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CE 371 Surveying
TRAVERSING _2, 3

Traverse Computations

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Overview

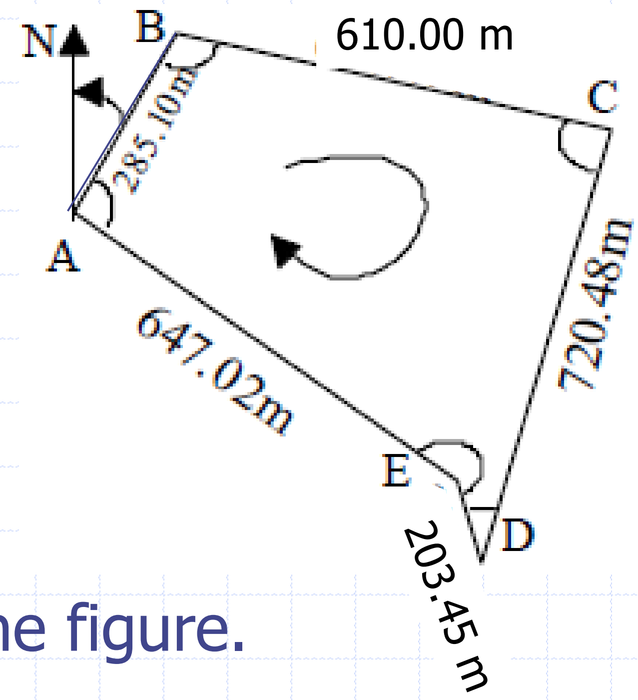
- Traverse Computations
  1. Balancing Measured Angles
  2. Computing Azimuth Angles
  3. Computing Departures and Latitudes
  4. Computing Rectangular Coordinates
  5. Traverse Precision
- Length and Azimuth From Coordinates or Latitude and Departure
- Geometrically open traverse

Traverse Computations

- The usual procedures followed in traverse computations are:
  1. Adjusting (balancing) measured angles to fixed geometric conditions.
  2. Computing azimuths (or bearings) for each traverse side.
  3. Computing departure and latitude then adjusting them for misclosure.
  4. Computing rectangular coordinates of traverse stations (corners).

Example

- A clockwise polygon traverse ABCDEA is made to determine the interior angles, lengths, and directions of all traverse sides.
- Interior angles are:
- A=100º 44.5',
- B=101º 35.0',
- C=089º 05.5',
- D=017º 12.0', and
- E=231º 24.5'.
- Azimuth of AB=26º 10.0'



- Lengths of all sides are given in the figure.
- A(1000.00,1000.00).
- Do complete traverse computations.

Balancing Measured Angles

- (Interior angles) = A+B+C+D+E= 540^{o} 1.5′
- Angle misclosure
- EC =540^{o} 1.5′ - 180^{o}(5-2)
- EC =540^{o} 1.5′ - 540^{o} =+1.5′
- Correction per angle = -1.5′/5 = -0.3′
- Add -0.3′ to each interior angle.
- Check: (Adjusted interior angles)=540^{o} 0.0′.

Table (1)Balancing interior angles

Interior angle	Measured angles	Balanced angles
A	100^{o} 44.5'	100^{o} 44.2'
B	101^{o} 35.0'	101^{o} 34.7'
C	089^{o} 05.5'	089^{o} 05.2'
D	017^{o} 12.0'	017^{o} 11.7'
E	231^{o} 24.5'	231^{o} 24.2'
Σ	540^{o} 01.5'	540^{o} 00.0'

