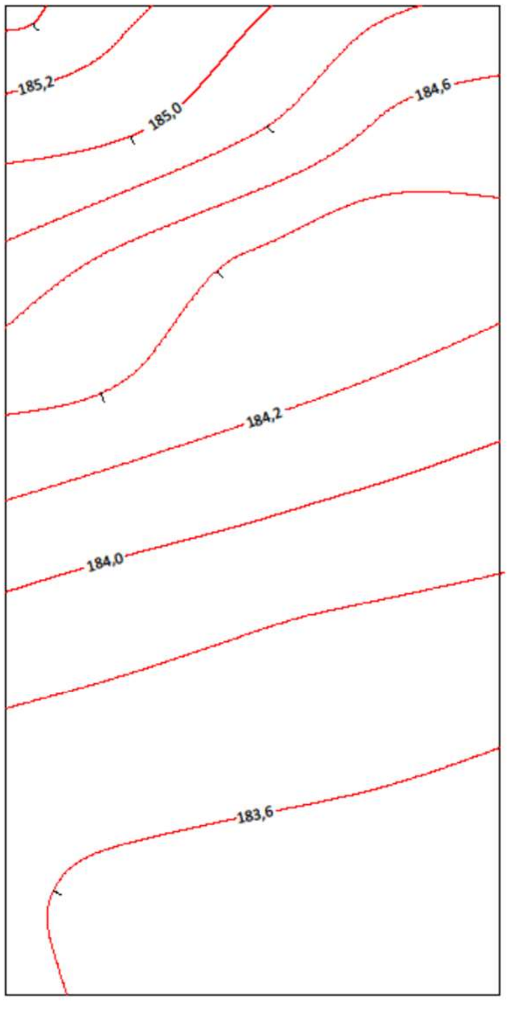
X/2cm=30mm/13cm

X=30mm*2cm/13cm=4,6mm

Y=30mm*11cm/13cm=25,4mm

X+Y=4,6mm+25,4mm=30mm

185,48 185,24 185,03 184,84 184,73
185,09 185,03 184,82 184,58 184,50
184,77 184,56 184,39 184,25 184,32
184,49 184,40 184,29 184,20 184,11
184,20 184,11 184,04 183,97 183,90
183,93 183,86 183,81 183,76 183,73
183,74 183,71 183,66 183,63 183,60
183,62 183,58 183,55 183,54 183,53
183,61 183,59 183,60 183,57 183,57
185,2
185,0
184,2
184,0
183,8
183,6



185,2
185,0
184,6
184,2
184,0
183,6

Surveying I.

Setting out straight lines, angles, points in given elevation, center line of roadworks and curves.

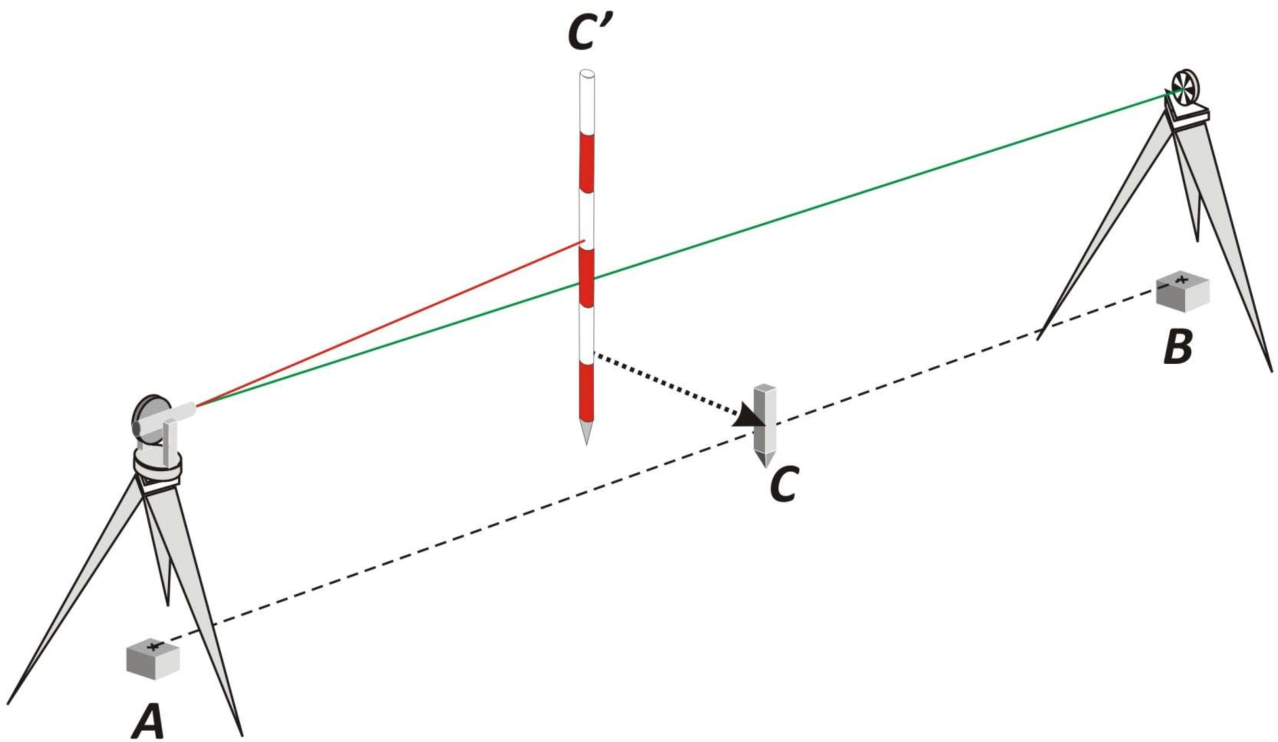
Setting out points with geometric criteria:

- straight lines: the points must be on a straight line, which is defined by two marked points;
- horizontal angles: one side of the angle is already set out, the other side should be set out;

Setting out points with defined horizontal coordinates:

- setting out points with defined horizontal coordinates in a local or national coordinate system;
- setting out points with defined elevation (local or national reference system)

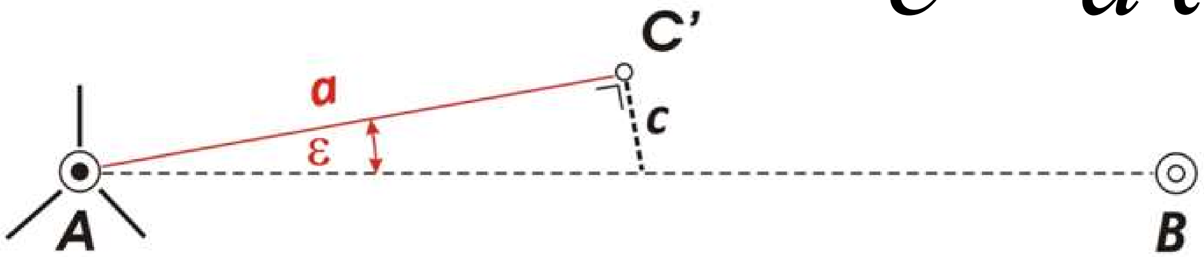
Setting out straight lines



Alignment from the endpoint

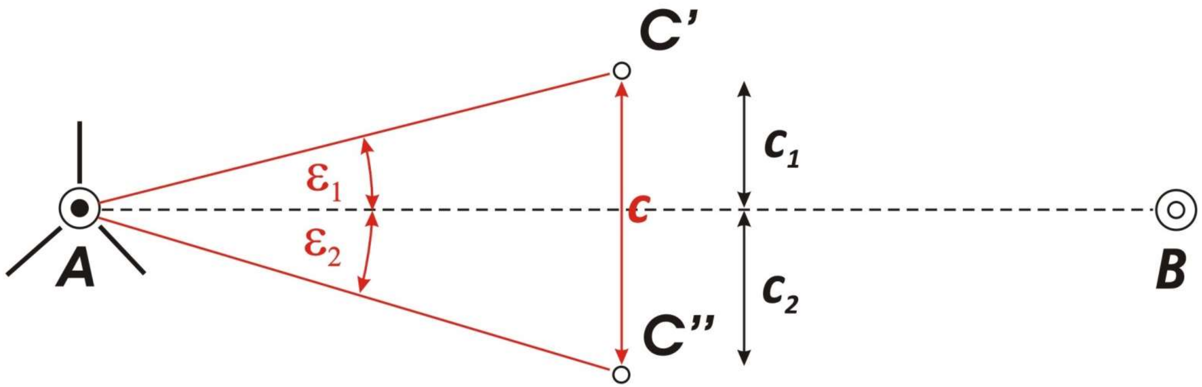
Alignment (AC' distance is observable)

$$c = a \tan \varepsilon$$



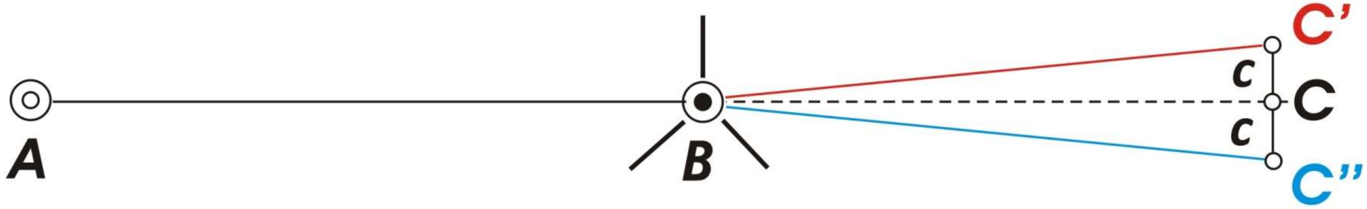
Alignment (AC' distance is not observable)

$$c_1 = \frac{\varepsilon_1}{\varepsilon_1 + \varepsilon_2} \cdot c \qquad c_2 = \frac{\varepsilon_2}{\varepsilon_1 + \varepsilon_2} \cdot c \qquad c_1 + c_2 = c$$



