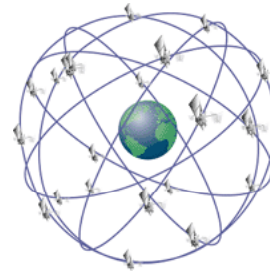
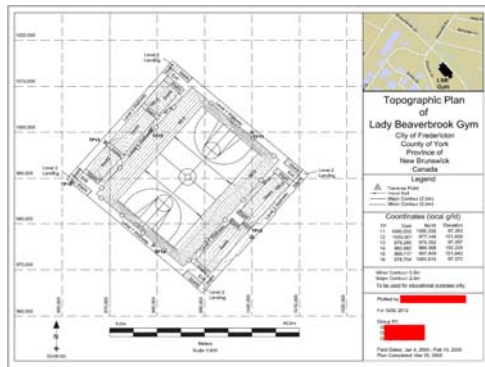


Control Surveys II

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y.ahn@unb.ca



1/00

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Traversing

◆ Pre-Computation

- Definition of azimuth
 - : horizontal angle between a line and arbitrary reference line
 - : true north – astronomic azimuth
 - : magnetic north – magnetic azimuth
 - : grid north – coordinate azimuth

- Calculate azimuth of the lines
 - : Traversing by interior angles or angles to the right
 - : Traversing by deflection angles

- Check the angle misclosure
 - : For a closed polygon –
$$\sum_{i=1}^n \beta_i - (n - 2) \times 180$$

(Dare, GGE2012 Lecture Note)

2/00

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Traversing

◆ Computation Procedures

-- Adjust angles

: angle conditions, e.g., $\sum_1^n \beta_i = (n-2) \times 180$

-- Calculate azimuth

-- Calculate and adjust latitudes and departures

: latitude conditions, e.g., $\sum_1^n \Delta X_i = \sum_1^n D_i \times \cos \alpha_i = 0$

: departure conditions, e.g., $\sum_1^n \Delta Y_i = \sum_1^n D_i \times \sin \alpha_i = 0$

-- Determine coordinates

◆ Errors

-- Permissible misclosure for angles: $\Delta = K \times \sqrt{n}$ (Dare, GGE2012 Lecture Note)

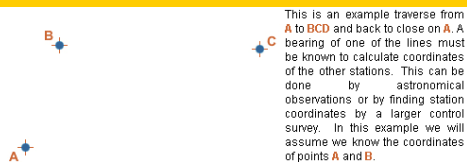
-- Traverse precision: (linear misclosure / traverse perimeter)

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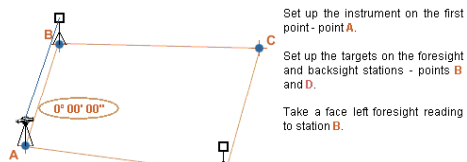
Ex. Traversing Calculation

<http://www.sli.unimelb.edu.au>



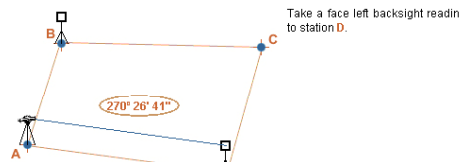
This is an example traverse from A to BCD and back to close on A. A bearing of one of the lines must be known to calculate coordinates of the other stations. This can be done by astronomical observations or by finding station coordinates by a larger control survey. In this example we will assume we know the coordinates of points A and B.

Station A	B.S.: Station D		F.S.: Station B	
	H. circle	Distance	H. circle	Distance
F.L.				
F.R.				
Check				



Set up the instrument on the first point - point A.
Set up the targets on the foresight and backsight stations - points B and D.
Take a face left foresight reading to station B.

Station A	B.S.: Station D		F.S.: Station B	
	H. circle	Distance	H. circle	Distance
F.L.			0° 00' 00"	
F.R.				
Check				



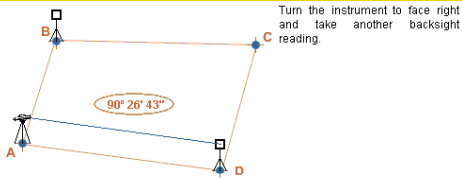
Take a face left backsight reading to station D.