Azimuth Computations

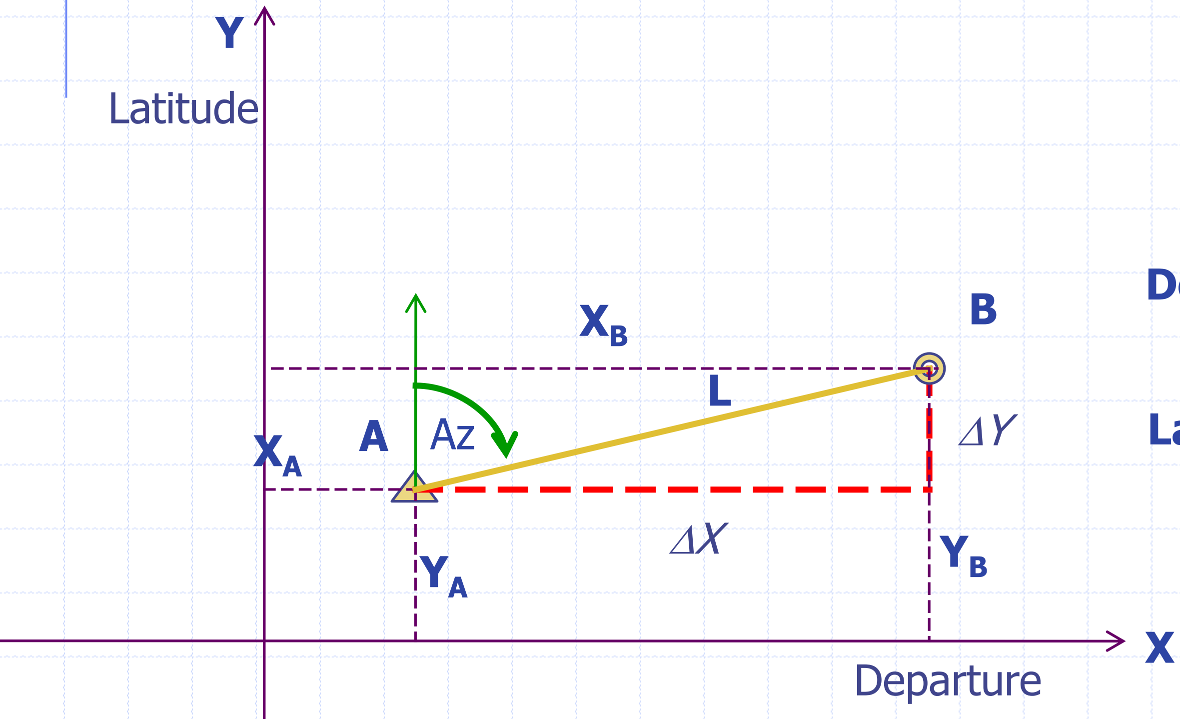
For a clockwise polygon traverse:

- Azimuth (Az) of a side = back azimuth (BAz) of the previous side - the interior angle between the two sides
- Add 360 for negative result

Line/ station	Forward Azimuth	Adjusted Left angle	Back Azimuth
AB	026° 10.0'	+ 180	206° 10.0'
B		101° 34.7'	
BC	104° 35.3'	+ 180	284° 35.3'
C		089° 05.2'	
CD	195° 30.1'		15° 30.1'
D		017° 11.7'	
DE	358° 18.4'		178° 18.4'
E		231° 24.2'	
EA	306° 54.2'		126° 54.2'
A		100° 44.2'	
AB (for check)	26° 10.0'		

Computing Departures and Latitudes

- Departure (ΔX) of a traverse side is its projection on the east-west axis.
- Latitude (ΔY) of a traverse side is its projection on the north-south axis.



Departure (ΔX) = L sin (Az)

Latitude (ΔY) = L cos (Az)

Computing Departures and Latitudes

Side	Length (m)	Azimuth	ΔX (m)	ΔY (m)	$C_{\Delta X}$	$C_{\Delta Y}$	ΔX′	ΔY′
AB	285.10	026° 10.0'	125.72	255.88	-0.010	0.018	125.710	255.898
BC	610.00	104° 35.3'	590.33	-153.64	-0.023	0.040	590.307	-153.600
CD	720.48	195° 30.1'	-192.56	-694.27	-0.026	0.047	-192.586	-694.223
DE	203.45	358° 18.4'	-6.01	203.36	-0.007	0.013	-6.017	203.373
EA	647.02	306° 54.2'	-517.39	388.51	-0.024	0.042	-517.414	388.552
Σ	2466.05		0.09	-0.16	-0.09	0.16	0.00	0.00