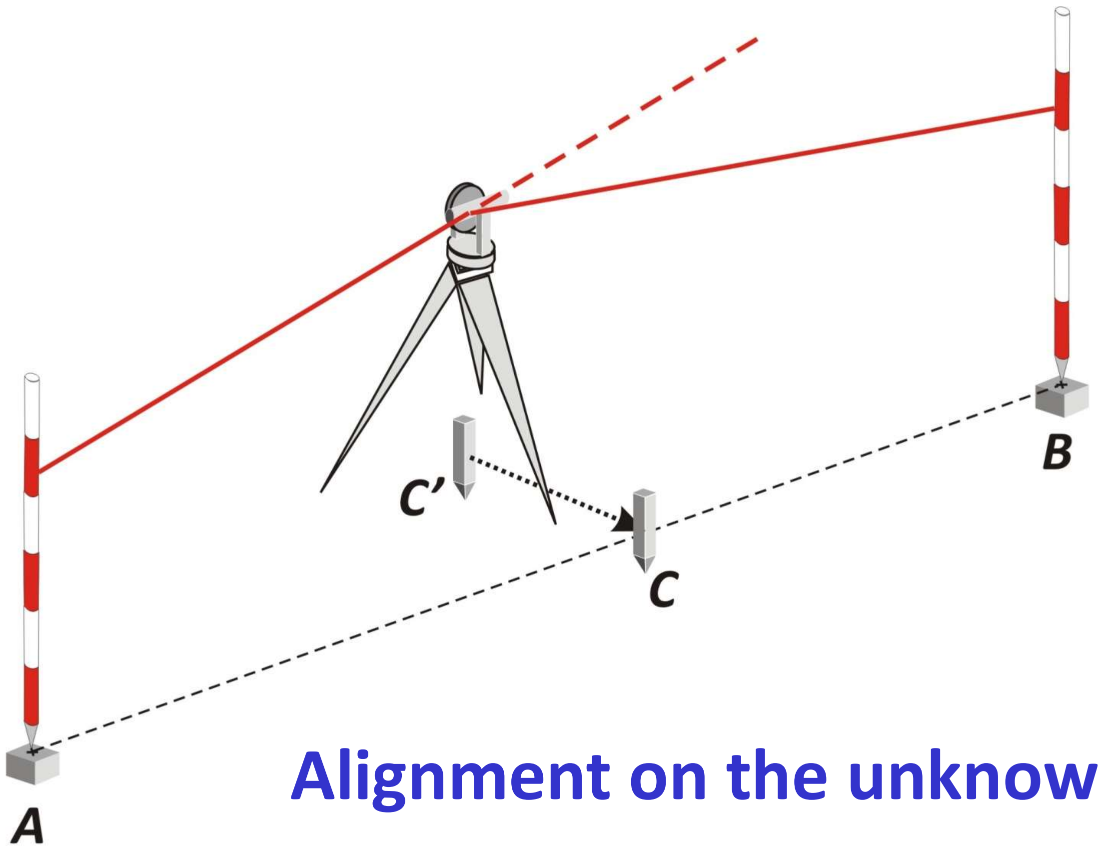
Alignment (C is located on the extension of AB line)

Set out the extension of the line in Face Left!



Set out the extension of the line in Face Right!

Setting out straight lines



Alignment on the unknown point

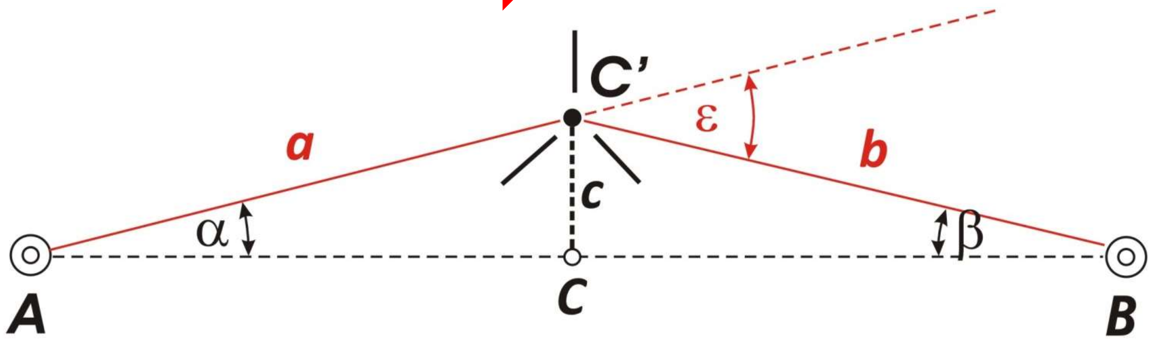
Setting out straight lines
(AC’ and BC’ distance is observable)

$$c = \alpha \cdot a$$

$$c = \beta \cdot b$$

$$\varepsilon = \alpha + \beta$$

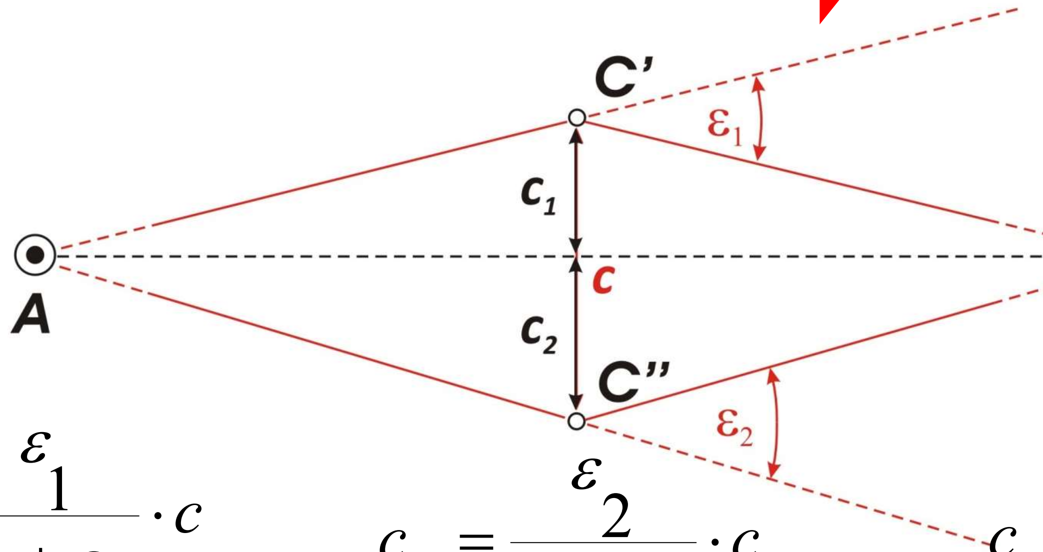
$$c = \frac{ab}{a+b} \cdot \frac{\varepsilon''}{\rho''}$$



Setting out straight lines
(AC’ and BC’ distance is NOT observable)

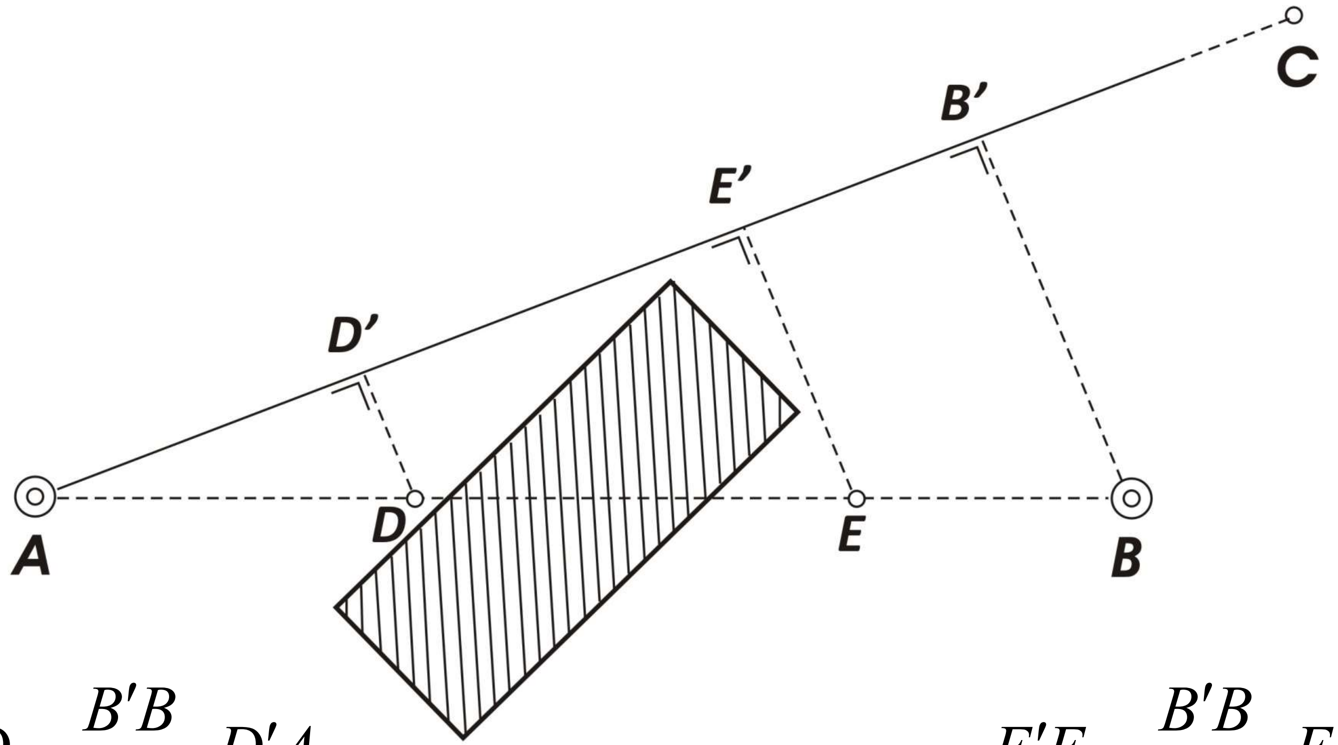
Let’s use the formula of the previous case for c_1 and c_2!

