American University of Beirut

Introduction to Surveying

CIVE 360-361

Lecture Notes

12

CIVE 360-361 Surveying:

Lecture 1: Monday, June 18, 2012

Purpose:

a) Determine horizontal position of points
b) Determine vertical position of points
c) Determine the length of lines
d) Determine the directions of lines
e) Determine the position of lines
f) Determine areas of tracks
g) Determine configuration of the earth
h) Planning of measurement of construction works
i) Production of maps, charts and reports
j) Positioning and monitoring physical features and engineering works

Stages:

a) Decision making
b) Data acquisition
c) Data processing
d) Data representation
e) Stake out

Types:

a) Property surveys (Location of the length of the line of the area)
b) Control surveys
c) Construction surveys (Location of construction points)
d) Topographic surveys
e) Hydrographic surveys
f) Photogrammetric surveys
g) Route surveying
h) AS-built surveys

CIVE 360-361 Surveying:

Lecture 2: Wednesday, June 20, 2012

Classification of Surveys:

I. Plane Surveying:
   - It is used when we neglect the ellipsoidal shape of earth.
   - All elevations are referenced to the mean level of the sea.
   - It is used when very high accuracy isn't needed.

II. Geodetic Surveying:
   - It is used when we consider the ellipsoidal shape of the earth.
   - It is used for very precise and large surveys.

Instruments used in surveying:

I. Tape (Chain):
   - A tape is a graduated flexible ribbon made of various types of material.
   - It is used for measuring distances.

II. Chaining Pin:
   - A Chain pin is steel composed.
   - It is used for temporarily marking points on the ground.

III. Plumb bob:
   - It is a pointed metallic weight that hangs by a string.
   - It is used for the vertical projection of a point on one level to another level.

IV. Engineering level:
   - It is a telescope that rotates about a vertical axis.
   - It has a spilled leveling tube attached to it.
   - By using it we will be able to find the difference in elevation between points.
   - It is mounted on a pole and is used it with a leveling rod.

V. Leveling Rod:
   - It is a graduated rod usually it is around 4 to 5 meters in length.
   - It is graduated in cm and made of wood and aluminum.
   - We use it in conjunction with the engineering level to determine the difference in the elevation of two points.

VI. Rage Pole:
   - It is a steel or wooden or aluminum rod.
   - It is painted in bands of white and red.
   - It is used as a sighting rod in angular measurement and distance measurement.

VII. Theodolite:
   - It is a telescope that rotates around a vertical axis.

- It is used ideally for measuring horizontal and vertical angles and sometimes for distances.

VIII. Total station:
- A very modern theodolite.
- It combines in it an electronic theodolite where it measures the angles electronically.
- It has an EDM (electronic distance measurement) which measures the distances electronically by a press of a button.
- It can measure distances.
- It has a microprocessor that will do all the calculation for us.

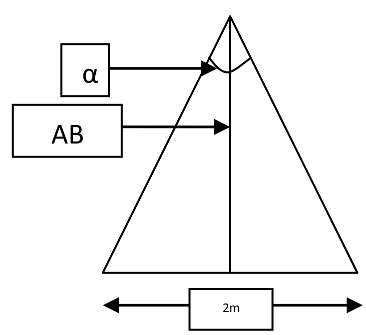
Distance Measurements in plane surveying → horizontal distance

I. Pacing:
- Walking and counting the steps.
- Accuracy: 1/50 →1/100

II. Odometer: It is when we can convert the number of revolutions of the wheel to a distance.
- One disadvantage it only reads inclined distances.
- Accuracy: 1/200

III. Tachometry (Stadia):
- When we measure distances using a theodolite.
- Accuracy: 1/500

IV. Sub tense Bar:
- $\tan \alpha = \frac{1}{AB}$
- When we know α we directly get AB
- Accuracy 1/3000

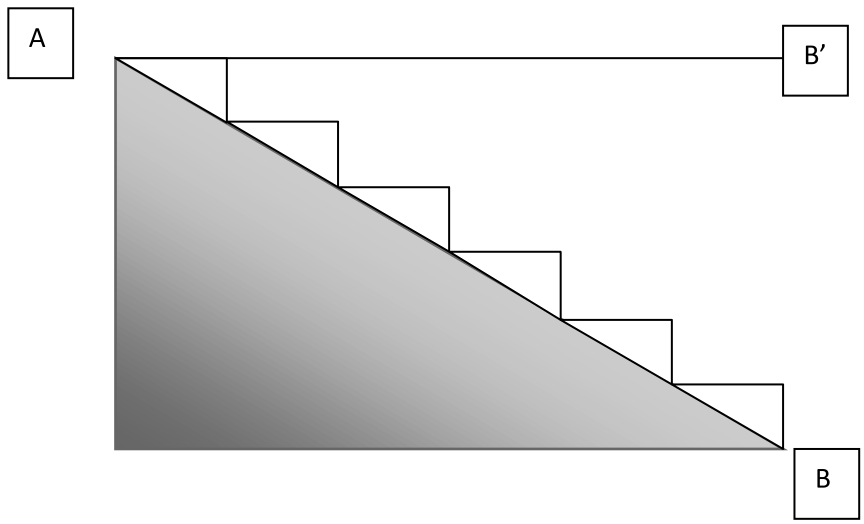


V. Taping/ Chaining:
- When we use chain/tape to measure the distances.
- Accuracy increases.

VI. EDM (electronic distance measurement):
- Most advanced.
- Most accurate.
- We use this device to send signals to reflector prism and consider temperature and pressure.
- It determines time of signal to go to prism and comes back.

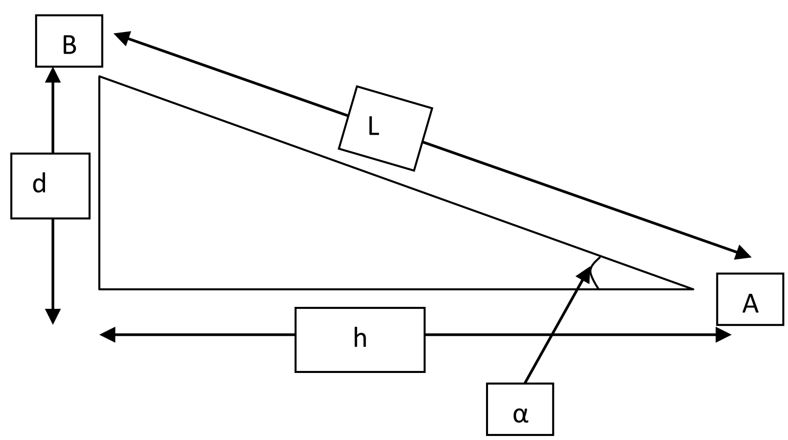
Example:

- We do chaining with a steep slope to measure the horizontal distance.
- We do it in steps in small distances line stairs to get AB’.
- This Method is called Breaking Tape



Slope Measurement:

- Measure L and α
- Get $h = L\cos\alpha$
- Or $h = \sqrt{L^2 - d^2}$



Example:

- L=290.43 ft
- Elevation of A = 865.2 ft
- Elevation of B = 981.4 ft

Then h=266.171 ft

CIVE 360-361 Surveying:

Lecture 3: Monday, June 25, 2012

Kinds of Errors in Taping:

a) Instrumental Errors: errors that come from the instruments itself.
b) Natural errors: errors that come from temperature variation or high wind.
c) Personal Errors: errors that come from the incorrect reading of the human.

Sources of Errors in Taping:

a) Incorrect tape length is an instrumental error. The formula to correct it is:

$$C_l = \frac{l - l'}{l'} \times L$$

Where:
C_L is the correction for length
l is the actual tape length
l' is the nominal tape length
$\bar{l}$ is the corrected distance
L is the measured distance

$$\bar{l} = L + C_l$$

If the tape is shorter than read➔ Negative C_l

If the tape is longer than read➔ Positive C_l

Example:

100 ft steel tape is 100.02ft. So that the nominal length l' is equal to 100ft and the actual length l is equal to 100.02 ft. a distance measured by this tape was L equal to 565.25 ft. what is the corrected distance ?