Station A	B.S.: Station D		F.S.: Station B	
	H. circle	Distance	H. circle	Distance
F.L.	270° 26' 41"		0° 00' 00"	
F.R.				
Check				

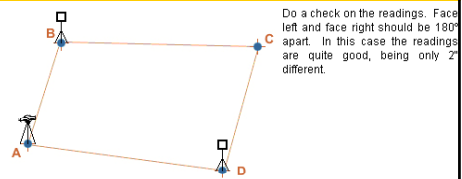
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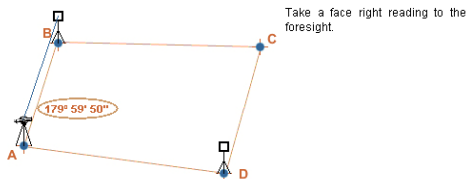
Ex. Traversing Calculation



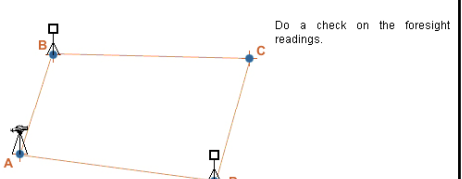
Station A	B.S.: Station D		F.S.: Station B	
	H. circle	Distance	H. circle	Distance
F.L.	270° 26' 41"		0° 00' 00"	
F.R.	90° 26' 43"			
Check	0° 00' 02"			



Station A	B.S.: Station D		F.S.: Station B	
	H. circle	Distance	H. circle	Distance
F.L.	270° 26' 41"		0° 00' 00"	
F.R.	90° 26' 43"			
Check	0° 00' 02"			



Station A	B.S.: Station D		F.S.: Station B	
	H. circle	Distance	H. circle	Distance
F.L.	270° 26' 41"		0° 00' 00"	
F.R.	90° 26' 43"		179° 59' 58"	
Check	0° 00' 02"			

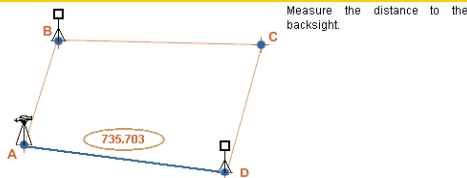


Station A	B.S.: Station D		F.S.: Station B	
	H. circle	Distance	H. circle	Distance
F.L.	270° 26' 41"		0° 00' 00"	
F.R.	90° 26' 43"		179° 59' 58"	
Check	0° 00' 02"			

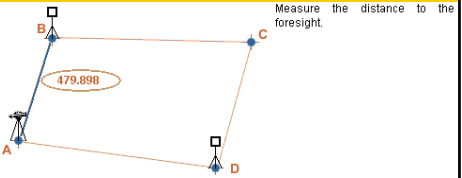
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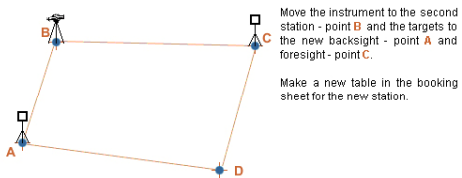
Ex. Traversing Calculation



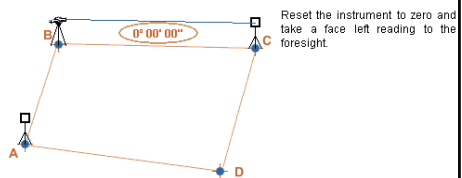
Station A	B.S.: Station D		F.S.: Station B	
	H. circle	Distance	H. circle	Distance
F.L.	270° 26' 41"	735.703	0° 00' 00"	
F.R.	90° 26' 43"		179° 59' 58"	
Check	0° 00' 02"		0° 00' 02"	



Station A	B.S.: Station D		F.S.: Station B	
	H. circle	Distance	H. circle	Distance
F.L.	270° 26' 41"	735.703	0° 00' 00"	479.898
F.R.	90° 26' 43"		179° 59' 58"	
Check	0° 00' 02"		0° 00' 02"	