$$c_1 = \frac{ab}{a+b} \cdot \varepsilon_1 \qquad c_2 = \frac{ab}{a+b} \cdot \varepsilon_2 \quad \Rightarrow \quad \frac{c_1}{c_2} = \frac{\varepsilon_1}{\varepsilon_2}$$



$$c_1 = \frac{\varepsilon_1}{\varepsilon_1 + \varepsilon_2} \cdot c \qquad c_2 = \frac{\varepsilon_2}{\varepsilon_1 + \varepsilon_2} \cdot c \qquad c_1 + c_2 = c$$

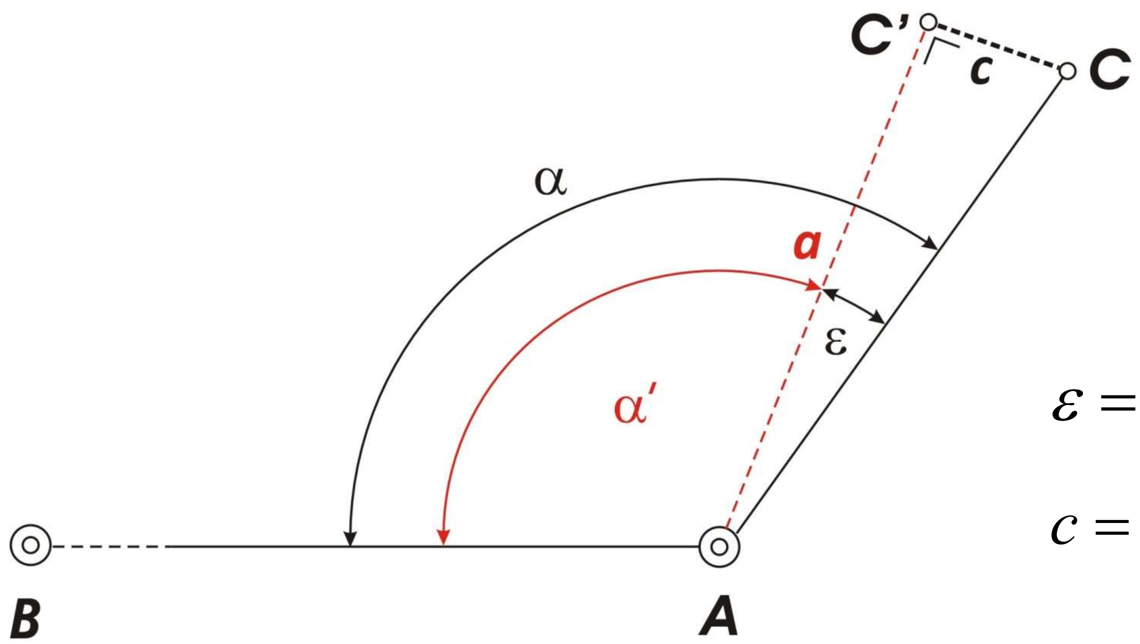
Setting out straight lines through obstacles



$$D'D = \frac{B'B}{B'A} \cdot D'A$$

$$E'E = \frac{B'B}{B'A} \cdot E'A$$

Setting out horizontal angles



$$\varepsilon = \alpha - \alpha'$$

$$c = a \tan \varepsilon$$

Compute ε and measure the distance a.
The linear correction c can be computed using ε and a.

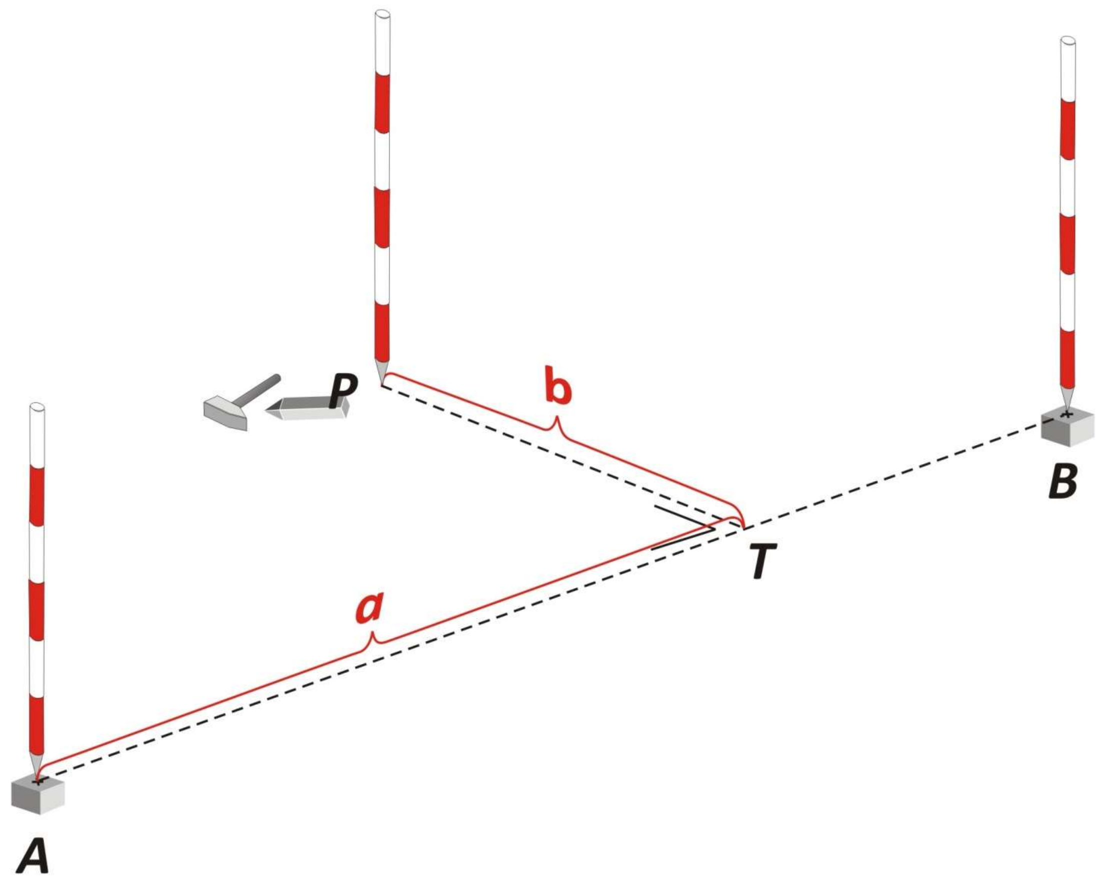
Setting out coordinated points

Setting out coordinated points

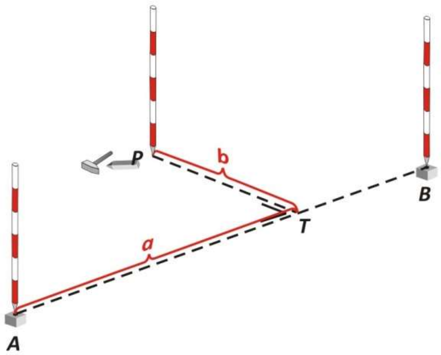
1. Tape surveying (offset surveys)

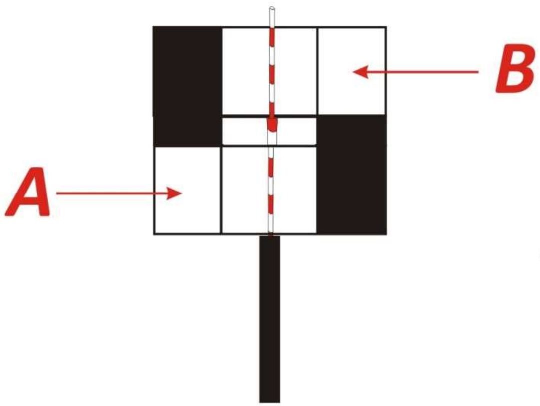
2. Setting out with polar coordinates (radiation)