$\bar{l} = L + C_l$

$C_l = \frac{l - l'}{l'} \times \bar{l}$

$$C_l = \frac{100.02 - 100.00}{100.00} \times 565.75 = 0.11\ ft$$

So $\bar{l}$ is equal to 565.363 ft

b) Temperature other than standard (Natural error): usually standardized at 68°C. The distance of the tape decreases if cooled and increases if heated depending on the coefficient of expansion.

$$C_t = K(T_1 - T) \times L$$

Where:
C_t is the correction temperature.
K is the coefficient of thermal expansion.
T_1 is the temperature at time of measurement.
T is the standard temperature.
L is the measured distance.
$\bar{l}$ is the corrected distance

$$\bar{l} = L + C_t$$

If $T_1 > T$ then we have elongation type and therefore a positive C_t

If $T_1 < T$ then we have contraction type and therefore a negative C_t

Example:

A steel tape was used at 30.5°F and it was used to measure a distance. The measured distance L is equal to 872.54 ft. then the temperature was standardized to 68°F. What is the corrected length knowing that "K" for steal is $6.45*10^{-6}$ /unit length /°F and $1.16*10^{-5}$ /unit length /°C.

C_t= $6.45*10^{-6}$ (30.5-68)*872.54 =-0.211ft

So $\bar{l}$ is equal to 872.54-0.21 = 872.329ft

c) Inconsistent Pull (Personal Error):

$$C_p = (P_1 - P) \times \frac{L}{AE}$$

Where:
C_p is the correction for pull
P_1 is the pull applied to the tape
P is the standard pull (pull standardization)
A is the cross sectional area of the tape
E is the modulus of elasticity of the tape
$\bar{l}$ is the corrected distance

$$\bar{l} = L + C_p$$

Example:

A steel tape that is 100in long undergoes a pull of 20 lb (where the standard pull is 12lb). And the length of the tape is 100 ft and the area is 0.005in^2 and L is equal to 686.79 in. Calculate the correct Distance

$$C_p = (P_1 - P) \times \frac{L}{AE} = (20 - 12) * \frac{686.79}{0.005 * 29 * 10^6} = 0.03789in$$

$$\bar{l} = L + C_p = 686.79 + 0.038 = 686.82789in$$

d) Sag (Natural Error)

$$C_s = -\frac{w^2 \times L_s^3}{24 \times P_1^2}$$

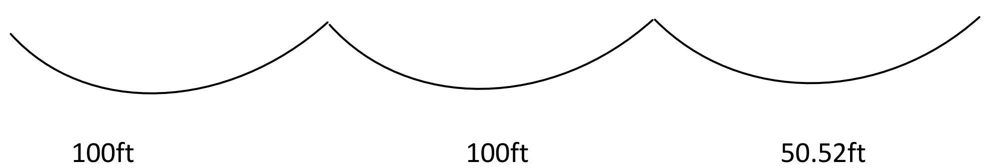
Where:
C_s is the correction for the sag
w is the unit weight of the tape
L_s is the unsupported length of the tape
P_1 is the applied pull

C_s is always negative because the tape is shorter when it sags

$$\bar{l} = L + \sum C_s$$

Example:

A steel tape is 100 ft long. Its weight is W= 1.5 lb and it is used in a way that it is supported at its ends only. It is used to measure a line in 3 segments using a 12 lb pull and the distance recorded is 250.52 ft. what is the corrected length?



We have $w = \frac{Weight}{length} = 0.015$

We have C_{s1}=C_{s2} = $-\frac{0.015^2 \times 3}{24 \times 12^2} = -0.065ft$

Similarly C_{s3}=$-0.008ft$

So

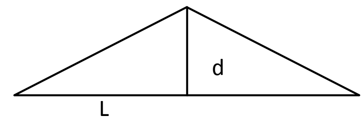
$$\bar{l} = L + \sum C_s = 250.52 + [2(-0.065) - 0.008] = 250.382ft$$

CIVE 360-361 Surveying:

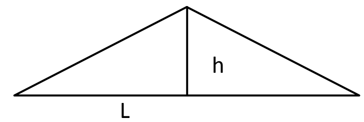
Lecture 4: Wednesday, June 27, 2012

Poor Alignment:

1. Correction for alignment error ➔ $C_a = \frac{-d^2}{2L}$

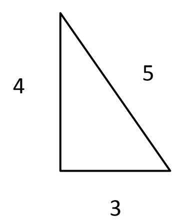


2. If the tape wasn't horizontal ➔ $C_g = \frac{-h^2}{2L}$

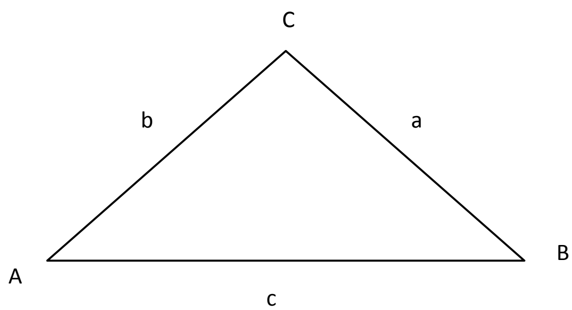


Field Operation using a tape:

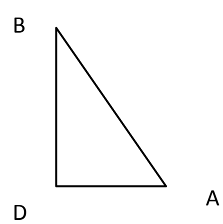
1. Laying a right angle: ($3^2+4^2=5^2$)



2. Measuring an angel: 'Using a chord method'➔ $\cos A = \frac{b^2+c^2-a^2}{2bc}$



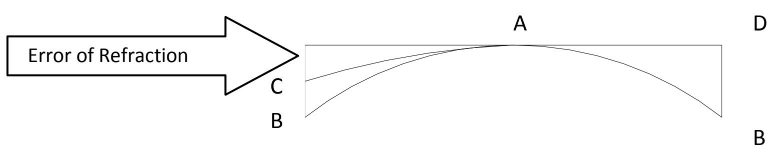
3. Measuring an angle: 'Using the tangent method' ➔$\tan A = \frac{BD}{AD}$



Definitions:

1. Leveling: it is the process of finding the elevation of points or the difference in the elevation between two points.
2. Vertical line: a line that follows the direction of gravity.
3. Level Surface: a surface where every point found on it is perpendicular to the vertical line or plumb bob.
4. Datum: a level surface to which the elevations are referred (usually MSL= Mean Sea Level).
5. Elevations: is the vertical distance from a reference datum to a point.
6. Bench Mark (BM). It is a fixed object having a marked point whose elevation above a certain datum is known.

Curvature & Refraction:



Error of curvature is C_m= $0.0785K^2$ where K is the distance of AB in kilometers (Km) due to the curvature of the earth.

Error of refraction is R_m=$0.011K^2$ where K is the Distance AC.