Station B	B.S.: Station A		F.S.: Station C	
	H. circle	Distance	H. circle	Distance
F.L.			0° 00' 00"	
F.R.				
Check				

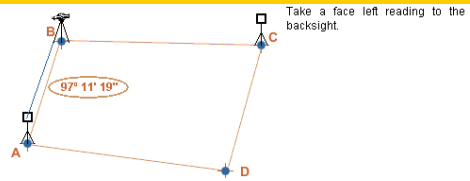


Station B	B.S.: Station A		F.S.: Station C	
	H. circle	Distance	H. circle	Distance
F.L.			0° 00' 00"	
F.R.				
Check				

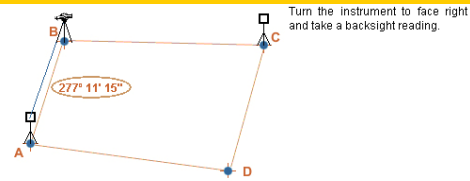
6/00

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Ex. Traversing Calculation



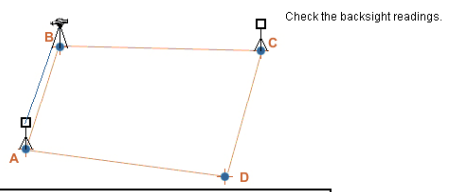
Take a face left reading to the backsight.



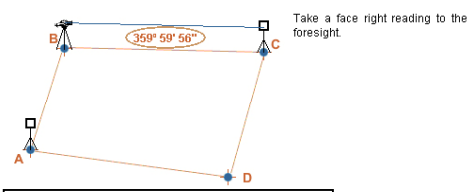
Turn the instrument to face right and take a backsight reading.

Station B		B.S. : Station A		F.S. : Station C	
	H. circle	Distance	H. circle	Distance	
F.L.	97° 11' 19"		0° 00' 00"		
F.R.	277° 11' 15"				
Check					

Station B		B.S. : Station A		F.S. : Station C	
	H. circle	Distance	H. circle	Distance	
F.L.	97° 11' 19"		0° 00' 00"		
F.R.	277° 11' 15"				
Check					



Check the backsight readings.

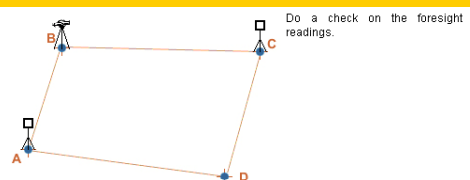


Take a face right reading to the foresight.

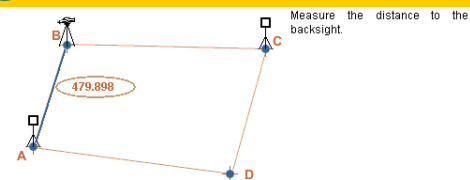
Station B		B.S. : Station A		F.S. : Station C	
	H. circle	Distance	H. circle	Distance	
F.L.	97° 11' 19"		0° 00' 00"		
F.R.	277° 11' 15"		359° 59' 56"		
Check		0° 00' 04"			

Station B		B.S. : Station A		F.S. : Station C	
	H. circle	Distance	H. circle	Distance	
F.L.	97° 11' 19"		0° 00' 00"		
F.R.	277° 11' 15"		359° 59' 56"		
Check		0° 00' 04"			

Ex. Traversing Calculation



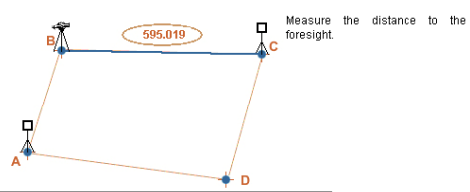
Do a check on the foresight readings.



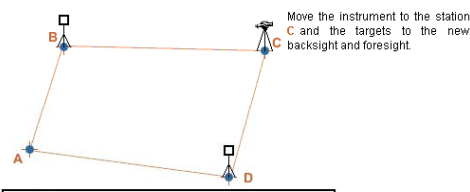
Measure the distance to the backsight.