$$\text{Departure misclosure} = \sum_{i=1}^{n} \Delta X_i$$

$$\text{Latitude misclosure} = \sum_{i=1}^{n} \Delta Y_i$$

$$\text{Traverse Peremeter } P = \sum_{i=1}^{n} L_i$$

Bowditch method

$$\text{Correction to departure } C_{\Delta X} = -L\left(\sum_{i=1}^{n} \Delta X_i / P\right)$$

$$\text{Correction to latitude } C_{\Delta Y} = -L\left(\sum_{i=1}^{n} \Delta Y_i / P\right)$$

$$\text{Adjusted departure} = \overline{\Delta X} = \Delta X + C_{\Delta X}$$

$$\text{Adjusted latitude} = \overline{\Delta Y} = \Delta Y + C_{\Delta Y}$$

Compute Rectangular Coordinates

- Rectangular coordinates of traverse stations can be calculated from the adjusted departure and latitude of traverse sides provided the (X,Y) coordinates of at least one station is known.

$$X_B = X_A + \Delta X'_{AB}$$

$$Y_B = Y_A + \Delta Y'_{AB}$$

Station/ Line	$\Delta X'$	$\Delta Y'$	X	Y
A			1000.00	1000.00
AB	125.710	255.898		
B			1125.710	1255.898
BC	590.307	-153.600		
C			1716.017	1102.298
CD	-192.586	-694.223		
D			1523.431	408.075
DE	-6.017	203.373		
E			1517.414	611.448
EA	-517.414	388.552		
A (for check)			1000.00	1000.00

Traverse Precision

- Traverse precision is the linear misclosure ΔL of the traverse divided by traverse perimeter P. These are defined by the following two equations:

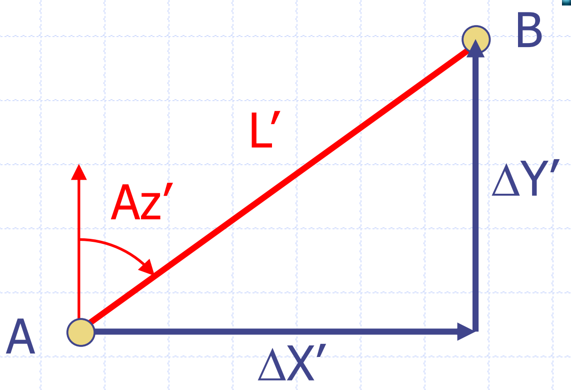
$$\text{Linear misclosure } \Delta L = \sqrt{(\Sigma\,\Delta X)^2 + (\Sigma\,\Delta Y)^2}$$

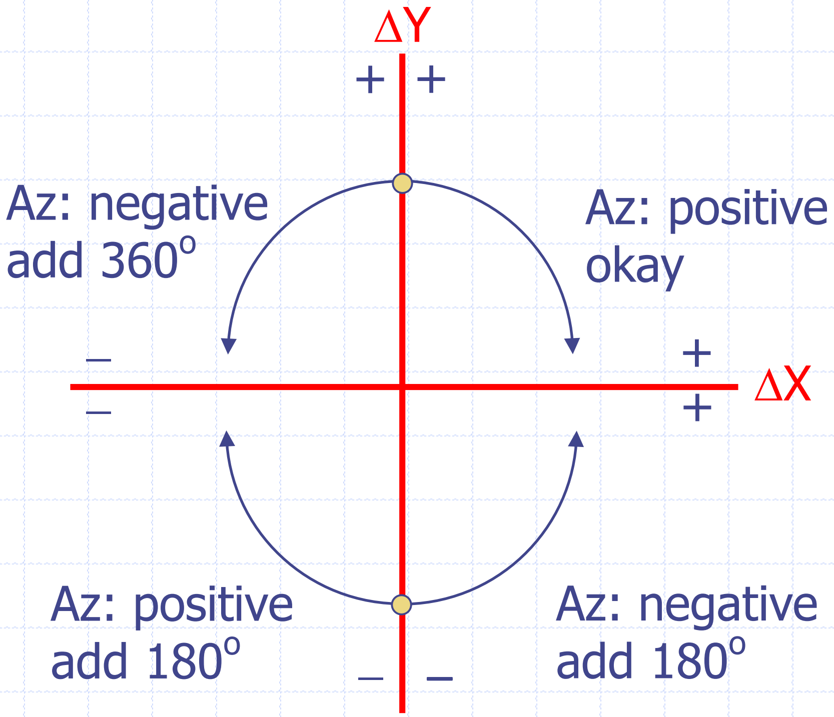
$$\text{Traverse precision} = \Delta L / P$$