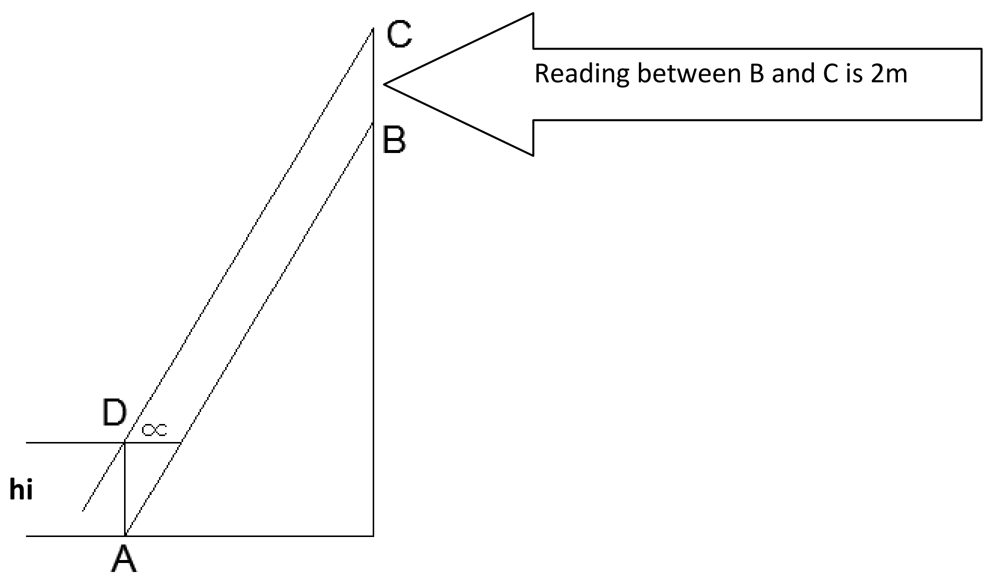
COMBINE — The combined result of curvature and refraction is h_m=$0.0675K^2$ ($0.0785\ K^2$-$0.11\ K^2$)

Methods to determine Elevation Difference:

1. Barometric leveling:
- It is referred by atmospheric pressure.
- Should be done in a stable weather
- 1ml of Hg = 12m of difference in elevation

2. Indirect leveling or trigonometric leveling:
- DC=150m
- Elevation of A = 100m
- Hi=1.5m
- Elevation of B
- $\propto = 5°$

Elevation of B = $Elevation\ of\ A + hi + DC \sin \propto\ - BC$



Elevation B= 100+1.5+150sin (5°)-2=112.57

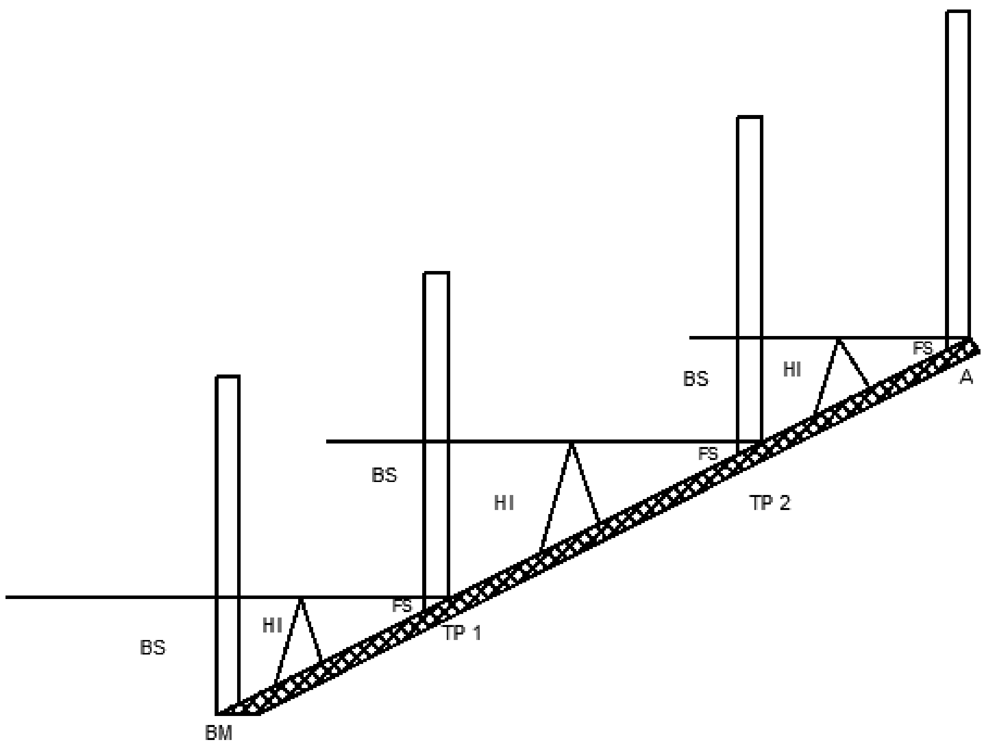
CIVE 360-361 Surveying:

Lecture 5: Monday, July 2, 2012

Methods to determine Elevation Difference (Continued):

3. Differential Leveling (Direct Leveling):
   FS (Foresight): From a point of unknown elevation
   BS (Back Sight): From a point of known elevation
   TP: Turning Points where we turn the leveling rod on.
   HI: Height of Instrument

$$\sum BS - FS = Difference\ in\ Elevation$$



Example: Elevation of Bench Mark is 100m From MSL What is the elevation of A?

Point	Back Sight	Height of Instrument	Foresight	Elevation
BM	3.512			100
		103.512		
			0.693	
TP1	3.098			102.819
		105.917		
			0.917	
TP2	2.934			105
		107.934		
			1.00	
A				106.934

Formula: HI= Elevation of (BM) + BS

Elevation TP1 = HI – FS

Therefore:

$$\sum BS = 9.544$$

$$\sum FS = 2.61$$

Then

$$\sum BS - \sum FS = 6.934$$

So to check our work,

$$\sum BS - \sum FS = Elevation(BM) - \ Elevation \ = (A) = 106.934 - 100 = 6.934 \ \equiv TRUE$$

TRICK: To eliminate the errors of curvature and refraction, we place the levels midway between FS&BS.

For simple construction surveys, the allowable misclosure is equal to 0.02$\sqrt{n}$ in feet. Where n is the number of setups we have.

Example:

Point	Back Sight	Height of instrument	Foresight	Elevation
BM	3.52			101.2
		104.72		
			1.21	
TP 1	3.09			103.51
		106.6		
			2.02	
TP2	0.91			104.58
		105.49		
			3.54	
TP 3	1.25			101.95
		103.2		
			1.99	
BM				101.21

We should start and end at the bench mark (BM)

We started with 101.2 at the Bench mark and ended up with 101.21 at the same bench mark. → there is an error in the loop closure. To correct this error, we compare it with the allowable

Then, $Misclosure = 0.02\sqrt{n}\,; but\ n = 4\ \ggg\ Misclosure = 0.02\sqrt{4} = 0.04\ ft$

1m=3.28ft → 0.04ft=0.0122m

Then our loop misclosure is 101.21-101.2 = 0.01m

Compare 0.01<0.0122 since our misclosure is lower than the allowable then it is acceptable.

If our misclosure is more than the allowable then we have to repeat our work

To correct, we use the formula: $\frac{My\ misclosure}{2} = \frac{0.01}{4} = 0.0025$

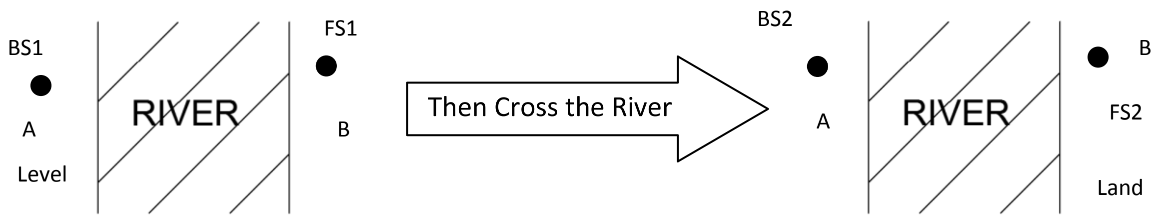
Point	Back Sight	Height of instrument	Foresight	Elevation	
BM	3.52			101.2	
		104.178			
			1.21		0.0025
TP 1	3.09			103.508	
		106.595			
			2.02		0.005
TP2	0.91			104.575	
		105.484			
			3.54		0.0075
TP 3	1.25			101.942	
		103.19			
			1.99		0.01
BM				101.2	

We correct in reverse sense of error always here; error is 0.0025 so we subtract it

Special Procedures for Leveling:

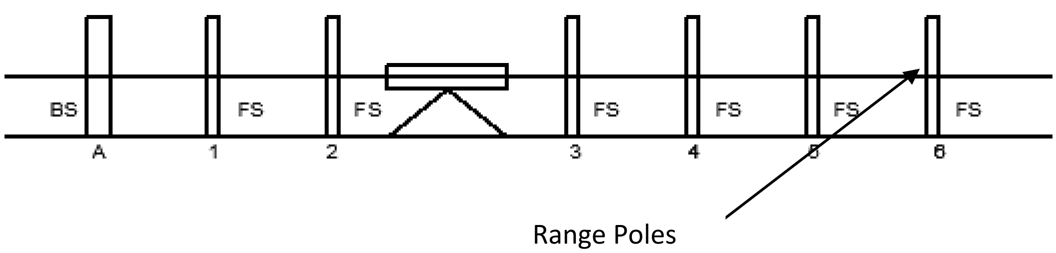
1) Reciprocal leveling:

When we have obstacles like rivers in the middle of two points, we can't put the level in the middle so we use this method. Elevation of A is known



Then use average elevation of point B

2) Profile Leveling: use in highway engineering for long distances



Point	Back Sight	Height of instrument	Foresight	Elevation
A	2.5			100
		102.5		
			2	
1				100.5
			1.5	
2				101
			2	
3				100.5
			2.25	
4				100.25
			2.5	
5				100
			2	
6				100.5

Errors in Leveling:

Types of errors:

a) Natural
b) Instrumental
c) Personal

- Example of a natural error in differential leveling is temperature that might affect the leveling rod and curvature/refraction. Also the leveling rod might sink if placed in soft soil.
- Example of instrumental error in leveling: problem with engineering level
- Example of personal error: read wrongly the numbers. The engineering level might be a bit inclined.

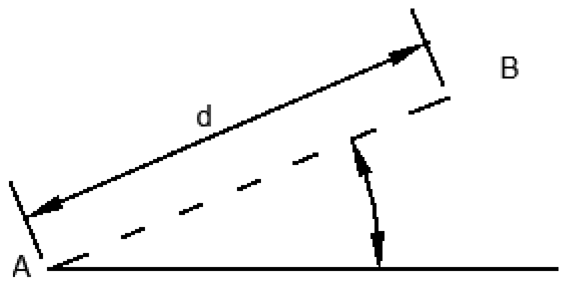
CIVE 360-361 Surveying:

Lecture 6: Wednesday, July 4, 2012

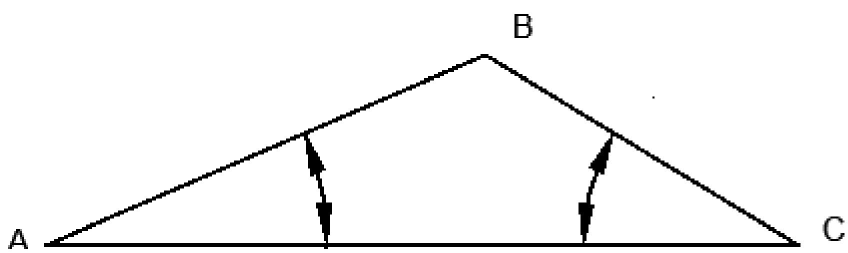
Angles and Directions:

To fix a location of a point we need:

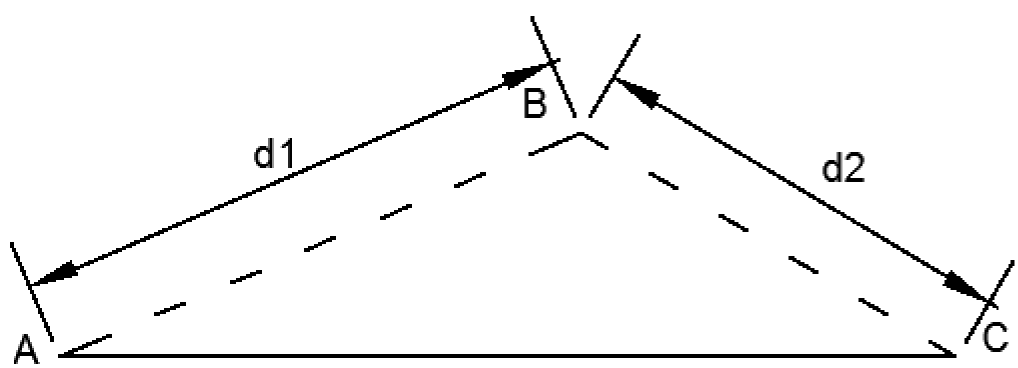
1- Direction and distance from a known point



2- Directions from two known points



3- Distances from 2 known points

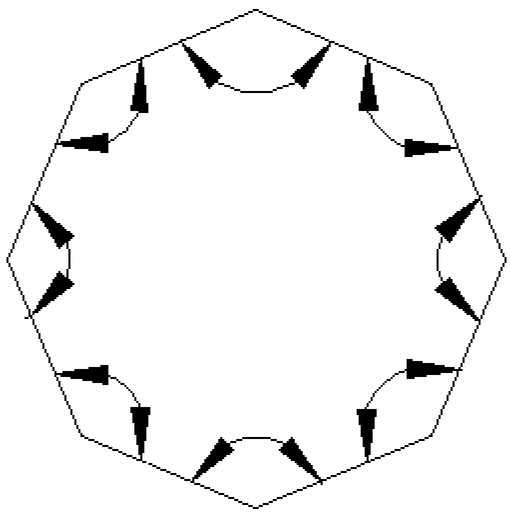


Requirements (elements) for determination of angles and the directions we need:

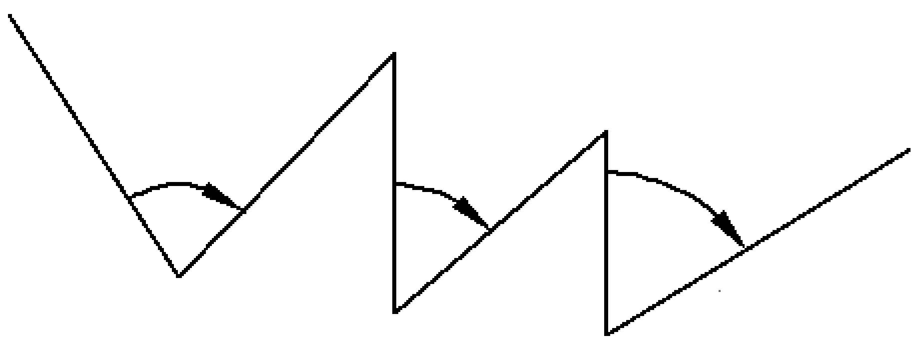
1- Reference line
2- Direction of rotation
3- Angular value

Kinds of horizontal angles:

1- Interior angles: when you have a polygon we measure the interior angles.
   Theoretical sum of angles = (n-2)*180 where n is the number of angles

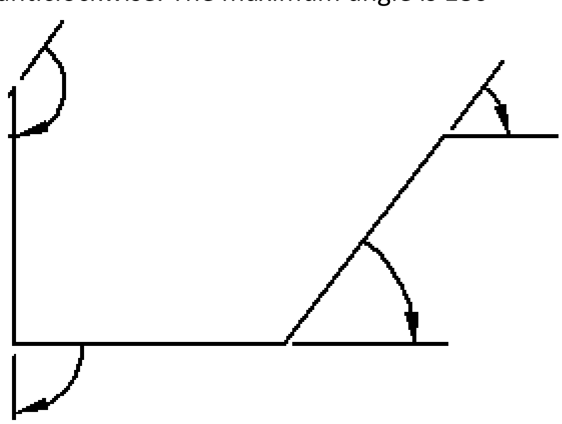


2- Angles to the right: when you measure the angles in a clockwise direction



   Also including the obtuse right angles

3- Deflection angles: usually used in highway engineering. We can measure clockwise or even anticlockwise. The maximum angle is 180°



Reference Lines:

1- Meridian: can be the geographic (true) meridian. Most common meridian is the true meridian North-South.
2- Magnetic Meridian: it is less common. It follows the direction of the magnetic poles of the earth which deviate slightly from the poles of the earth.
3- Assumed meridian: for a survey we wish to use one meridian that we choose to apply on it only.

How do we define the direction of designated lines?