Offset surveys

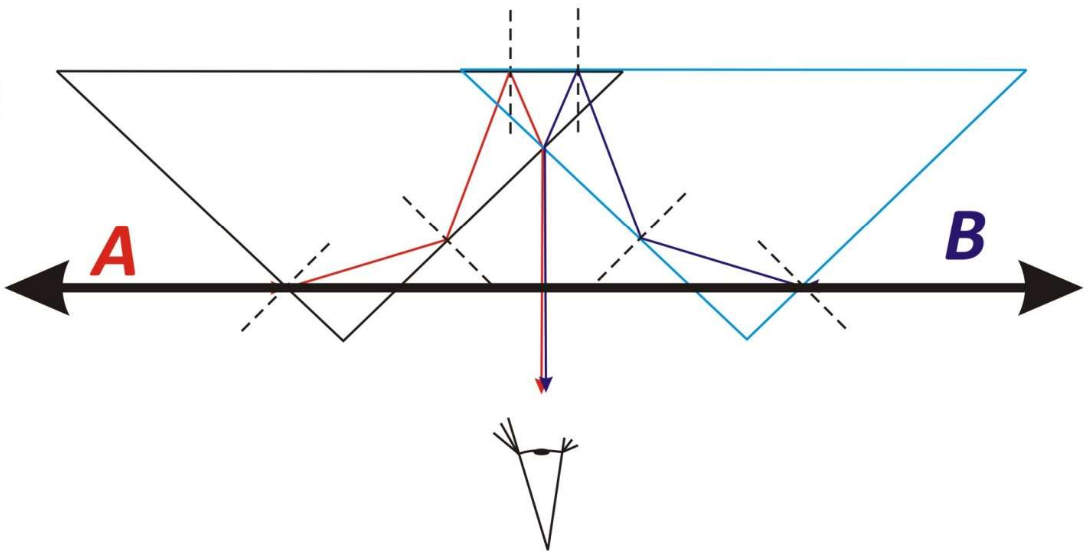


The optical square

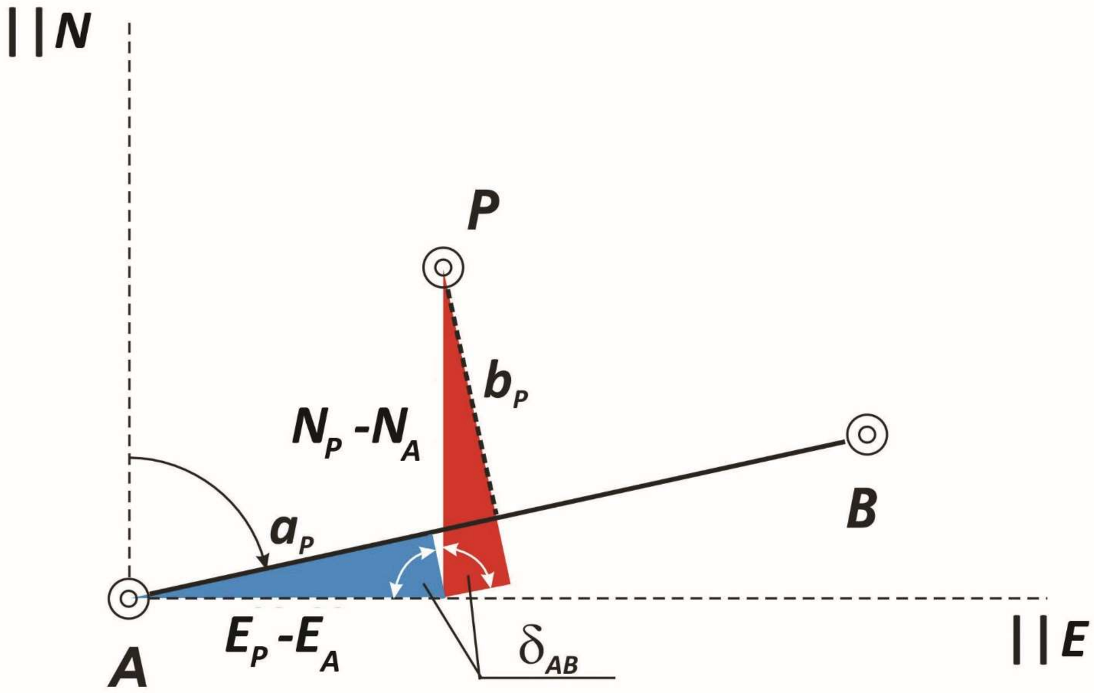




Top view



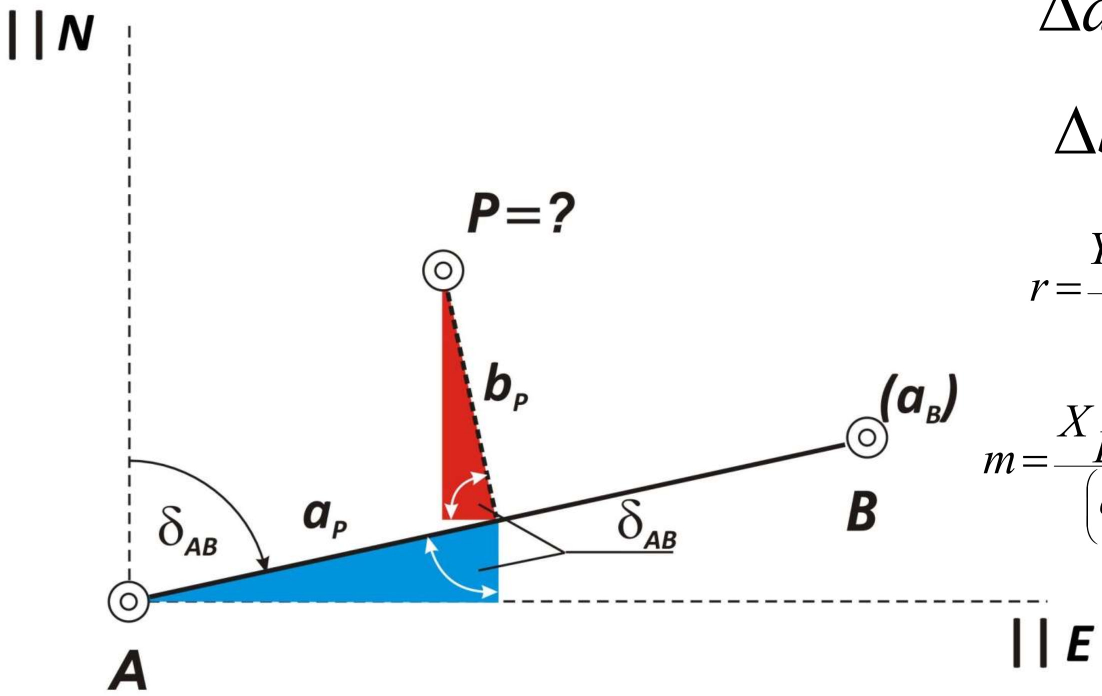
Offset surveys – computation of chainage and offset



$$a_P = (E_P - E_A)\sin WCB_{AB} + (N_P - N_A)\cos WCB_{AB},$$
$$b_P = -(E_P - E_A)\cos WCB_{AB} + (N_P - N_A)\sin WCB_{AB},$$

$$a_i = a_{i-1} + \Delta E_{i-1,i}\sin WCB_{AB} + \Delta N_{i-1,i}\cos WCB_{AB},$$
$$b_i = b_{i-1} - \Delta E_{i-1,i}\cos WCB_{AB} + \Delta N_{i-1,i}\sin WCB_{AB}.$$

Offset surveys – computation of coordinates



$$\Delta a_i = a_i - a_{i-1}$$

$$\Delta b_i = b_i - b_{i-1}$$

$$r = \frac{Y_B - Y_A}{\left(a_{AB}\right)} \approx \sin\delta_{AB}$$

$$m = \frac{X_B - X_A}{\left(a_{AB}\right)} \approx \cos\delta_{AB}$$

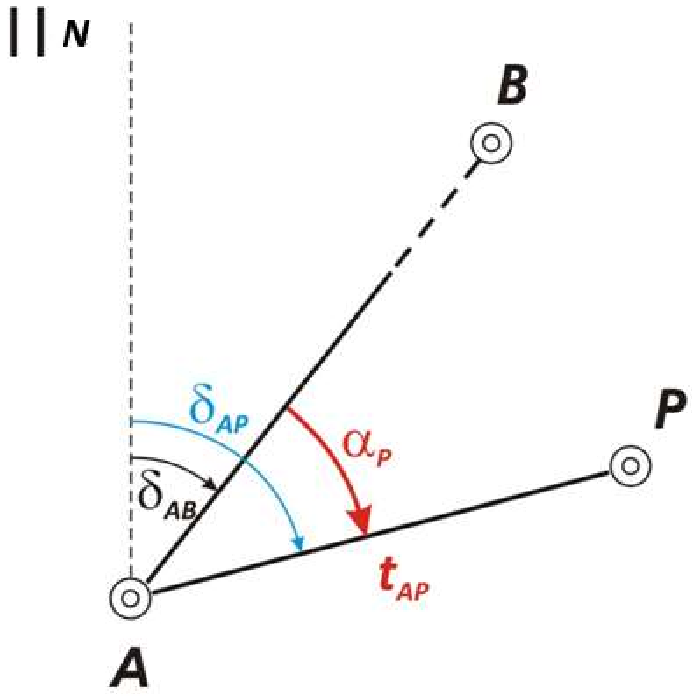
$$E_P = E_A + a_P \sin\delta_{AB} - b_P \cos\delta_{AB}$$

$$N_P = N_A + a_P \cos\delta_{AB} + b_P \sin\delta_{AB}$$

$$E_i = E_{i-1} + \Delta a_i \cdot r - \Delta b_i \cdot m$$

$$N_i = N_{i-1} + \Delta b_i \cdot r + \Delta a_i \cdot m$$

Setting out with polar coordinates (radiation)



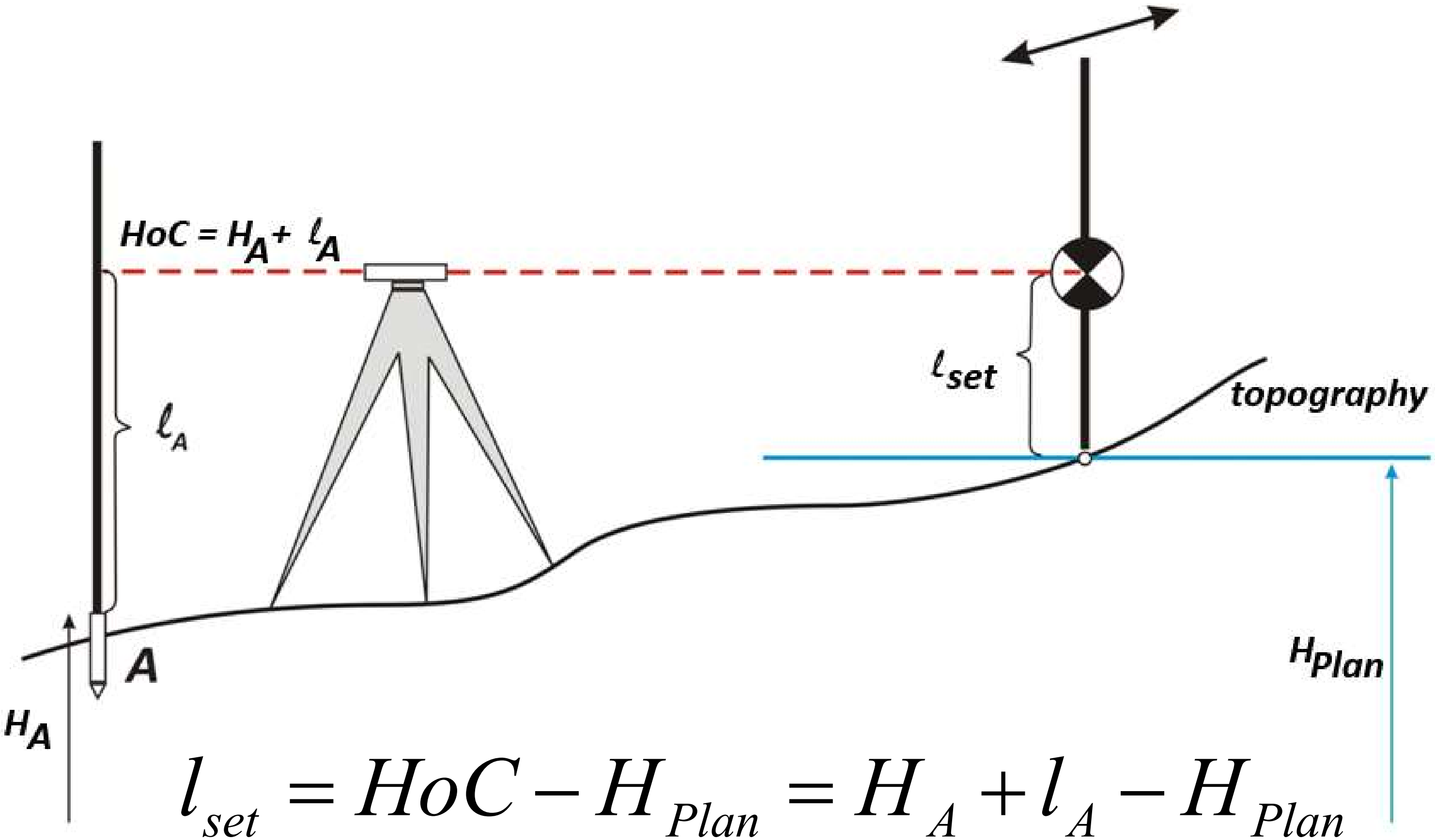
Given: *A*, *B* and *P*

2nd fundamental task of surveying:

$$\delta_{AB}, \delta_{AP}, t_{AP}$$

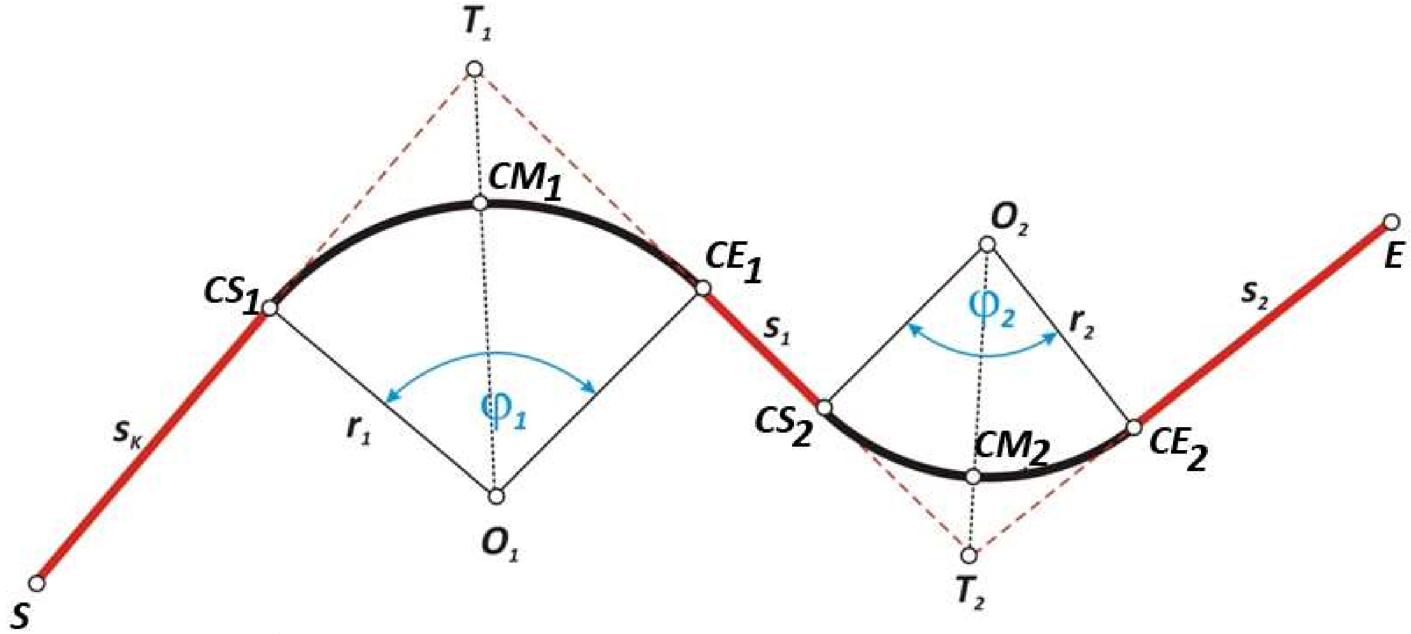
$$\alpha_P = \delta_{AP} - \delta_{AB}$$

Setting out points with given elevation



$$l_{set} = HoC - H_{Plan} = H_A + l_A - H_{Plan}$$

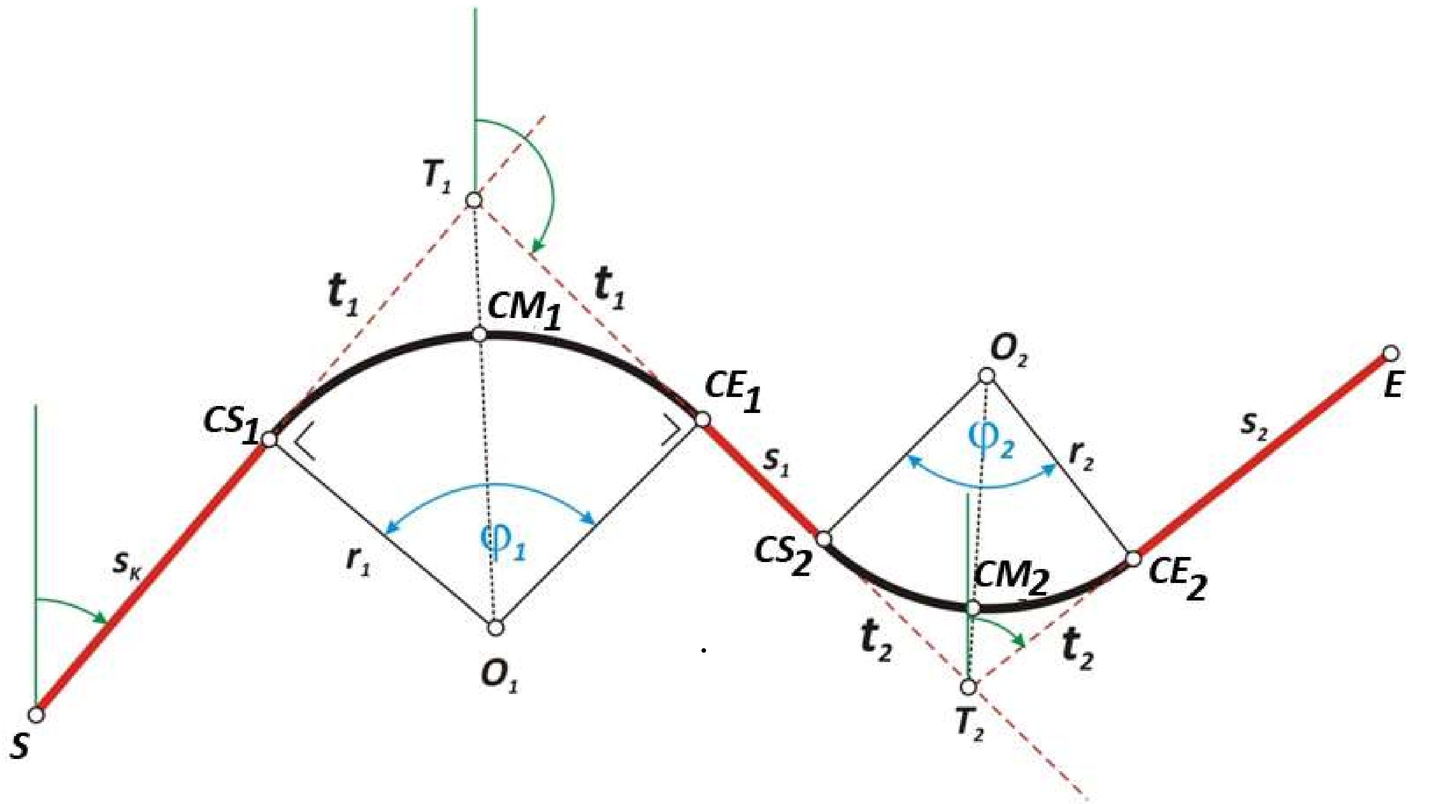
VI. Setting out the centerline of roadworks



1. Preparations:

- Given: S , E, T_1, T_2, ... T_n, and r_1, r_2, ...r_n,

- 2nd fundamental task: $d_{K1}, d_{12}, \ldots, d_{nV}$ $\delta_{K1}, \delta_{12}, \ldots, \delta_{nV}$

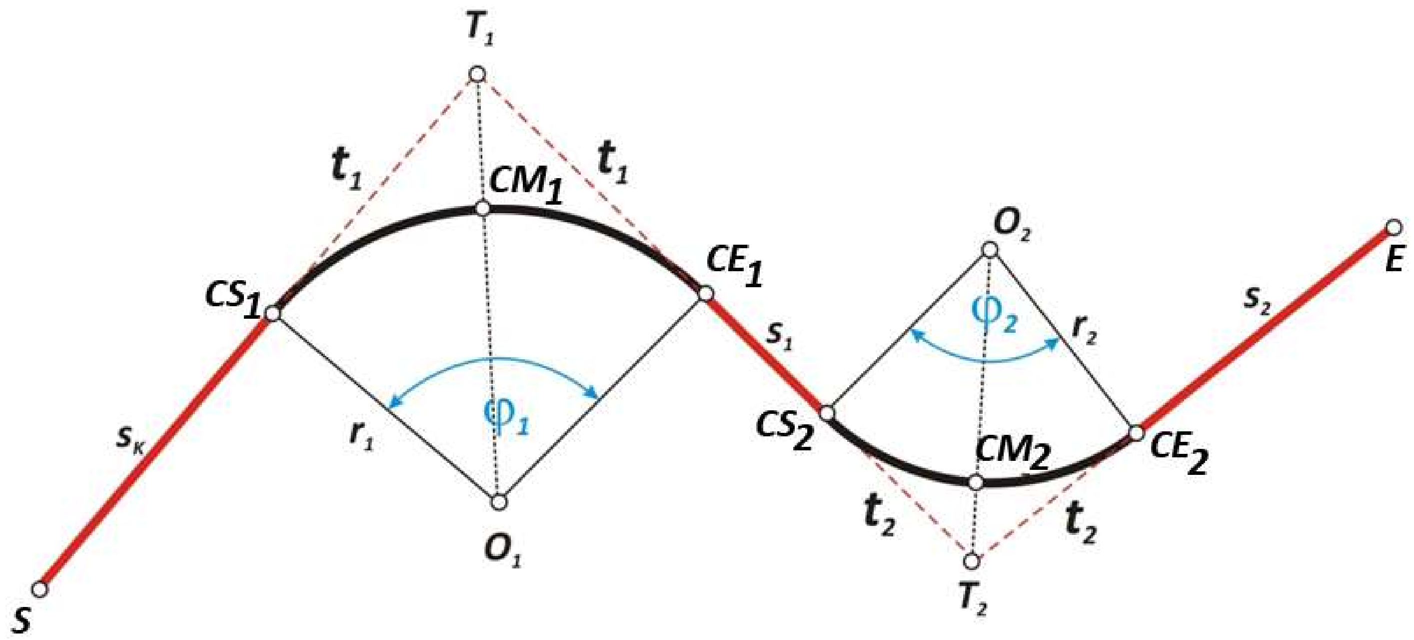


$$\varphi_i = \delta_{i,i+1} - \delta_{i-1,i}$$

(*in case of right curves – facing to increasing stationing)*

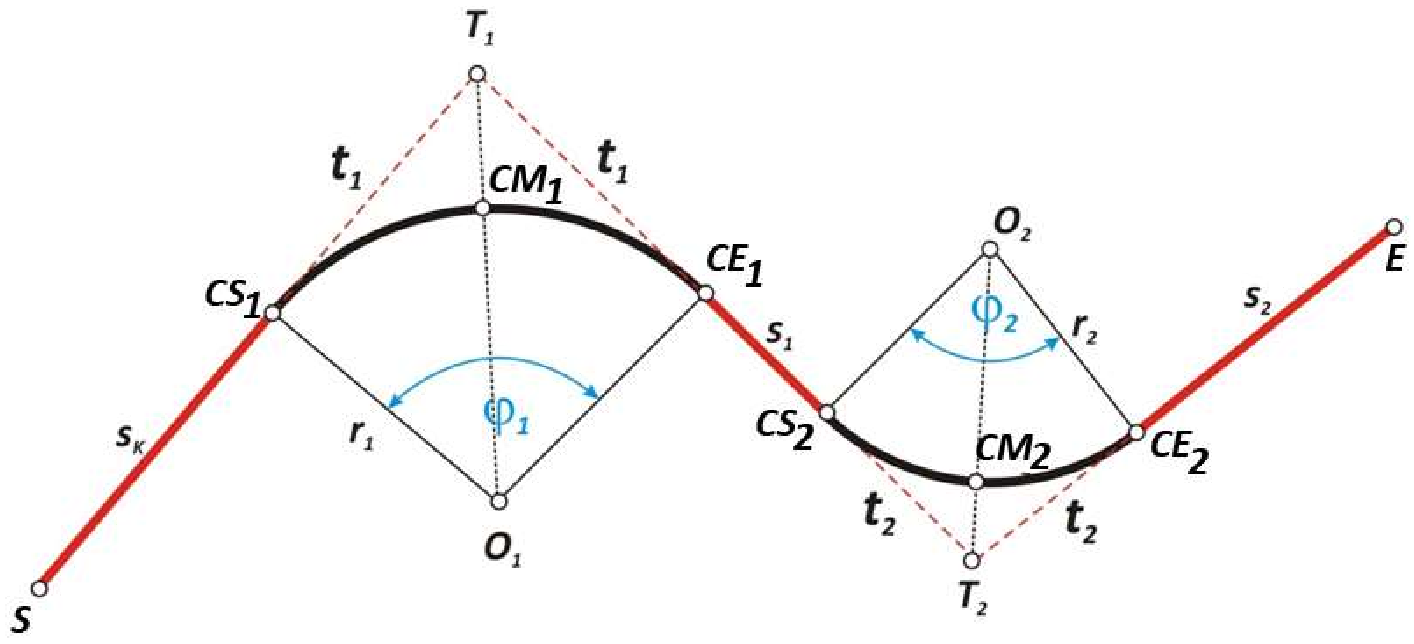
$$\varphi_i = \delta_{i-1,i} - \delta_{i,i+1}$$

(*in case of left curves – facing to increasing stationing)*



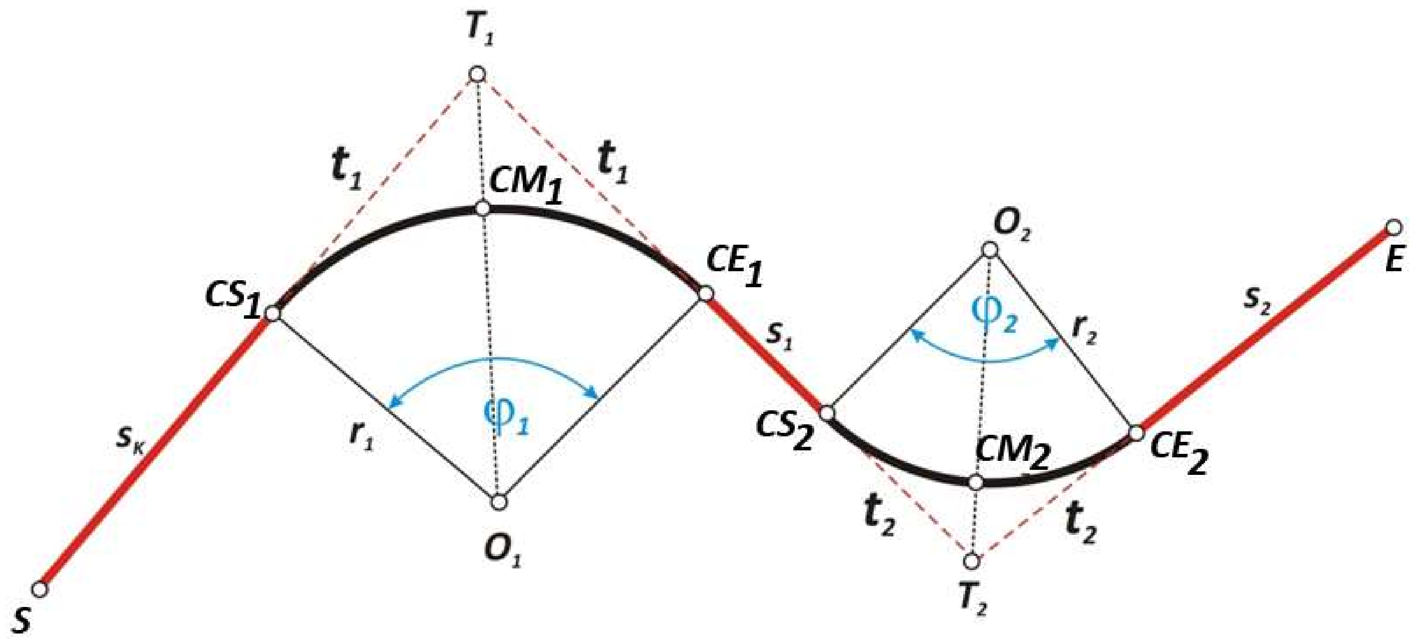
Tangent-length: $$t_i = r_i \tan \frac{\varphi_i}{2}$$

Length of arc: $$A_i = 2 r_i \pi \cdot \frac{\varphi_i^\circ}{360^\circ}$$

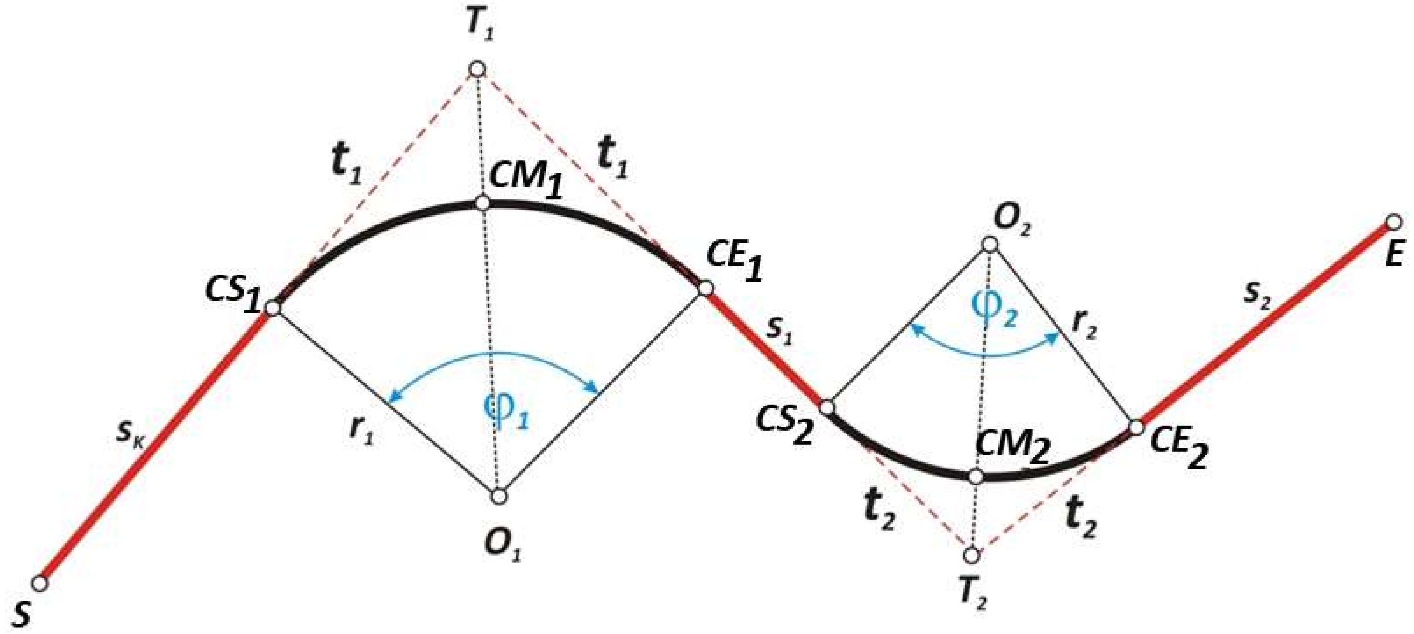


2. Stationing (computation of chainages)

- *The station of S*: 0+00
- *Round stations between S and CS_1*
- CS_1 station: $d_{K1} - t_1$



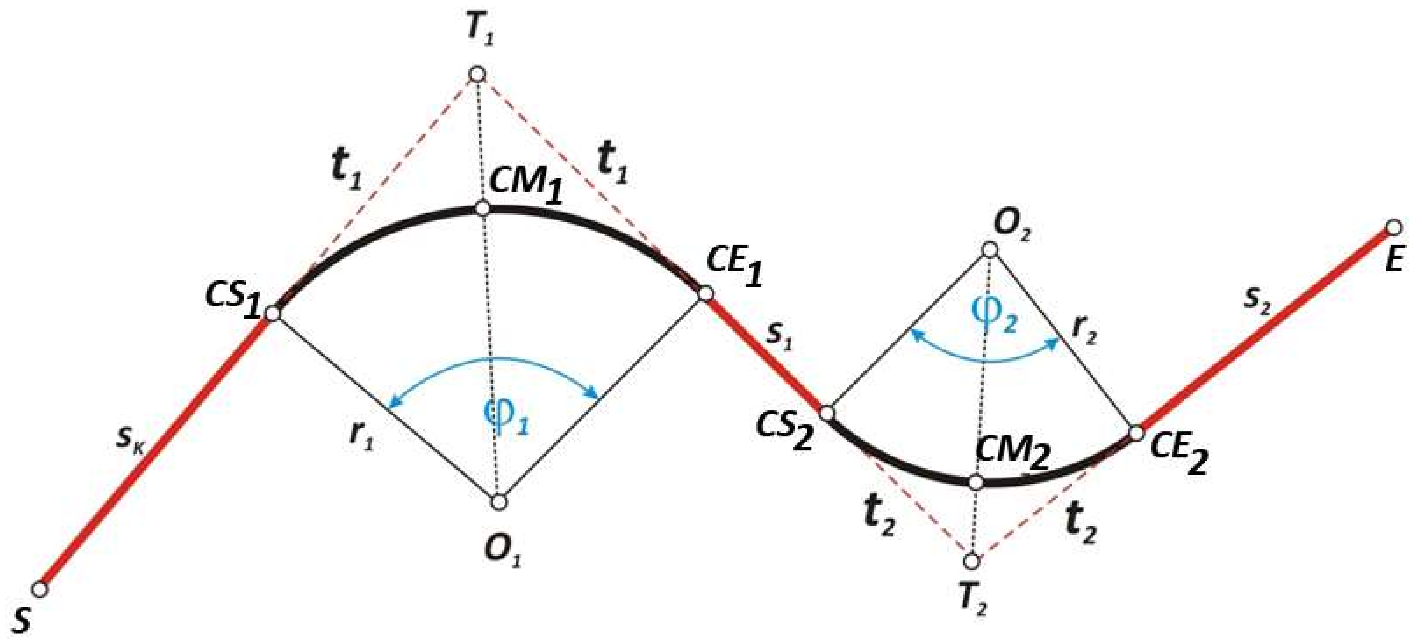
- CE_1 station = CS_1 Station + *Length of Arc*
- $CE_1 \ldots CS_2$ first round station is S_1, the station of CE_1 should be rounded upwards (amount of rounding is Δ_1);
- CS_2 station = CE_1 station + $d_{12} - (t_1 + t_2)$
- *between* CE_1 and CS_2 round stations should be computed



• $CE_n \ldots E$ section: first station is S_n, the value is the upward rounded station of CE_n

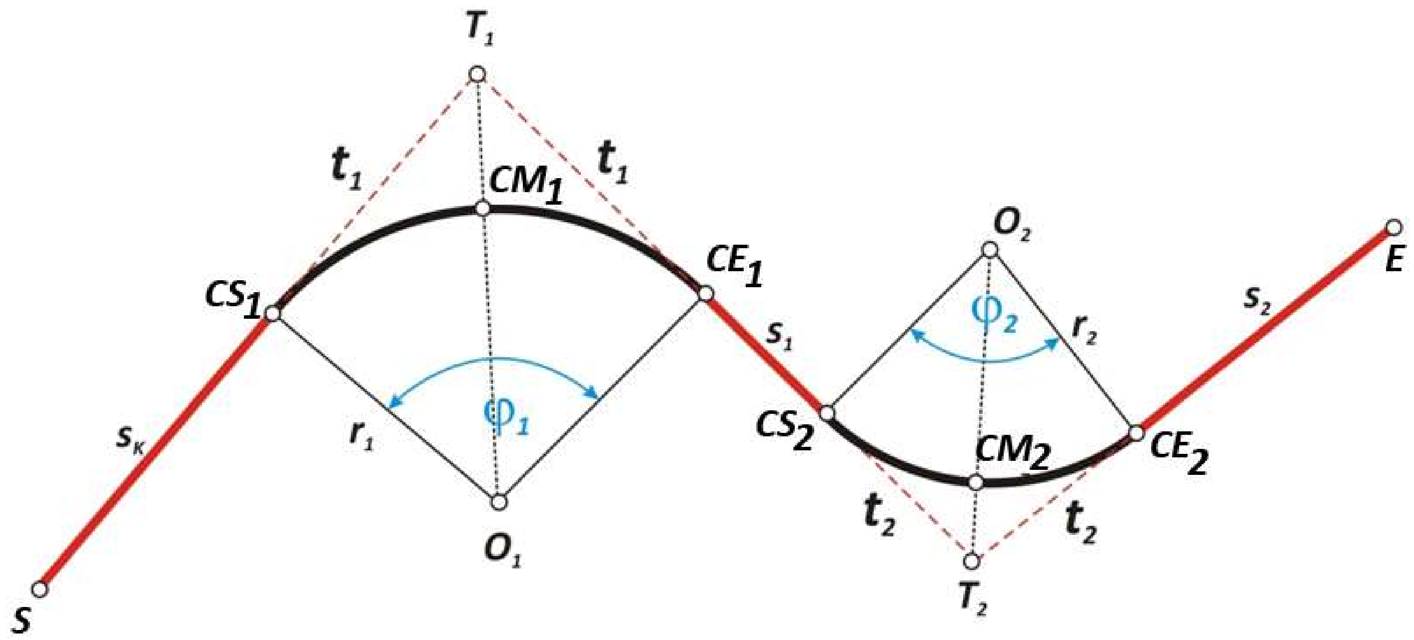
• *Station of E* $= Ce_n + (d_{nV} - t_n)$

• *Round stations between* CE_n és E



3. Computing the coordinates of CL points (stations) – along the straight lines

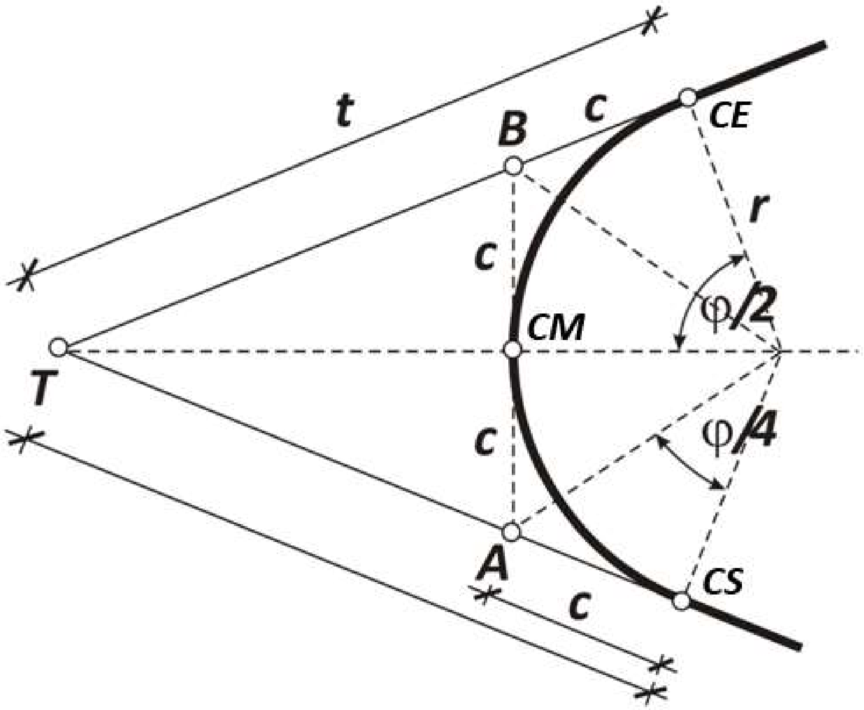
• Coordinates can be computed based on the distance between the traverse points (Ti) and the WCB between the traverse points.