Station B		B.S. : Station A		F.S. : Station C	
	H. circle	Distance	H. circle	Distance	
F.L.	97° 11' 19"		0° 00' 00"		
F.R.	277° 11' 15"		359° 59' 56"		
Check		0° 00' 04"		0° 00' 04"	

Station B		B.S. : Station A		F.S. : Station C	
	H. circle	Distance	H. circle	Distance	
F.L.	97° 11' 19"	479.898	0° 00' 00"		
F.R.	277° 11' 15"		359° 59' 56"		
Check		0° 00' 04"		0° 00' 04"	



Measure the distance to the foresight.



Move the instrument to the station C and the targets to the new backsight and foresight.

Station B		B.S. : Station A		F.S. : Station C	
	H. circle	Distance	H. circle	Distance	
F.L.	97° 11' 19"	479.898	0° 00' 00"	595.019	
F.R.	277° 11' 15"		359° 59' 56"		
Check		0° 00' 04"		0° 00' 04"	

Station C		B.S. : Station B		F.S. : Station D	
	H. circle	Distance	H. circle	Distance	
F.L.					
F.R.					
Check					

Ex. Traversing Calculation

Take all the readings as before.

Station C		B.S.: Station B		F.S.: Station D	
	H. circle	Distance	H. circle	Distance	Distance
F.L.	97° 11' 19"	595.019	0° 00' 00"	567.553	
F.R.	277° 11' 15"		179° 59' 58"		
Check	0° 00' 04"		0° 00' 02"		

Set up the instrument on the final point - station D, and move the targets appropriately.

Station D		B.S.: Station C		F.S.: Station A	
	H. circle	Distance	H. circle	Distance	Distance
F.L.					
F.R.					
Check					

Take all the readings as before.

Station D		B.S.: Station C		F.S.: Station A	
	H. circle	Distance	H. circle	Distance	Distance
F.L.	75° 36' 32"	567.553	0° 00' 00"	735.703	
F.R.	255° 36' 28"		180° 00' 04"		
Check	0° 00' 04"		0° 00' 04"		

The direction measurements must be reduced to internal angles.
Calculate the internal angle from the face left readings.

$$0^\circ 00' 00'' - 270^\circ 26' 41'' = -270^\circ 26' 41''$$

$$= 89^\circ 33' 19''$$

Station A		B.S.: Station D		F.S.: Station B		Angle
	H. circle	Distance	H. circle	Distance	Distance	
F.L.	270° 26' 41"	735.703	0° 00' 00"	479.898		F.L. 89° 33' 19"
F.R.	90° 26' 43"		179° 59' 58"			F.R. 89° 33' 15"
Check	0° 00' 02"		0° 00' 02"			Average 89° 33' 17"

9/00

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Ex. Traversing Calculation

Calculate the internal angle from the face right readings.

$$179^\circ 59' 58'' - 90^\circ 26' 43'' = 89^\circ 33' 15''$$

Station A		B.S.: Station D		F.S.: Station B		Angle
	H. circle	Distance	H. circle	Distance	Distance	
F.L.	270° 26' 41"	735.703	0° 00' 00"	479.898		F.L. 89° 33' 19"
F.R.	90° 26' 43"		179° 59' 58"			F.R. 89° 33' 15"
Check	0° 00' 02"		0° 00' 02"			Average 89° 33' 17"

Average the face left and face right angles to come up with a final answer for the internal angle at A.

$$\frac{(89^\circ 35' 19'' + 89^\circ 33' 15'')}{2} = 89^\circ 33' 17''$$

Station A		B.S.: Station D		F.S.: Station B		Angle
	H. circle	Distance	H. circle	Distance	Distance	
F.L.						F.L. 89° 33' 19"
F.R.						F.R. 89° 33' 15"
Check						Average 89° 33' 17"

Other angles are calculated similarly.

97° 11' 15"

89° 33' 17"

Station B		B.S.: Station A		F.S.: Station C		Angle
	H. circle	Distance	H. circle	Distance	Distance	
F.L.	97° 11' 19"	479.898	0° 00' 00"	595.019		F.L. 97° 11' 19"
F.R.	277° 11' 15"		359° 59' 58"			F.R. 97° 11' 11"
Check	0° 00' 04"		0° 00' 04"			Average 97° 11' 15"

Other angles are calculated similarly.

97° 11' 15"

97° 39' 00"

89° 33' 17"

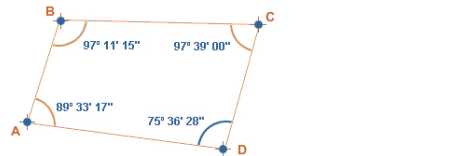
Station C		B.S.: Station B		F.S.: Station D		Angle
	H. circle	Distance	H. circle	Distance	Distance	
F.L.	97° 11' 19"	595.019	0° 00' 00"	567.553		F.L. 97° 39' 02"
F.R.	277° 11' 15"		179° 59' 58"			F.R. 97° 38' 58"
Check	0° 00' 04"		0° 00' 02"			Average 97° 39' 00"

10/00

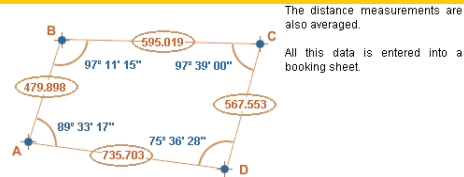
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Ex. Traversing Calculation

Other angles are calculated similarly.

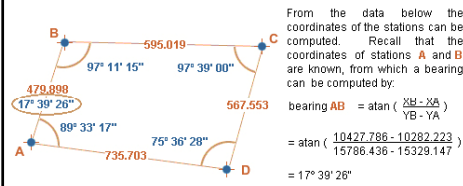


Station D		B.S. : Station C		F.S. : Station A		Angle	
	H. circle	Distance	H. circle	Distance			
F.L.	75° 36' 32"	567.553	0° 00' 00"	735.703	F.L.	75° 36' 32"	
F.R.	25° 36' 28"		180° 00' 04"		F.R.	75° 36' 24"	
Check	0° 00' 04"		0° 00' 04"		Average	75° 36' 28"	



The distance measurements are also averaged.
All this data is entered into a booking sheet.

Station	F.S.	Angle	Distance
A	B	89° 33' 17"	479.898
B	C	97° 11' 15"	595.019
C	D	97° 39' 00"	567.553
D	A	75° 36' 28"	735.703



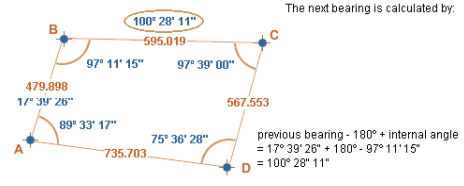
From the data below the coordinates of the stations can be computed. Recall that the coordinates of stations A and B are known, from which a bearing can be computed by:

$$\text{bearing AB} = \text{atan} \left(\frac{X_B - X_A}{Y_B - Y_A} \right)$$

$$= \text{atan} \left(\frac{10427.786 - 10282.223}{15786.436 - 15329.147} \right)$$

$$= 17^\circ 39' 26''$$

Station	F.S.	Angle	Distance	Bearing
A	B	89° 33' 17"	479.898	17° 39' 26"
B	C	97° 11' 15"	595.019	
C	D	97° 39' 00"	567.553	
D	A	75° 36' 28"	735.703	



The next bearing is calculated by:

$$\text{previous bearing} - 180^\circ + \text{internal angle}$$

$$= 17^\circ 39' 26'' + 180^\circ - 97^\circ 11' 15''$$

$$= 100^\circ 28' 11''$$

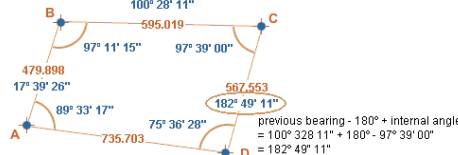
Station	F.S.	Angle	Distance	Bearing
A	B	89° 33' 17"	479.898	17° 39' 26"
B	C	97° 11' 15"	595.019	100° 28' 11"
C	D	97° 39' 00"	567.553	
D	A	75° 36' 28"	735.703	

11/00

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Ex. Traversing Calculation

The next bearing is calculated by:



$$\text{previous bearing} - 180^\circ + \text{internal angle}$$

$$= 100^\circ 28' 11'' + 180^\circ - 97^\circ 39' 00''$$

$$= 182^\circ 49' 11''$$

Station	F.S.	Angle	Distance	Bearing
A	B	89° 33' 17"	479.898	17° 39' 26"
B	C	97° 11' 15"	595.019	100° 28' 11"
C	D	97° 39' 00"	567.553	182° 49' 11"
D	A	75° 36' 28"	735.703	

Since the coordinates of A and B are known, only those of C and D have to be calculated. Coordinates are calculated as follows:

$$x (\text{next station}) = x (\text{previous station}) + \text{distance} * \sin (\text{bearing})$$

$$y (\text{next station}) = y (\text{previous station}) + \text{distance} * \cos (\text{bearing})$$

$$X_C = X_B + 595.019 * \sin (100^\circ 28' 11'')$$

$$X_C = 10427.786 + 595.109 * \sin (100^\circ 28' 11'')$$

$$X_C = 110102.899$$

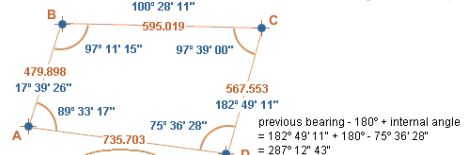
$$Y_C = Y_B + 595.019 * \cos (100^\circ 28' 11'')$$

$$Y_C = 15786.436 + 595.109 * \cos (100^\circ 28' 11'')$$

$$Y_C = 15678.312$$

Station	F.S.	Angle	Distance	Bearing	X	Y
A	B	89° 33' 17"	479.898	17° 39' 26"	10282.223	15329.147
B	C	97° 11' 15"	595.019	100° 28' 11"	10427.786	15786.436
C	D	97° 39' 00"	567.553	182° 49' 11"	11012.899	15678.312
D	A	75° 36' 28"	735.703	287° 12' 43"		

The next bearing is calculated by:



$$\text{previous bearing} - 180^\circ + \text{internal angle}$$

$$= 182^\circ 49' 11'' + 180^\circ - 75^\circ 36' 28''$$

$$= 287^\circ 12' 43''$$

Station	F.S.	Angle	Distance	Bearing
A	B	89° 33' 17"	479.898	17° 39' 26"
B	C	97° 11' 15"	595.019	100° 28' 11"
C	D	97° 39' 00"	567.553	182° 49' 11"
D	A	75° 36' 28"	735.703	287° 12' 43"

Coordinates are calculated as follows:

$$x (\text{next station}) = x (\text{previous station}) + \text{distance} * \sin (\text{bearing})$$

$$y (\text{next station}) = y (\text{previous station}) + \text{distance} * \cos (\text{bearing})$$

$$X_D = X_C + 567.552 * \sin (182^\circ 49' 11'')$$

$$X_D = 11012.899 + 567.552 * \sin (182^\circ 49' 11'')$$

$$X_D = 10984.979$$

$$Y_D = Y_C + 567.552 * \cos (182^\circ 49' 11'')$$

$$Y_D = 15678.312 + 567.552 * \cos (182^\circ 49' 11'')$$

$$Y_D = 15111.447$$

Station	F.S.	Angle	Distance	Bearing	X	Y
A	B	89° 33' 17"	479.898	17° 39' 26"	10282.223	15329.147
B	C	97° 11' 15"	595.019	100° 28' 11"	10427.786	15786.436
C	D	97° 39' 00"	567.553	182° 49' 11"	11012.899	15678.312
D	A	75° 36' 28"	735.703	287° 12' 43"	10984.979	15111.447

12/00

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Traversing

◆ Angular Misclosure - First checkup

-- Angular closure : $\sum_1^n \beta_i - (n-2) \times 180$

-- β is the internal angle, and have to eliminated the closure, e.g. by repetition etc.

◆ Linear Misclosure - Second checkup

-- Checking the linear distance component of the closed traverse :

$$\Delta \text{Easting} = D \cdot \sin \alpha, \quad \Delta \text{Northing} = D \cdot \cos \alpha,$$

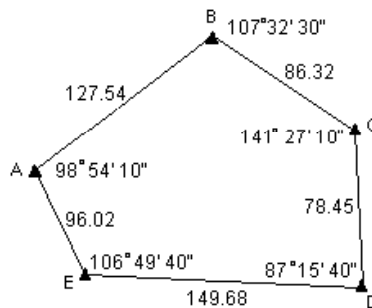
-- Check the linear misclosure. If it's acceptable, this can be adjusted out of network. If it's too large, the fieldwork must be repeated (unless you can isolate the problem)

13/00

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Traversing

◆ Ex. Misclosure



-- Angular misclosure is $539^{\circ} 59' 10''$, Ideally it must be 540° . Therefore, misclosure is $50''$ for whole, or $10''$ per angle.

-- Distribute those angle evenly throughout the traverse. After this, bearing must be calculated.

14/00

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Traversing

Line	Bearing	Distance	D Easting	D Northing	Easting	Northing
AB	0°00'00"	127.54	0.000	127.540	2000.000	5000.000
BC	72°27'20"	86.32	82.305	26.021	2000.000	5127.540
CD	111°00'00"	78.45	73.239	-28.114	2082.305	5153.561
DE	203°44'10"	149.68	-60.250	-137.018	2155.544	5125.447
EA	276°54'20"	96.02	-95.323	11.545	2095.294	4988.429
			—	—	1999.971	4999.974
			-0.029	-0.026	-0.029	-0.026

- $\Sigma\Delta E = -0.029$, and $\Sigma\Delta N = -0.026$.
- Closure Errors $= \sqrt{\epsilon_x^2 + \epsilon_y^2}$, $\sqrt{(\Sigma\Delta E)^2 + (\Sigma\Delta N)^2} = 0.039$
- Converted in a vector, expressing the misclosure in terms of a bearing and distance.
- Distance = 538.01 metres
- Conventional way: express the ratio of the total perimeter of the traverse. This case is 1:13,795 (min: 1/5000~1/7500)

$$(0.039 / 538.01 = 1 / (538.01 * 1000 / 39) = 1 / 13,795)$$

15/00

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Adjustment of Traversing

- Only valid if the traverse closes within the acceptable tolerance.

◆ Bowditch Method

- assumes that the misclosure of a traverse is proportional to the total length of the perimeter.

$$\text{Corr. to } \Delta E \text{ (or } \Delta N) = \text{Misclosure of } \Delta E \text{ (or } \Delta N) \times \frac{\text{Length Side}}{\text{Perimeter}}$$

- The corrections are then subtracted from the original ΔE to compute the adjusted ΔE

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Adjustment of Traversing

Line	Δ Easting	Δ Northing	Corr to ΔE	Corr to ΔN	Adj ΔE	Adj ΔN
AB	0.000	127.540	-0.007	-0.006	0.007	127.546
BC	82.305	26.021	-0.005	-0.004	-82.310	26.025
CD	73.239	-28.114	-0.004	-0.004	73.243	-28.110
DE	-60.250	-137.018	-0.008	-0.007	-60.242	-137.011
EA	-95.323	11.545	-0.005	-0.005	-95.318	11.550
	-0.029	-0.026	-0.029	-0.026	0.000	0.000

$$\text{Corr. to } \Delta E = (-0.029) \times \frac{127.54}{538.010} = -0.007$$

$$\text{Corr. to } \Delta N = (-0.026) \times \frac{127.54}{538.010} = -0.006$$

-- Then, adjust the new coordinates based on the adjusted ΔE or ΔN to get the final coordinate.

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Intersection

-- Conventional method of angular measurement and computation
 -- Minimum requirement: two known points. Other redundant points whose coordinate are already known can be used as a check on gross error.

- ◆ Solution of Triangle
- ◆ Bearing Method
- ◆ **Angles Method**

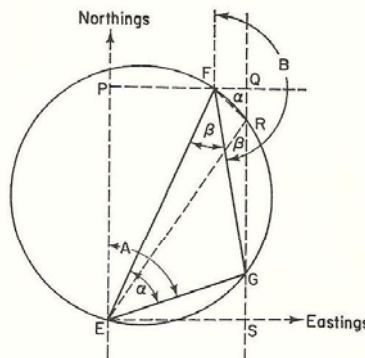


Figure 6.8

[Allan et al. (1968) "Practical field surveying and computation"]

18/00

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Intersection

◆ Angles Method

-- This method involves the coordination of G using the observed angle α and β , and the coordinates of E and F.

$$E_G - E_E = ES = RS \tan \beta$$

$$E_G - E_F = FQ = QR \tan \alpha$$

$$N_F - N_E = QS = QR + RS$$

$$= (E_G - E_F) \cot \alpha + (E_G - E_E) \cot \beta$$

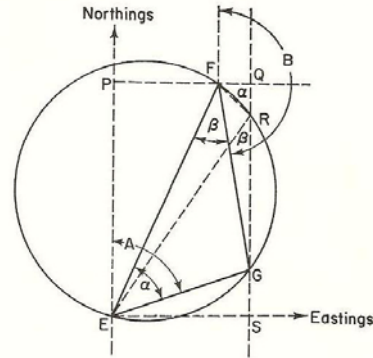


Figure 6.8

$$E_G = \frac{E_E \cot \beta + E_F \cot \alpha - N_E + N_F}{\cot \alpha + \cot \beta}, \quad N_G = \frac{N_E \cot \beta + N_F \cot \alpha - E_E - E_F}{\cot \alpha + \cot \beta}$$

19/00

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Resection

-- Conventional method of angular measurement and computation
 -- Minimum requirement: three known points. Other redundant points whose coordinate are already known can be used as a check. There are three common methods.

◆ Tienstra (or Barycentric) method

◆ Pothonot-Snellius

◆ Collin's point, or Bessel's

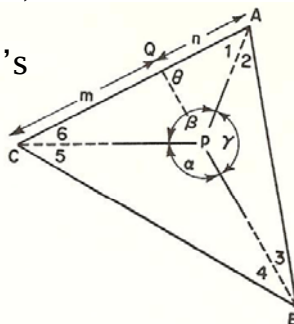


Figure 6.9

-- Known: $\alpha, \beta, \gamma, \angle A, \angle B, \angle C$

-- Unknown: P

-- Known points: A, B, C

20/00

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Resection

◆ Tienstra (or Barycentric) method

$$E_p = \frac{K_1 E_A + K_2 E_B + K_3 E_C}{K_1 + K_2 + K_3},$$

$$N_p = \frac{K_1 N_A + K_2 N_B + K_3 N_C}{K_1 + K_2 + K_3}$$

$$1/K_1 = \cot A - \cot \alpha$$

$$1/K_2 = \cot B - \cot \beta$$

$$1/K_3 = \cot C - \cot \gamma$$

$$\text{-- Check: } (E_p - E_A)K_1 + (E_p - E_B)K_2 + (E_p - E_C)K_3 = 0$$

$$(N_p - N_A)K_1 + (N_p - N_B)K_2 + (N_p - N_C)K_3 = 0$$

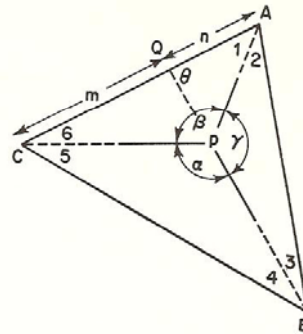


Figure 6.9