To determine it we either use:

1- Bearing
   a. The bearing of a line is the acute angle between the reference meridian and the line less than 90°.
   b. It is designated by numerical and alphabetical values.
   c. True bearing is measured from the geographical meridian.
   d. Magnetic bearing is measured from the magnetic meridian.
   e. Back Bearing is the reverse of Bearing

B_{AB}=N60°E

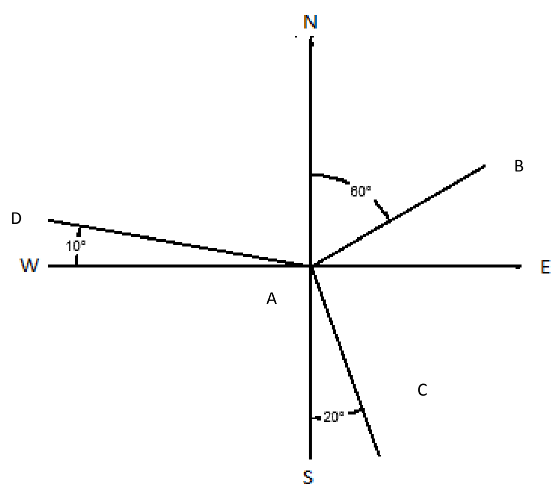
B_{AC}=S20°E

B_{AD}=N80°W

BB_{AB}=S60°W

BB_{AC}=N20°W

BB_{AD}=S80°E



2- Azimuth:

a. It is the clockwise angle measured from the reference meridian which we usually take as the north.

b. It could go up all the way to 360°

c. BAZ=AZ±180°

AZ_{AB}=210°

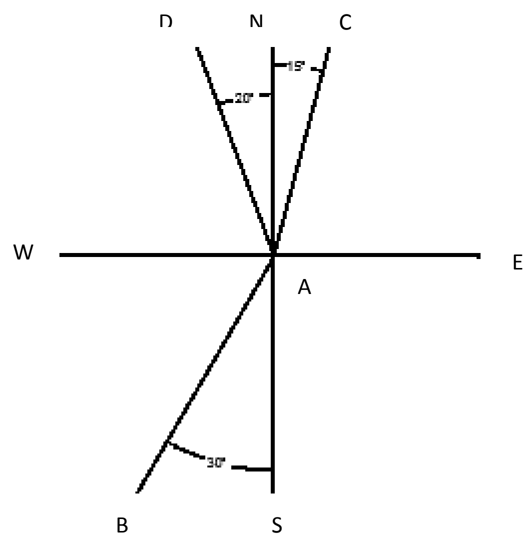
AZ_{AC}=15°

AZ_{AD}=340°

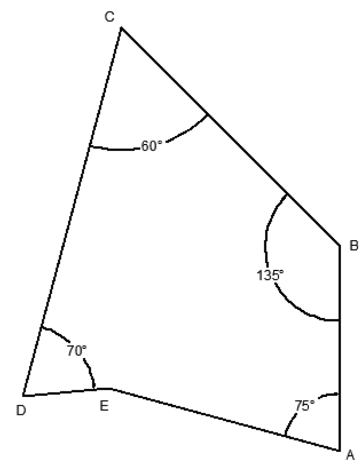
BAZ_{AB}=AZ_{BA}=30°

BAZ_{AC}=AZ_{CA}=195°

BAZ_{AD}=AZ_{DA}=160°



BEARING	AZIMUTH
Vary between 0° & 90°	Vary between 0° & 360°
Require 2 letters and 1 numerical value	Require only numerical value
Maybe true, magnetic and assumed	Maybe true, magnetic and assumed
Measures clockwise and anticlockwise	Measures only clockwise
Measures from north and south	Usually measures from north



<u>Example:</u>

Given AZAB = 0°

Point C is west of B

Interior angles of polygon ABCDE Such that:

A=75°

B=135°

C=60°

D=70°

E=200°

Find the Azimuth and Bearing of all it's sides

<u>AZIMUTH:</u>

BAZ_{AB}=180°

AZ_{BC}=180+135=315°

AZ_{CB}=135°

AZ_{CD}=160+135=195°

AZ_{DC}=15°

AZ_{DE}=15+70=85°

AZ_{ED}=85+80=265°

AZ_{EA}=265-200-360=105°

AZ_{AE}=285°

CHECK: AZ_{AB}=285+75=360°=0° = INITIAL AZIMUTH

<u>BEARING:</u>

B_{AB}=0= B_{BA}

B_{BC}=N45°W

B_{CB}=S45°E

B_{CD}=S15°W

B_{DC}=N15°E

B_{DE}=N85°E

B_{ED}=S85°W

B_{EA}=S75°E

B_{AE}=N75°W

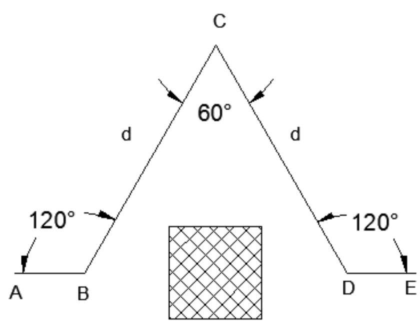
B_{AB}=0°

CIVE 360-361 Surveying:

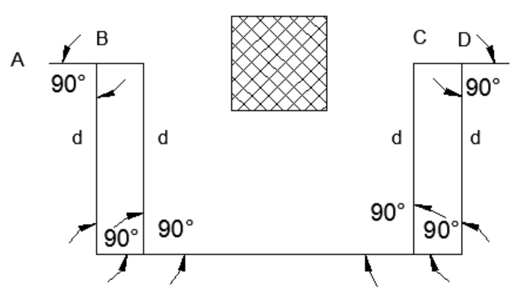
Lecture 7: Monday, July 9, 2012: REVISION FOR THE EXAM

How to prolong a line past an obstacle:

1. Equilateral triangle Method:



2. Measured Offset Method:



Two offsets are made to obtain more accuracy.

Revision Problems:

1. Differential Leveling:

Point	Back Sight	Height of instrument	Correction HI	Foresight	Elevation	Correction E
BMA	3				100	100
		103	103.003			
				2		
TP 1	2.5				101	101.003
		103.5	103.503			
				1		
TP2	2.5				102.5	102.503
		105.5	105.03			
				0.5		
BMB	3				105	105.009

Given That Elevation of BMB = 105.009

Section Misclosure is 0.009 which is lower than the allowable (0.01)

Therefore, we apply the correction

2. Combined Correction in Taping:

A 30m steel tape standardized at 20C and supported throughout with a tension of 90N was found to be 300.004m long. Section area is equal to 5mm2 while the unit weight is 40g/m was used supported at its ends with a tension of 70N to measure AB in two steps.

Section	Measured Distance	Measured Temperature
A-I	30.00m	15C
I-B	25.348m	18C

Do the necessarily corrections.

Correction for length: $C_l = \frac{l-l\prime}{l\prime} \times L = \frac{(30.004-30)}{30} \times (20 + 25.348) = 0.007m$

Correction for temperature: $C_{t1} = K(T_1 - T) \times L = 1.16 \times 10^{-6}(15 - 20) \times 30 = -0.002m$

$$C_{t2} = K(T_1 - T) \times L = 1.16 \times 10^{-6}(18 - 20) \times 25.348 = -0.001m$$

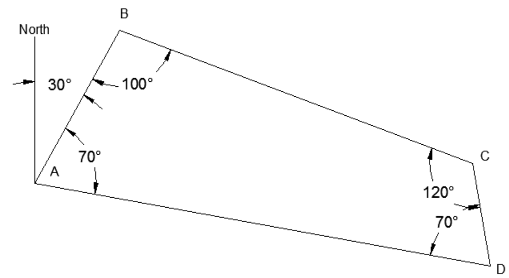
Correction for pull: $C_p = (P_1 - P) \times \frac{L}{AE} = (70 - 90) \times \frac{(30+25.348)}{5\times10^{-6}\times1.96\times10^{11}} = -0.001m$