4. Setting out the CL points:

• Using polar setting out (radiation) from the traverse points.

5. The setting out of principal points on the curves:



Measure the tangent length from T! Thus the CS and CE points can be found:

$$t = r \tan \frac{\varphi}{2}$$

With the distance ***T-CM*** the points CM can be found:

$$d_{T\text{-}CM} = r/\cos(\phi/2) - r$$

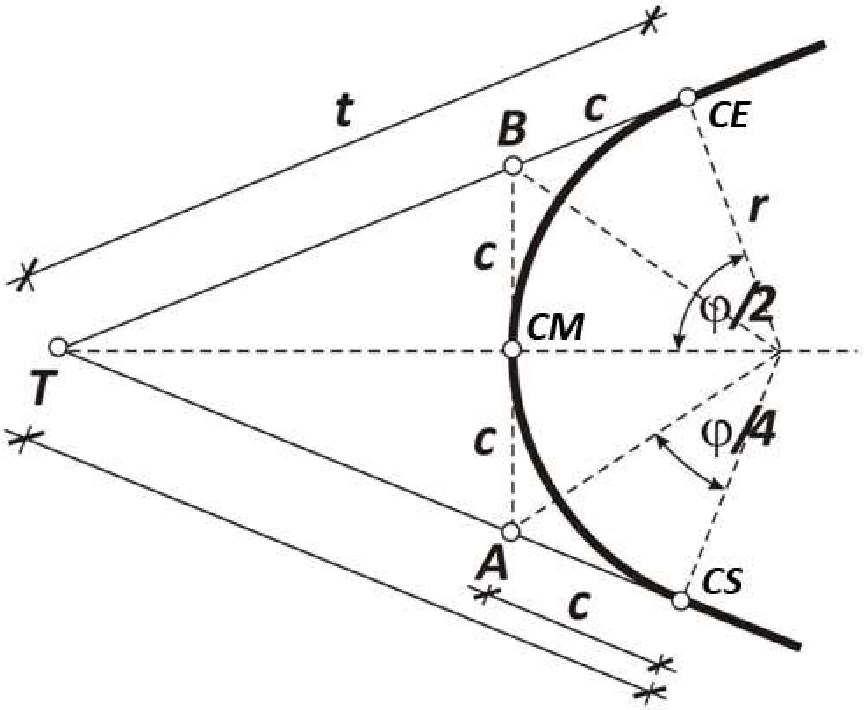
Curve length can be calculated from:

$L_{arc} = r * \phi_{rad}$

where:

$\phi_{rad} = \phi/180 * p$

5. The setting out of principal points on the curves:



Measure the tangent length from T! Thus the CS and CE points can be found:

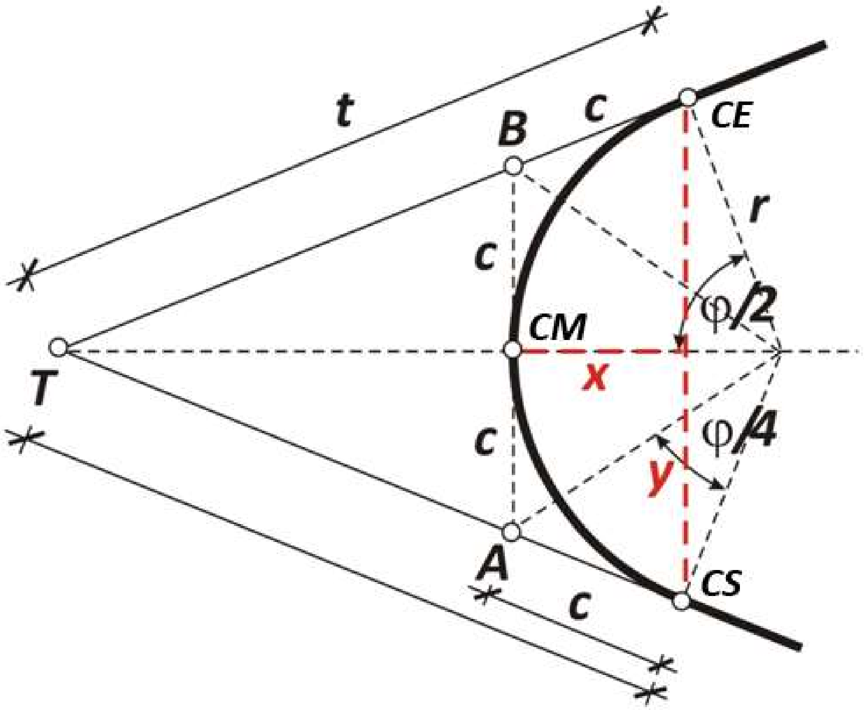
$$t = r \tan \frac{\varphi}{2}$$

With the distance ***c*** the points A and and B can be found:

$$c = r \tan \frac{\varphi}{4}$$

CM is exactly between A and B.

5. The setting out of principal points on the curves:

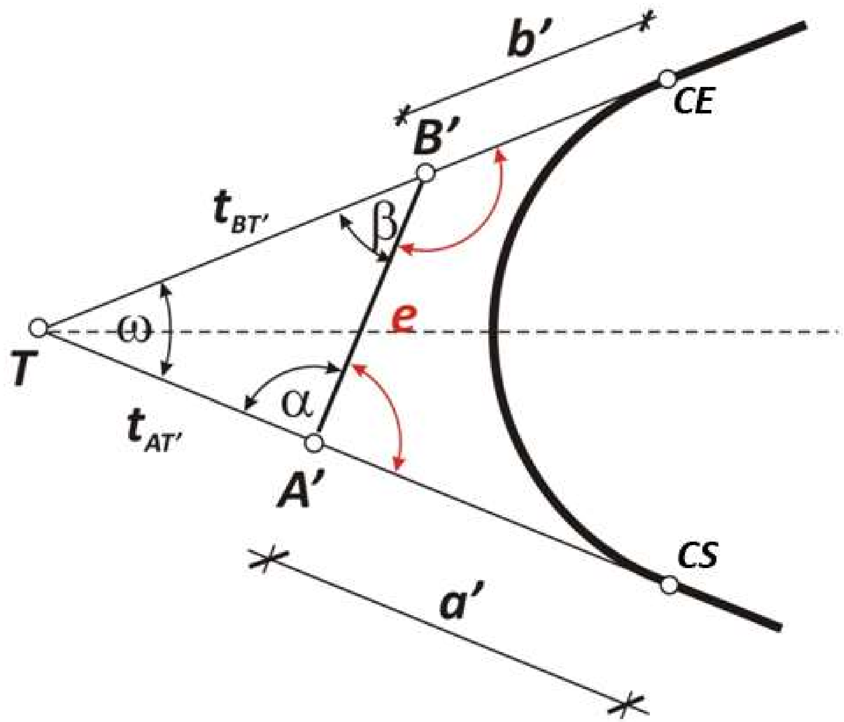


The point CM can be set out from the chord CS-CE:

$$y = r \sin \frac{\varphi}{2}$$

$$x = r - r \cos \frac{\varphi}{2}$$

5. The setting out of principal points on the curves:



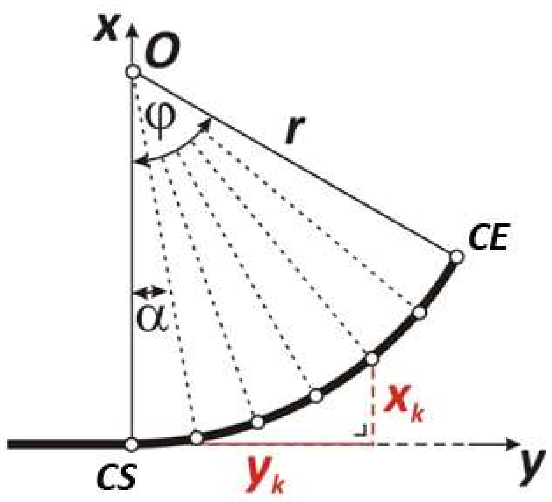
When T is not suitable for observations, then the points A′ and B′ are set out.

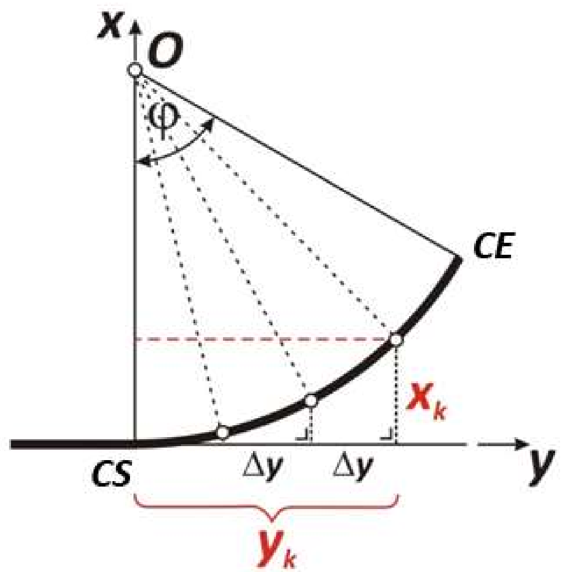
The distance $e = A'B'$ is measured,
And the complementer angle of α and β.

The distances $A'T$ and B' *are computed (sine-theorem)*

The a' and b' distances *are computed, and the points CS and CE are computed***.**

6. Setting out the detail points on the curves





Detail points with equal distance:

$$\alpha' = \frac{\varphi}{n}$$

$$y_k = r \sin k\alpha'$$

$$x_k = r - r\cos k\alpha'$$

Detail points with equal Δy diff.:

$$\Delta y = \frac{y_{IV}}{n} = \frac{r \sin \varphi}{n}$$

$$y_k = k \cdot \Delta y$$

$$x_k = r - \sqrt{r^2 - y_k^2}$$