- $\Delta L = \sqrt{(\Delta X)^2 + (\Delta Y)^2} = \sqrt{(0.09)^2 + (-0.16)^2} = 0.184$
- Traverse precision = 0.184/2466.05 = 7.444E-5 = 1/13433
- Accepted traverse precisions
  - construction surveys: 1/3000 to 1/10000
  - Control survey: 1/30000

Length and Azimuth From ΔX & ΔY

- $L' = \sqrt{(\Delta X')^2 + (\Delta Y')^2}$
- $L' = \sqrt{(X_B - XA)^2 + (Y_B - YA)^2}$
- $Az' = tan^{-1}\left(\frac{\Delta X\prime}{\Delta Y\prime}\right)$





Length and Azimuth From ΔX & ΔY

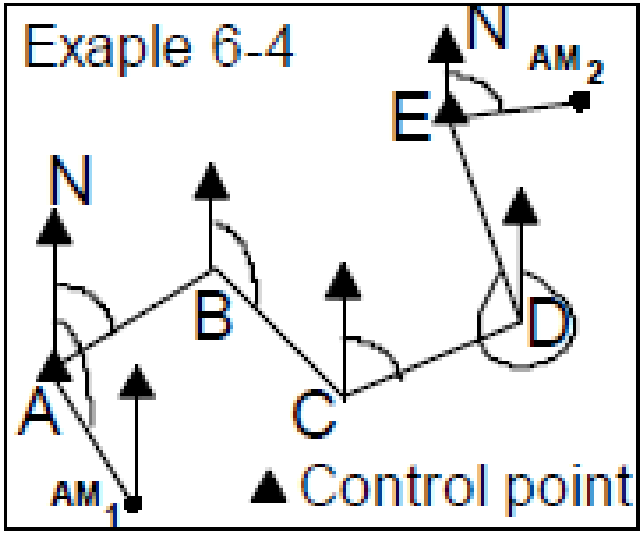
- $L' = \sqrt{(\Delta X')^2 + (\Delta Y')^2}$ $\qquad$ $Az' = tan^{-1}\left(\frac{\Delta X'}{\Delta Y'}\right)$

Station/ Line	ΔX′	ΔY′	X	Y	Adjusted Az′	Adjusted L′
A			1000.00	1000.00		
AB	125.710	255.898			026° 09.75'	285.11
B			1125.710	1255.898		
BC	590.307	-153.600			104° 35.44'	610.73
C			1716.017	1102.298		
CD	-192.586	-694.223			195° 30.28'	720.44
D			1523.431	408.075		
DE	-6.017	203.373			358° 18.32'	203.46
E			1517.414	611.448		
EA	-517.414	388.552			306° 54.28'	647.06
A (for check)			1000.00	1000.00		

Example2

- Traverse ABCDE in the figure starts at control point A and closes at control point E.
- A (2765.48, 3280.21)
- E (4797.12, 4384.41)
- $Az_{AM1\text{-}A}$ =319º 5′ 45″ and
- $Az_{E\text{-}AM2}$ =86º 20′ 47″
- The measured values:
-

side	length	angle	measured
AB	1,045.50	A	283º 50′ 10″
BC	1,007.38	B	256º 17′ 18″
CD	897.81	C	098º 12′ 41″
DE	960.36	D	103º 30′ 34″
		E	285º 24′ 59″



Complete traverse computations

Azimuth Computations

For a counterclockwise polygon traverse:

- Azimuth (Az) of a side = back azimuth (BAz) of the previous side + the interior angle between the two sides
- Add 360 for negative result

Line/ station	Forward Azimuth	Measured angle	Back Azimuth
AM_1 -A	319° 05′ 45″	- 180	139° 05′ 45″
A		283° 50′ 10″	
AB	062° 55′ 55″	+ 180	242° 55′ 55″
B		256° 17′ 18″	
BC	139° 13′ 13″		319° 13′ 13″
C		098° 12′ 41″	
CD	057° 25′ 54″		237° 25′ 54″
D		103° 30′ 34″	
DE	340° 56′ 28″		160° 56′ 28″
E		285° 24′ 59″	
E-AM_2	086° 21′ 27″		

solution

Using unadjusted azimuth

Station/ Line	Length (m)	Azimuth	ΔX (m)	ΔY (m)	Prelim. X	Prelim. Y	$C_{\Delta X}$	$C_{\Delta Y}$	X	Y
A					2765.48	3280.21			2765.48	3280.21
AB	1,045.50	062° 55′ 55″	**930.98**	**475.75**			-0.093	0.067		
B					**3696.463**	**3755.963**	-0.093	0.067	**3696.369**	**3756.030**
BC	1,007.38	139° 13′ 13″	**657.97**	**-762.81**			-0.090	0.064		
C					**4354.436**	**2993.149**	-0.183	0.131	**4354.252**	**2993.279**
CD	897.81	057° 25′ 54″	**756.63**	**483.30**			-0.080	0.057		
D					**5111.065**	**3476.444**	-0.264	0.188	**5110.802**	**3476.632**
DE	960.36	340° 56′ 28″	**-313.60**	**907.72**			-0.086	0.061		
E					**4797.469**	**4384.161**	-0.349	0.249	**4797.120**	**4384.410**
E (correct)					4797.12	4384.41				
Σ	3911.05				0.349	-0.249	-0.349	+0.249		

Azimuth Adjustment

Angle misclosure

EC =086° 21′ 27″ - 086° 20′ 47″ = 40″

Correction per Azimuth = -40″/5 = -8″

Add -8″ to each Azimuth in an Accumulative manner.

Check: (the last Azimuth = its corrected value)

A (2765.48, 3280.21)

E (4797.12, 4384.41)

ΔX=-2031.64

ΔY=-1104.2

EA = 2312.32

Az_{EA}= 241° 28′ 33″

Line/ station	Forward Azimuth	Back Azimuth
AM_1 -A	319° 05′ 45″	319° 05′ 45″
A		
AB	062° 55′ 55″	062° 55′ 47″
B		+1*(-8)
BC	139° 13′ 13″	139° 12′ 57″
C		+2*(-8)
CD	057° 25′ 54″	057° 25′ 30″
D		+3*(-8)
DE	340° 56′ 28″	340° 55′ 56″
E		+4*(-8)
E-AM_2 (for check)	086° 21′ 27″	086° 20′ 47″ +5*(-8)

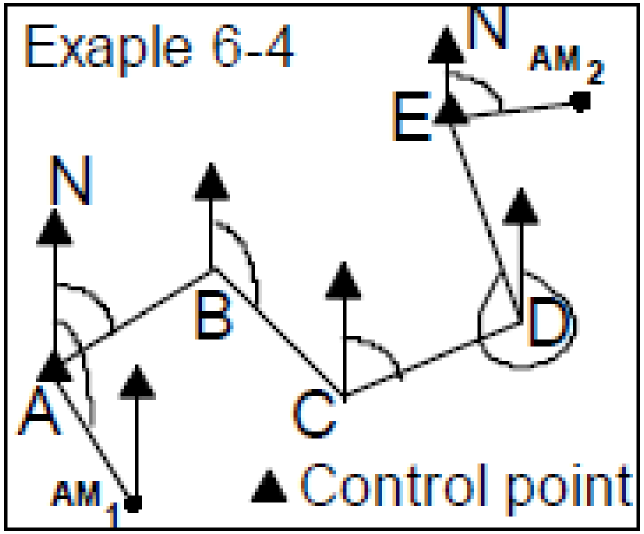
Another solution

Using adjusted azimuth

Station/ Line	Length (m)	Azimuth	ΔX (m)	ΔY (m)	Prelim. X	Prelim. Y	$C_{\Delta X}$	$C_{\Delta Y}$	X	Y
A					2765.48	3280.21			2765.48	3280.21
AB	1,045.50	062° 55′ 47″	930.96	475.79			-0.052	0.033		
B					**3696.444**	**3755.999**	-0.052	0.033	**3696.393**	**3756.032**
BC	1,007.38	139° 12′ 57″	658.03	-762.76			-0.050	0.032		
C					**4354.477**	**2993.236**	-0.101	0.064	**4354.375**	**2993.300**
CD	897.81	057° 25′ 30″	756.57	483.38			-0.044	0.028		
D					**5111.050**	**3476.620**	-0.146	0.093	**5110.904**	**3476.712**
DE	960.36	340° 55′ 56″	-313.74	907.67			-0.047	0.030		
E					**4797.313**	**4384.287**	-0.193	0.123	4797.12	4384.41
E (correct)					4797.12	4384.41				
Σ	3911.05				0.193	-0.123	-0.193	+0.123		

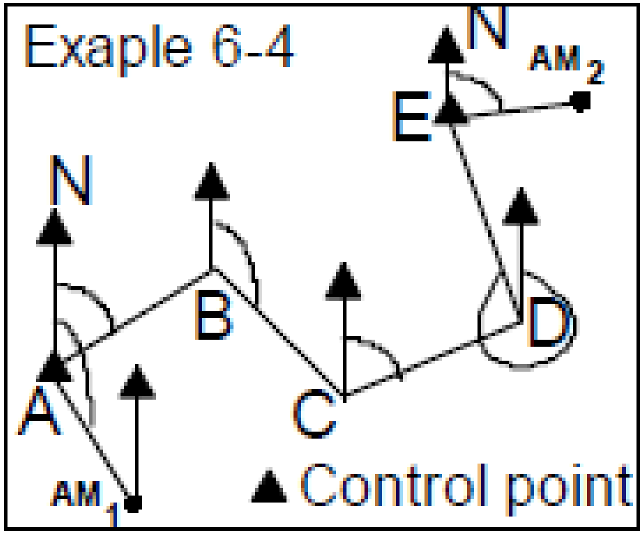
Geometrically open traverse

- it starts at control point A and ends at another control point E
- If point A can see point E, we deal with it exactly as the geometrically closed traverse.
- If not, The azimuth of a line from control point A to an azimuth mark, such as AM_1 in the figure, must be known along with the azimuth of another line from control point E to another azimuth mark AM_2.
- The computational procedures start with azimuth computations



Example

- Traverse ABCDE in the figure starts at control point A and closes at control point E.
- A (2765.48, 3280.21)
- E (4797.12, 4384.41)
- Az_{AM1-A} =319° 5′ 45″ and
- Az_{E-AM2} =86° 20′ 47″
- The measured values:



side	length	angle	measured
AB	1,045.50	A	283° 50′ 10″
BC	1,007.38	B	256° 17′ 18″
CD	897.81	C	098° 12′ 41″
DE	960.36	D	103° 30′ 34″
		E	285° 24′ 59″

Complete traverse computations

Azimuth Computations

For a counterclockwise polygon traverse:

- Azimuth (Az) of a side = back azimuth (BAz) of the previous side + the interior angle between the two sides
- Add 360 for negative result

Line/ station	Forward Azimuth	Adjusted Left angle	Back Azimuth
AM_1 -A	319° 05′ 45″	- 180	139° 05′ 45″
A		283° 50′ 10″	
AB	062° 55′ 55″	+ 180	242° 55′ 55″
B		256° 17′ 18″	
BC	139° 13′ 13″		319° 13′ 13″
C		098° 12′ 41″	
CD	057° 25′ 54″		237° 25′ 54″
D		103° 30′ 34″	
DE	340° 56′ 28″		160° 56′ 28″
E		285° 24′ 59″	
E-AM_2	086° 21′ 27″		

Azimuth Computations

Angle misclosure
EC =086° 21′ 27″ - 086° 20′ 47″ = 40″

Correction per Azimuth = -40″/5 = -8″
Add -8″ to each Azimuth in an Accumulative manner.
Check: (the last Azimuth = its corrected value)

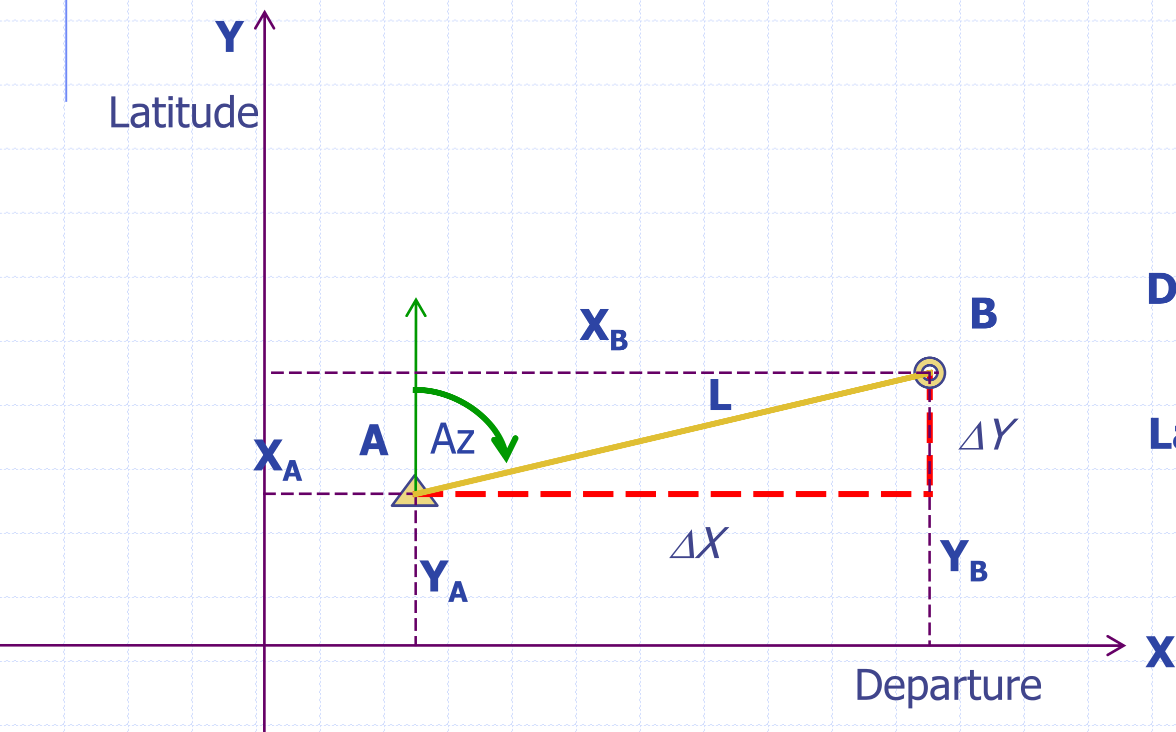
A (2765.48, 3280.21)
E (4797.12, 4384.41)

ΔX=-2031.64
ΔY=-1104.2
EA = 2312.32
Az_{EA}= 241° 28′ 33″

Line/ station	Forward Azimuth	Back Azimuth
AM_1 -A	319° 05′ 45″	319° 05′ 45″
A		
AB	062° 55′ 55″	062° 55′ 47″
B		+1*(-8)
BC	139° 13′ 13″	139° 12′ 57″
C		+2*(-8)
CD	057° 25′ 54″	057° 25′ 30″
D		+3*(-8)
DE	340° 56′ 28″	340° 55′ 56″
E		+4*(-8)
E-AM_2 (for check)	086° 21′ 27″	086° 20′ 47″ +5*(-8)

Computing Departures and Latitudes

- Departure (ΔX) of a traverse side is its projection on the east-west axis.
- Latitude (ΔY) of a traverse side is its projection on the north-south axis.



$$\alpha_{AC} = \alpha + \theta$$

Departure (ΔX) = L sin (Az)

Latitude (ΔY) = L cos (Az)

Computing Departures and Latitudes

Side	Length (m)	Azimuth	ΔX (m)	ΔY (m)	$C_{\Delta X}$	$C_{\Delta Y}$	ΔX′	ΔY′
AB	1,045.50	062° 55′ 47″	930.96	475.79	-0.048	0.032	930.91	475.82
BC	1,007.38	139° 12′ 57″	658.03	-762.76	-0.046	0.031	657.98	-762.73
CD	897.81	057° 25′ 30″	756.57	483.38	-0.042	0.028	756.53	483.41
DE	960.36	340° 55′ 56″	-313.74	907.67	-0.044	0.029	-313.78	907.70
EA (Correct)	2312.32	241° 28′ 33″	-2031.64	-1104.2			-2031.64	-1104.2
Σ	3911.05		0.18	-0.12	-0.18	+0.12	0.00	0.00

$$Departure\ misclosure = \sum_{i=1}^{n} \Delta X_i$$

$$Latitude\ misclosure = \sum_{i=1}^{n} \Delta Y_i$$

$$Traverse\ Peremeter\ P = \sum_{i=1}^{n} L_i$$

Bowditch method

$$Correction\ to\ departure\ C_{\Delta X} = -L\left(\sum_{i=1}^{n} \Delta X_i / P\right)$$

$$Correction\ to\ latitude\ C_{\Delta Y} = -L\left(\sum_{i=1}^{n} \Delta Y_i / P\right)$$

$$Adjusted\ departure = \widehat{\Delta X} = \Delta X + C_{\Delta X}$$

$$Adjusted\ latitude = \widehat{\Delta Y} = \Delta Y + C_{\Delta Y}$$

Compute Rectangular Coordinates

- Rectangular coordinates of traverse stations can be calculated from the adjusted departure and latitude of traverse sides provided the (X,Y) coordinates of at least one station is known.

$$X_B = X_A + \Delta X'_{AB}$$

$$Y_B = Y_A + \Delta Y'_{AB}$$

Station/ Line	ΔX′	ΔY′	X	Y
A			2765.48	3280.21
AB	930.91	475.82		
B			3696.39	3756.03
BC	657.98	-762.73		
C			4354.37	2993.30
CD	756.53	483.41		
D			5110.90	3476.71
DE	-313.78	907.70		
E (for check)			4797.12	4384.41

Traverse Precision

- Traverse precision is the linear misclosure ΔL of the traverse divided by traverse perimeter P. These are defined by the following two equations:

$$\text{Linear misclosure } \Delta L = \sqrt{(\Sigma\,\Delta X)^2 + (\Sigma\,\Delta Y)^2}$$

$$\text{Traverse precision} = \Delta L / P$$

- $\Delta L = \sqrt{(\Delta X)^2 + (\Delta Y)^2} = \sqrt{(0.18)^2 + (-0.12)^2} = 0.216$
- Traverse precision = 0.216/ 3911.05 = 5.531E-5 = 1/18078
- Accepted traverse precisions
  - construction surveys: 1/3000 to 1/10000
  - Control survey: 1/30000

Length and Azimuth From ΔX & ΔY

- $L' = \sqrt{(\Delta X')^2 + (\Delta Y')^2}$ $\qquad Az' = tan^{-1}\left(\frac{\Delta X'}{\Delta Y'}\right)$

Station/ Line	ΔX'	ΔY'	X	Y	Adjusted Az'	Adjusted L'
A			2765.48	3280.21		
AB	930.91	475.82			062° 55' 37"	1045.47
B			3696.39	3756.03		
BC	657.98	-762.73			139° 13' 01"	1,007.32
C			4354.37	2993.30		
CD	756.53	483.41			057° 25' 20"	897.79
D			5110.90	3476.71		
DE	-313.78	907.70			340° 55' 49"	960.40
E			4797.12	4384.41		

Summary

- Traverse Computations
  1. Balancing Measured Angles
  2. Computing Azimuth Angles
  3. Computing Departures and Latitudes
  4. Computing Rectangular Coordinates
  5. Traverse Precision
- Length and Azimuth From Coordinates or Latitude and Departure
- Geometrically open traverse