Correction for sag: $C_s = -\frac{w^2\times L_s^3}{24\times P_1^2} = -\frac{(4\times10^{-3}\times9.8)^2\times30^3}{24\times70^2} - \frac{(4\times10^{-3}\times9.8)^2\times25.348^3}{24\times70^2} = -0.056$

Full correction$\equiv 0.007 - 0.003 - 0.056 - 0.001 = -0.056m$

New corrected length $\equiv -0.056 + 30 + 25.348 = 55.295m$

3. Azimuth & Bearing:



AZIMUTH:
AZ_{BA} =210°
AZ_{BC}=210-100=110°
AZ_{CB}=290°
AZ_{CD}=290-120=170°
AZ_{DC}=350°
AZ_{DA}=280°
AZ_{AD}=100°
CHECK: AZ_{AB}=100-70=30°=INITIAL AZIMUTH

BEARING:
B_{AB}= N30°E
B_{BA}= W30°E
B_{BC}=S70°E
B_{CB}=N70°W
B_{CD}=S10°E
B_{DC}=N10°W
B_{DA}=N80°E
B_{AD}=S80°W

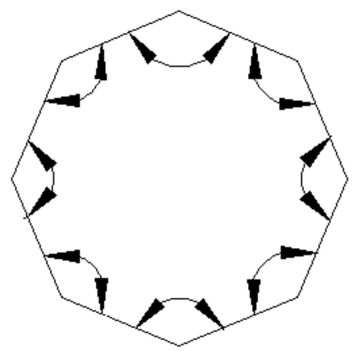
CIVE 360-361 Surveying:

Lecture 8: Monday, July 16, 2012

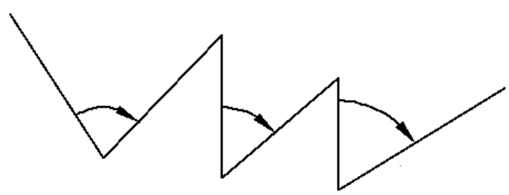
Traverse: a series of consecutive lines whose length and directions have been determined by field measurements.

We can do traversing by:

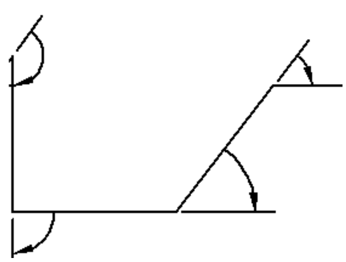
1. Interior angles:



2. Deflection angles: (Usually used in highway engineering)

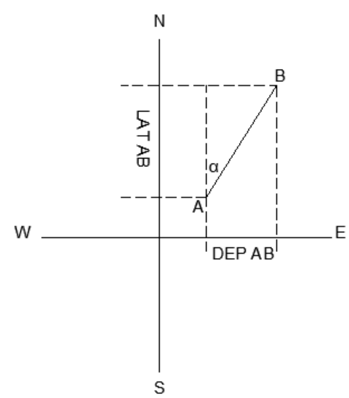


3. Angles to the right (Clockwise angles)



Traverse Computations:

1. Adjust angles to geometric conditions: the sum of the measured angles should be equal to the theoretical sum.
2. Computation of bearings and azimuths
3. Calculate latitudes and departures: $\text{Latitude of a line} = \text{Length of the traverse line} \times \text{Cos(Azimuth)}$. The latitude of AB is also the projection of the traverse AB on the North-South axis. $\text{Departure of a line} = \text{Length of the traverse line} \times \text{Sin(Azimuth)}$. Departure of AB is also the projection of the traverse AB on the East-West Axis.
4. Adjust them to misclosure
5. Calculate coordinates



$$\sum Lat = \sum Dep = 0$$

To balance Latitudes and Departures we use the Bowditch Method or the Compass Rule:

AB= 42.79m

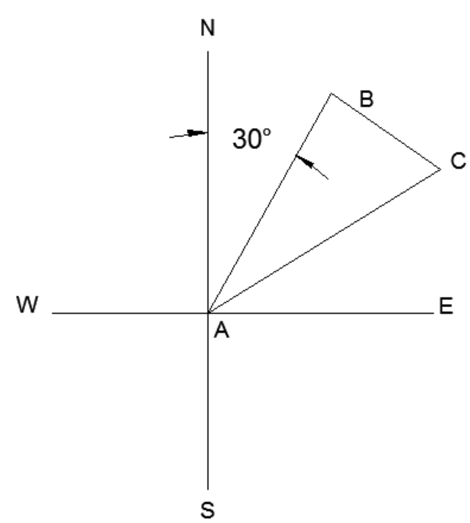
BC= 24.705m

CD=49.500m

Angle B = 89°59’40”

Angle A=29°59’50”

Angle C=60°0’30”



Point/Line	Azimuth	Length	Measured Latitude	Measured Departure	Corrected Latitude	Corrected Departure	X Coordinate	Y coordinate
A							0	0
AB	30°	42.795m	37.062m	21.398m	37.078m	21.425m		
B							21.425	37.078
BC	120°00'20"	24.705m	-12.355m	21.394m	-12.345m	21.410m		
C							42.835	24.733
CA	239°59'50"	42.500m	-24.752m	-42.867m	-24.733m	-42.835m		
A							0	0
Total		117.00	-0.045	-0.075	0	0		

Linear misclosure = $\sqrt{0.045^2 + 0.075^2 = 0.0875}$

$$Precision\ of\ Traverse = \frac{Linear\ Misclosure}{Paremeter} = \frac{0.0875}{117} = \frac{1}{1340}$$

<u>Bowditch Rule:</u>

$$Correction\ of\ Lat_{AB} = \frac{Latitude\ Misclosure \times L_{AB}}{Traverse\ Paremeter} = \frac{-0.045 \times 42.795}{117} = -0.016$$

Corrected length of AB is = -0.016+42.795=37.075m

$$Correction\ of\ Dep_{AB} = \frac{Departure\ Misclosure \times L_{AB}}{Traverse\ Paremeter}$$

$$X_B = X_A + Dep(AB)$$

$$Y_B = Y_A + Lat(AB)$$

<u>Length Of a line:</u>

Length of AB = $\sqrt{Lat(AB)^2 + Dep(AB)^2} = \sqrt{(X_B - X_A)^2 + (Y_B - Y_A)^2}$

CIVE 360-361 Surveying:

Lecture 9: Wednesday, July 18, 2012

Area Calculations

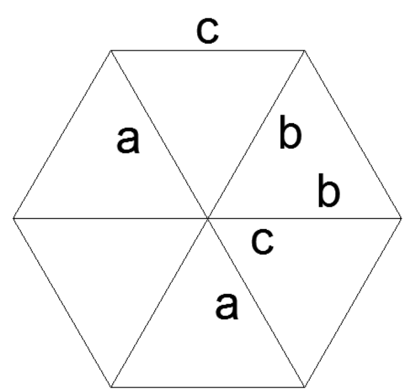
We can apply Area calculations using:

1. Division into simple figures
2. Offsets from a straight line
3. Double meridian distance method
4. Coordinates method

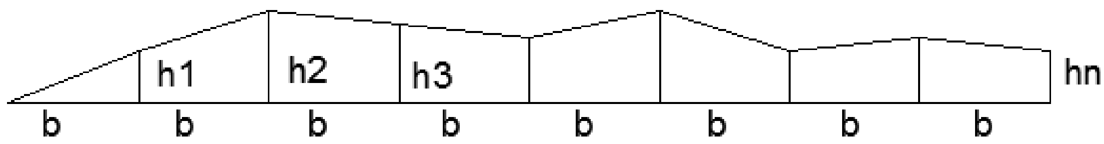
1. Division into Simple Figures method:

$$Area = \sqrt{S(S-a)(S-b)(S-c)} \quad where\ S = \frac{a+b+c}{2}$$

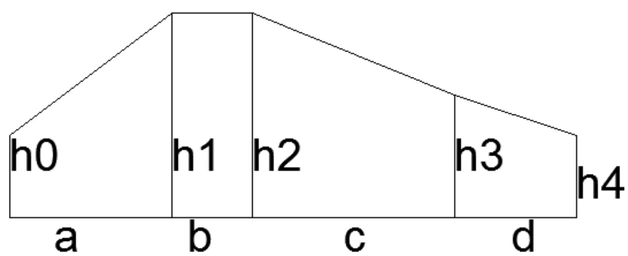
$$Area = \frac{ab \sin c}{2}$$



2. <u>Offsets from a straight line method</u>



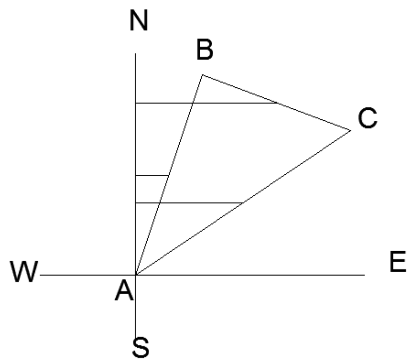
$$Area = b\left(\frac{h1}{2} + h2 + h3 + \cdots + \frac{hn}{2}\right) \quad ;Where\ we\ have\ regularly\ spaced\ offsets$$



$$Area = \frac{1}{2}[a(h0 + h1) + b(h1 + h2) + c(h2 + h3) + \cdots]$$

$Where\ we\ have\ irregular\ spacedoffset$

3. Double Meridian Distance Method:



Meridian distance of a line is the distance from the line's midpoint to the reference meridian.

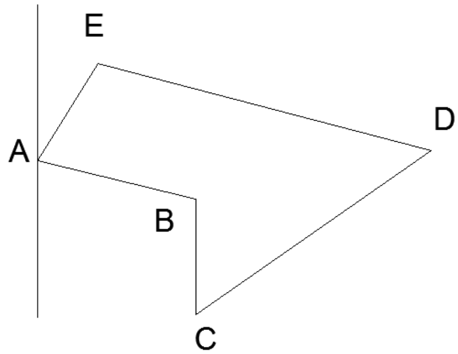
$$\begin{aligned} &Meridian\ distance\ of\ a\ line \\ &= meridian\ distance\ of\ the\ previous\ line + \frac{1}{2}\ departure\ of\ previous\ line \\ &+ \frac{1}{2} departure\ of\ the\ line\ itself \end{aligned}$$

$$Medirian\ distance\ of\ BC = MdAB + \frac{1}{2} Departure\ AB + \frac{1}{2}\ departure\ of\ BC$$

$$\begin{aligned} &Double\ Meridian\ distance\ of\ a\ line \\ &= Double\ meridian\ distance\ of\ the\ previous\ line + \ departure\ of\ previous\ line \\ &+ \ departure\ of\ the\ line\ itself \end{aligned}$$

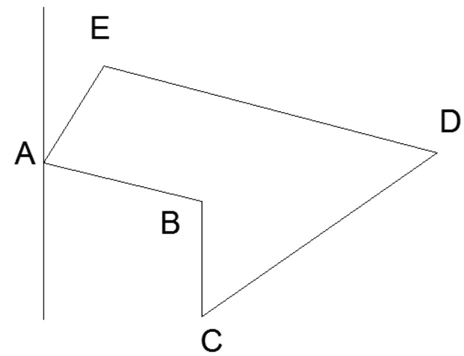
Example:

Calculate the area of a closed region using the double meridian distance method



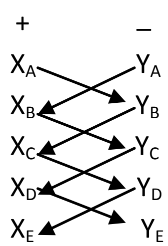
Line	Balanced Departure	Balanced Latitude	DMD	Double Area Plus	Double Area Minus
AB	517.44	-388.84	517.44		20120
BC	5.96	-202.95	1040.85		211240
CD	192.88	694.02	123.70	860376	
DE	-590.57	153.69	842.01	129408	
EA	-125.72	-225.93	125.72		32176
Total	0	0		545167 ft^2 ➔ A=272584 ft^2	

4. Area by coordinates method

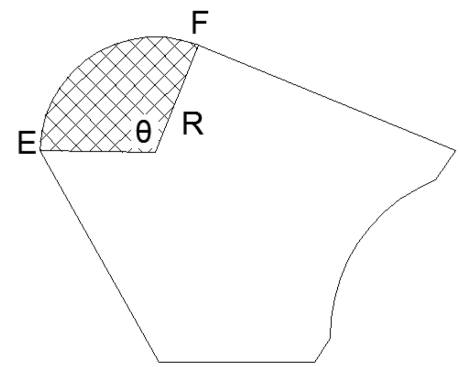


$$\left(\frac{X_E + X_D}{2}\right)\left(\frac{Y_E + Y_D}{2}\right) + \left(\frac{X_D + X_C}{2}\right)\left(\frac{Y_D + Y_C}{2}\right) - \left(\frac{X_A + X_E}{2}\right)\left(\frac{Y_E + Y_A}{2}\right) - \left(\frac{X_B + X_C}{2}\right)\left(\frac{Y_B + Y_C}{2}\right) - \left(\frac{X_A + X_B}{2}\right)\left(\frac{Y_A + Y_B}{2}\right)$$

$2A = X_A Y_B + X_B Y_C + X_C Y_A + X_D Y_E + X_E Y_A - X_B Y_A - X_C Y_B - X_D Y_C - X_E Y_D - X_A Y_E$



Hatched Area = $\Pi R^2 \times \left(\frac{\theta}{360^{\circ}}\right)$



CIVE 360-361 Surveying:

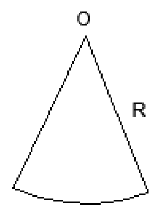
Lecture10: Monday, July 23, 2012

The elements that determine a circular curve:

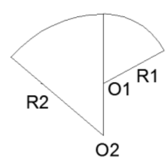
- Degree of the curve
- Radius of the curve

Types of curves:

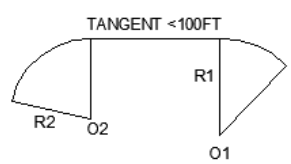
1. Simple curve



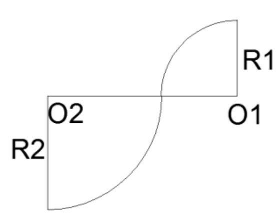
2. Compound curve: 2 circular curves tangent to each other with centers on the same side



3. Broken back curve: two circular curves connected with a tangent line that is less than or equal to 100 ft with radii on the same side



4. Reversed curve: 2 circular curves tangent to each other with centers on different sides

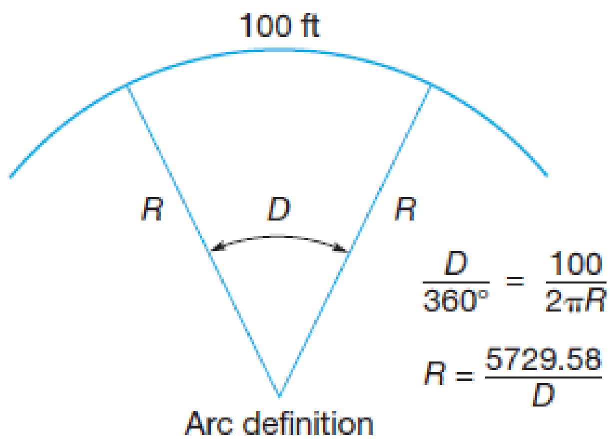


5. Spiral curves: their radius varies from infinity to zero. Usually used in railways

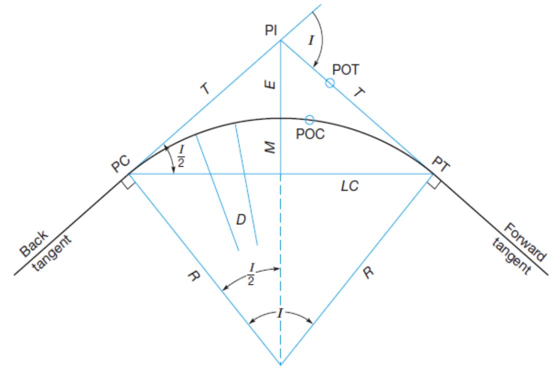
<u>Arc Definition:</u>

It defines a relationship between the degree of the curve and the radius of the curve.

$$\frac{D}{360°} = \frac{100}{2\Pi R} \Rightarrow R = \frac{5729.58}{D}$$



Circular Curve



- PC → Point of curvature
- PT → Point of Tangency
- T → Tangent Distance
- PI → Point of intersection of tangents
- I → Central angle ≡ Reflection Angle
- E → External Coordinate Distance
- M→ Middle ordinate Distance
- L → Length of the Curve
- LC→ Length of the chord

$L = R \times I\ (\ I\ in\ radians)$

$$\frac{L\ (ft)}{100\ ft} = \frac{I^{\circ}}{D^{\circ}}$$

$$R = \frac{5729.58\ (ft)}{D^{\circ}}$$

$$\frac{T}{R} = \tan\frac{I}{2} \leftrightarrow T = R \times \tan\frac{I}{2}$$

$$\frac{R}{R+E} = \cos\frac{I}{2} \leftrightarrow \ E = R(\frac{1}{\cos\frac{I}{2}} - 1\ )$$

$$\frac{R-M}{R} = \cos\frac{I}{2} \leftrightarrow M = R(1 - \cos\frac{I}{2})$$

$$LC = 2R \times \sin\frac{I}{2}$$

Usually our station line is the central line ≡ tangent line in highway engineering

$Station\ PC = Station\ PI - T$

$Station\ PT = Station\ PC + L$

Example:

For a circular curve assume that:

- I=8°24’
- Station PI = 6427.46 (also written as 64 + 27.46)
- R=2864.79 ft (Arc Definition)

Calculate PC & PT Stations

Find the external coordinate & Middle coordinate distances

$$T = 2864.79 \times \tan \frac{8°24'}{2} = 210.38\, ft$$

$$Station\ of\ PC = Station\ of\ PI - T = (64 + 27.46) - 210.38 = 6427.46 - 210.38 = 6217.08$$

$$L = 2864.79 \times 8°24' \left(\frac{\pi}{360}\right) = 420\, ft$$

PT = PC + L = 6217.08+420=6637.08= 66 + 37.08

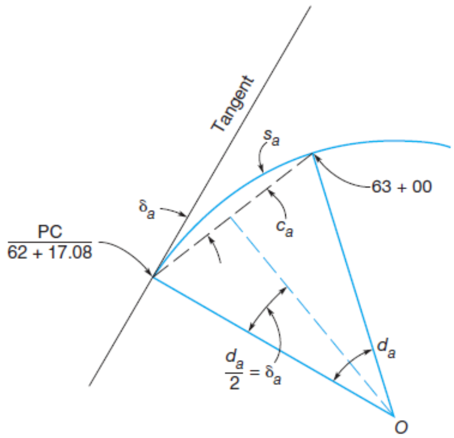
$$\text{External coordinate distance} = E = R\left(\frac{1}{\cos\frac{I}{2}} - 1\right) = 7.71 ft$$

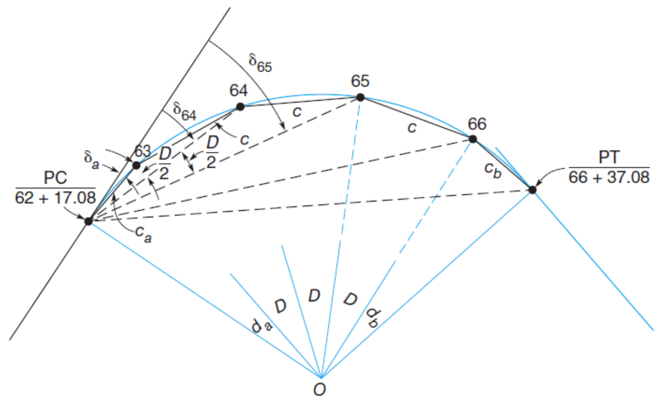
$$Middle\ Coordinate\ Distance = M = R(1 - \cos\frac{I}{2}) = 7.69\, ft$$

CIVE 360-361 Surveying:

Lecture11: Wednesday, July 25, 2012

How to layout a curve using the deflection method or the increment chord method:





$$\frac{d_a}{s_a} = \frac{D}{100} \leftrightarrow d_a = \frac{s_a D}{100} (Degrees)$$

$$\delta_a = \frac{s_a D}{200} = \frac{82.92 \times 2}{200} = 0.8292° = 0°49'45"$$

$$\delta = \frac{sD}{200} = \frac{100 * 2}{200} = 1°$$

$$\delta_b = \frac{37.08 \times 2}{200} = 0.3708° = 0°22'15"$$

$$\sin \delta_a = \frac{C_a}{2R} \leftrightarrow C_a = 2R \sin \delta_a$$

$$C_a = 2R \sin \delta_a = 2 \times 2864.79 \times \sin 0°49'45" = 82.92\ ft$$

$$C_b = 2 \times 2864.79 \times \sin 0°22'15" = 37.08\ ft$$

$$C = 2R \sin \delta = 2 \times 2864.79 \times \sin 1° = 99.99\ ft$$

Station	Incremental Chord (ft)	Deflection Increment	Deflection angle
62+17.08			
63+00	82.92	0°49’45”	0°49’45”
64+00	99.99	1°	1°49’45”
65+00	99.99	1°	2°49’45”
66+00	99.9	1°	3°49’45”
66+37.08	37.08	0°25’15”	4°12’00”

CIVE 360-361 Surveying:

Lecture12: Monday, July 30, 2012

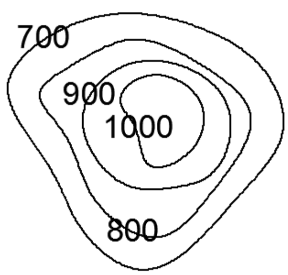
Topographic Surveys: We do topographic surveys to determine the relief of the earth and to determine the location of the natural and artificial features. Topographic surveys are used by engineers, architects, landscapers etc.

- ❖ Horizontal control is established by control points.
- ❖ Vertical control is established by the Bench Mark

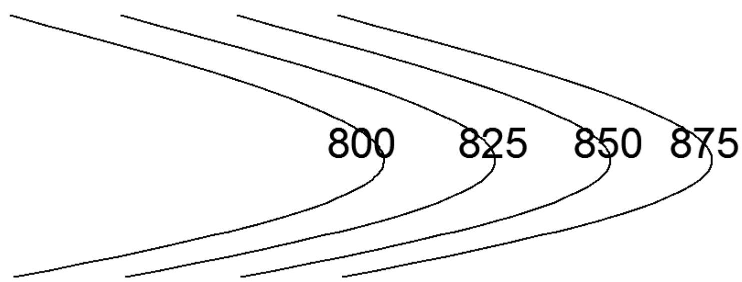
Contours: A contour is a line that connects points of equal elevation contour map that is used to represent topography. Contour interval is the difference between contour lines.

Properties of contours:

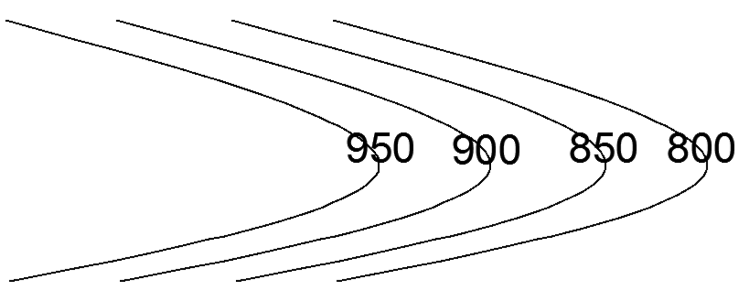
- Run perpendicular to direction of maximum slope
- Distance between contours indicates steepness of slope (the smaller the distance, the steeper the slope)
- Contours of different elevations don't meet except on a shear or a cliff.



Mountain / Hill



Valley



Ridge / Top of the mountain

Determine the contour lines by Grid and interpretation: