HEWLETT PACKARD

HP-35

SURVEYING PAC

INTRODUCTION

The programs contained in this booklet are a brief representation of the many problems which may be solved on the HP-35 Pocket Calculator. The intention is to provide routines for the more widely encountered areas of surveying--traverses, intersects, curves, areas, and triangles.

We hope that you find this booklet useful in your day-to-day calculations.

Civil Engineering Products

Note: [ENT] is used to denote the [ENTER ↑] key throughout the tables in this text.

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CURVES

DEGREES, MINUTES, SECONDS TO DECIMAL EQUIVALENT

LINE	DATA	OPERATIONS	DISPLAY	REMARKS
1.		6 0 STO		
2.	Degrees	ENT		
3.	Minutes	ENT		
4.	Seconds	RCL ÷ +		
5.		RCL ÷ +	Decimal Degrees	Record - See Note 1

Note 1: To convert bearing to azimuth:
If bearing is SE or NW, press CHS . Then if bearing is SE or SW, press ENTER↑ , 180, + . Then if bearing is NW, press ENTER↑ , 360, + .

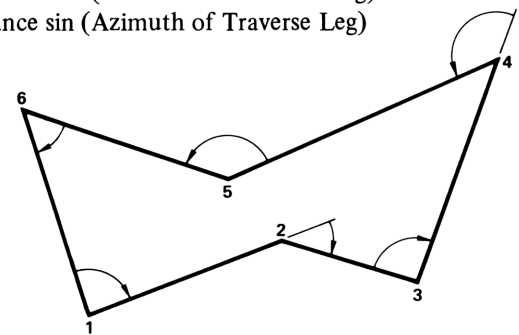
DECIMAL DEGREES TO DEGREES, MINUTES, SECONDS

LINE	DATA	OPERATIONS	DISPLAY	REMARKS
1.	Decimal Degrees	ENT		
2.	Integer Degrees		Degrees	Record
3.		− 6 0 X		
4.	Integer Minutes		Minutes	Record
5.		− 6 0 X	Seconds	Record

FIELD ANGLE TRAVERSE

Azimuth of Traverse Leg = Reference Bearing + Field Angle
Horizontal Distance = Slope distance sin (Zenith)
$N_n = N_o$ + Horizontal Distance cos (Azimuth of Traverse Leg)
$E_n = E_o$ + Horizontal Distance sin (Azimuth of Traverse Leg)

Example:



Field Data

Reference Bearing 1 → 6: N 17° 23' 45"W

Starting Coordinates: N_1 = 10,000.000, E_1 = 10,000.000

Point	Field Angle	Zenith Angle	Slope Distance
1	87° 22' 17" Right	88° 07' 18"	745.832
2	38° 06' 54" Deflection Right	89° 54' 07"	510.089
3	92° 13' 06" Right	91° 13' 31"	853.760
4	133° 12' 46" Deflection Left	Horizontal	1053.916
5	137° 46' 30" Left	90° 48' 57"	789.671
6	53° 16' 47" Right	89° 41' 55"	784.406
1			

Computed Data

Point	N	E	Point	N	E
1	10,000.000	10,000.000	5	10,487.192	10,510.672
2	10,255.251	10,700.367	6	10,748.438	9,765.552
3	10,096.859	11,185.240	1	9,999.933	10,000.107
4	10,897.362	11,481.496			

FIELD ANGLE TRAVERSE (Continued)

Computed Azimuth $6 \rightarrow 1$: $162^\circ\ 36'\ 03''$

$\therefore$ Angular Closure = 12"

$\sqrt{(\text{Corr}_N)^2 + (\text{Corr}_E)^2} = 0.126$

Position Closure (Before Adjustment of Angles): Length of Traverse $\cong 4738$

$\text{Corr}_N = +0.067$, $\text{Corr}_E = -0.107$ Precision Ratio $\cong 1/37{,}600$

LINE	DATA	OPERATIONS	DISPLAY	REMARKS
1.	Reference Bearing Degrees	ENT		
2.	Minutes	ENT		
3.	Seconds	ENT 6 0 ÷ +		
4.		6 0 ÷ +	Decimal Ref. Bearing	See Note 1
5.		STO	Decimal Ref. Azimuth	
6.	Field Angle Degrees	ENT		
7.	Minutes	ENT		
8.	Seconds	ENT 6 0 ÷ +		

9.		6 0 ÷ +	Decimal Field Angle	See Note 2
10.		RCL +		See Note 3
11.		STO	Decimal Azimuth of Traverse Leg	See Note 4
12.	Zenith (Vert) Angle Degrees	ENT		
13.	Minutes	ENT		
14.	Seconds	ENT 6 0 ÷ +		
15.		6 0 ÷ +	Decimal Zenith (Vert.) Angle	See Note 5
16.		SIN		
17.	Slope Distance	X	Horizontal Distance	
18.		RCL ENT COS X⇄Y SIN		
19.		R↓ X	Latitude	
20.	Previous Northing	+	Current Northing	Record
21.		R↓ X	Departure	
22.	Previous Easting	+	Current Easting	Record See Notes 6 & 7

FIELD ANGLE TRAVERSE (Continued)

Note 1: If the first field angle is an angle right or angle left, the ref. bearing direction is AWAY from the first point. If the first field angle is a deflection right or left, the ref. bearing direction is TOWARDS the first point. For SE or NW ref. bearing, depress [CHS]. Then for SE or SW ref. bearing, depress [ENTER↑], 180, [+] or for NW ref. bearing, depress [ENTER↑], 360, [+]. See Note 8.

Note 2: Depress [CHS] for angle left or deflection left.

Note 3: If display is greater than 360, depress 360, [−]. If display is less than zero, depress 360, [+]. See Note 8.

Note 4: If a slope distance is to be entered, continue on line 12. If a horizontal distance is to be entered, enter the horizontal distance, skip to line 18 and continue.

Note 5: If vertical angles are observed instead of zenith angles, depress [COS] instead of [SIN] in line 16.

Note 6: If the next field angle is an angle right or angle left, depress [RCL], then if display becomes 1) greater than 180, depress 180, [−]; or 2) less than 180, depress 180 [+]. Then return to line 5 and continue; or if the next field angle is a deflection right or left, return to line 6 and continue.

Note 7: After the last coordinates are computed, a check on the angular closure can be made as follows: Depress [RCL] and convert the displayed decimal angle to degrees, minutes and seconds. This computed closing azimuth can then be checked against the actual closing azimuth.

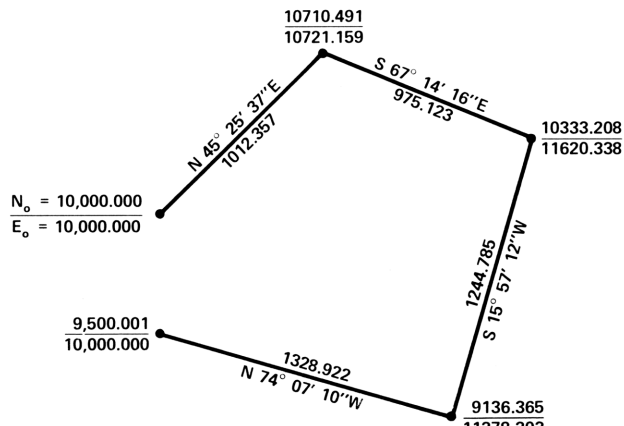
Note 8: If a surveyor does not feel uncomfortable with azimuths greater than 360° or with negative azimuths, the statements about adding (or subtracting) 360 in notes (1) and (3) can be ignored. These operation were employed solely to keep the azimuth values in the range most used by the surveyor, i.e., in the range 0° to 360°. These "corrections" are not really necessary when using the Model 35.

NOTES

BEARING TRAVERSE

$$N_{n+1} = N_n + \text{Distance cos (Bearing)}$$
$$E_{n+1} = E_n + \text{Distance sin (Bearing)}$$

Example:



LINE	DATA	OPERATIONS	DISPLAY	REMARKS
1.	Beginning North (N_o)	STO		
2.	Beginning East (E_o)	ENT		
3.	Bearing Degrees	ENT		
4.	Minutes	ENT 6 0 ÷ +		
5.	Seconds	ENT 3 6 0 0		
6.		÷ +	Decimal Bearing	See Note 1
7.		ENT SIN X⇄Y COS		
8.	Distance	X RCL + STO	New Northing	Record
9.	Distance	X +	New Easting	Record
10.				Go To Line 3 For Next Leg

Note 1: If bearing is SE or NW, press CHS. Then if bearing is SE or SW, press ENTER↑, 180, +. Then proceed to next line.

INVERSE - DISTANCE AND BEARING FROM COORDINATES

$$\text{Bearing} = \tan^{-1}\left(\frac{E_2 - E_1}{N_2 - N_1}\right)$$

$$\text{Distance} = \sqrt{(E_2 - E_1)^2 + (N_2 - N_1)^2}$$

Example:

$N_1 = 10{,}000$

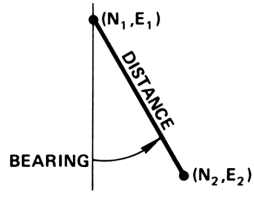
$E_1 = 10{,}000$

$N_2 = 9{,}000$

$E_2 = 10{,}500$

Distance = 1118.034

Bearing = S 26° 33' 54"E



LINE	DATA	OPERATIONS	DISPLAY	REMARKS
1.	$Easting_2$	ENT		
2.	$Easting_1$	− ENT ENT X STO		
3.	$Northing_2$	ENT		
4.	$Northing_1$	− ENT ENT X RCL		
5.		+ $\sqrt{X}$	Distance	Record
6.		R↓ ÷ ARC TAN	Decimal Bearing	See Note 1
7.		ENT		
8.	Integer Degrees		Bearing Degrees	Record
9.		− 6 0 STO X		
10.	Integer Minutes		Bearing Minutes	Record
11.		− RCL X	Bearing Seconds	Record
12.				Return to Line 1

Note 1: If decimal bearing is positive, bearing is NE or SW. If decimal bearing is negative, bearing is SE or NW. If bearing is negative, press CHS before proceeding to next line.

AREA OF A TRAVERSE FROM COORDINATES

$$A = \frac{1}{2}\left[E_1 (N_2 - N_n) + \left[E_2(N_3 - N_1) + E_3(N_4 - N_2) + \ldots + E_{n-1}(N_n - N_{n-2})\right] + E_n(N_1 - N_{n-1})\right]$$

Example:

	E	N
1	100.29	491.72
2	447.68	823.14
3	774.43	648.49
4	753.48	318.75
5	610.91	72.23
6	229.34	223.35
1	100.29	491.72

Area = 328,277.19

LINE	DATA	OPERATIONS	DISPLAY	REMARKS
1.		CLR		
2.	Starting Easting	ENT		
3.	Starting Northing	ENT		
4.	Next Easting	ENT R↓ X RCL X⇄Y		
5.		− STO		
6.	Next Northing	ENT R↓ X RCL +		
7.		STO R↓ X⇄Y		See Note 1
8.		RCL ENT 2 ÷	Area	See Note 2/Record

Note 1: Return to line 4 until starting coordinates have been re-entered, then proceed through to line 8 to obtain area.

Note 2: Negative values may result. Absolute value is recorded.

SLOPE DISTANCE REDUCTION

$$S = \left[(\text{Ht. of D. M.}) - (\text{Ht. of Theo.}) - (\text{Ht. of D. M. target}) + (\text{Ht. of Theo. target})\right]$$

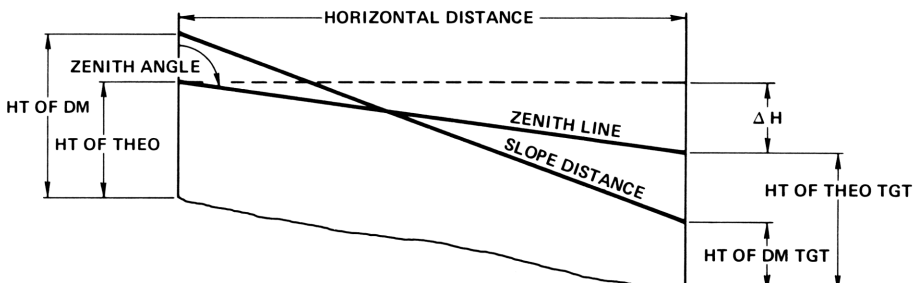
$$k = S \cdot \sin(\text{Zenith})$$
$$p = S \cdot \cos(\text{Zenith})$$

$$\text{Horizontal Distance} = \left(\sqrt{(\text{Slope distance})^2 - k^2} + p\right)\left(\sin(\text{Zenith})\right)$$

Example:

Ht. of D.M. = 5.87
Ht. of Theo. = 5.12
Ht. of D.M. Tgt. = 4.91
Ht. of Theo. Tgt. = 5.17

Zenith Angle = 93° 13' 00"
Slope Distance = 487.132
Horizontal Distance = 486.307



SLOPE DISTANCE REDUCTION (Continued)

LINE	DATA	OPERATIONS	DISPLAY	REMARKS
1.		6 0 STO		
2.	Zenith Degrees	ENT		
3.	Minutes	ENT		
4.	Seconds	RCL ÷ + RCL ÷		
5.		+ ENT ENT		
6.	Ht. D.M.	ENT		
7.	Ht. Theo.	−		
8.	Ht. D.M. Tgt.	−		
9.	Ht. Theo. Tgt.	+ STO R↓		
10.		COS RCL X	p	See Note 1/Record

11.		R↓ SIN RCL X	k	See Note 1/Record
12.		X⇄Y SIN STO		
13.	Slope Distance	ENT X		
14.	k	ENT X − √X		
15.	p	+ RCL X	Horizontal Dist.	Record

Note 1: Values of p and k may be negative. Be sure to retain sign when reentering at lines 14 and 15.

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NOTES

DISTANCE - DISTANCE INTERSECT

Example:

$N_1 = 1000$

$E_1 = 1000$

$N_2 = 1250$

$E_2 = 2000$

$N_3 = 1614.409$

$E_3 = 1657.649$

$N_4 = 767.353$

$E_4 = 1869.411$

$B = 500$

$A = 900$

$\phi = 29.017°$

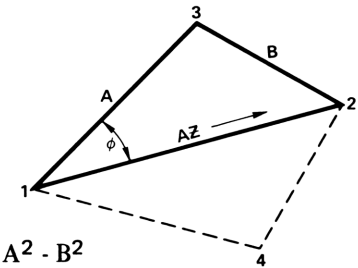
$\text{Azimuth}_{1 \to 2} = 75° 57' 50''$

$\text{Distance}_{1 \to 2} = 1030.776$

$$\phi = \cos^{-1} \frac{(\text{Distance}_{1\text{-}2})^2 + A^2 - B^2}{2\,(A)\,(\text{Distance}_{1\text{-}2})}$$

$N = N_1 + A \cos (Az \pm \phi)$

$E = E_1 + A \sin (Az \pm \phi)$



DISTANCE - DISTANCE INTERSECT (Continued)

LINE	DATA	OPERATIONS	DISPLAY	REMARKS
1.	N_2	ENT		
2.	N_1	− ENT X		
3.	E_2	ENT		
4.	E_1	− ENT X + STO	$(Distance_{1\text{-}2})^2$	
5.		RCL		
6.	Distance B	ENT X −		
7.	Distance A	ENT ENT R↓ X +		
8.		RCL $\sqrt{X}$ ÷ 2 ÷		
9.		X⇄Y ÷ ARC COS STO		
10.	Azimuth 1 → 2 Degrees	ENT		

11.	Minutes	ENT		
12.	Seconds	ENT 6 0 ÷ +		
13.		6 0 ÷ + RCL	ϕ	See Note 1
14.		+ ENT SIN X⇄Y COS		
15.	Distance A	STO X		
16.	N_1	+	N_3	Record
17.		RCL X⇄Y R↓ X		
18.	E_1	+	E_3	Record

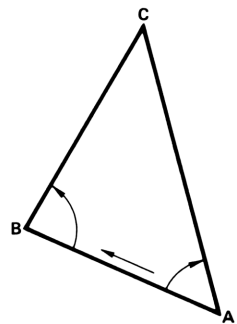
Note 1: If solution desired is to left of line 1 → 2, press CHS before proceeding to line 14.

NOTES

ANGLE - ANGLE INTERSECT

Example:

$A = 76^\circ\ 30'\ 00''$	$N_B = 3200.000$
$B = 38^\circ\ 20'\ 00''$	$E_B = 4200.000$
$N_A = 5200.000$	$N_C = 6143.552$
$E_A = 6100.000$	$E_C = 4467.774$



$$N_C = \frac{E_A - E_B + N_B \cot A + N_A \cot B}{\cot A + \cot B}$$

$$E_C = \frac{N_B - N_A + E_B \cot A + E_A \cot B}{\cot A + \cot B}$$

ANGLE - ANGLE INTERSECT (Continued)

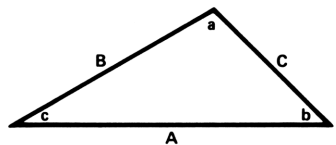
LINE	DATA	OPERATIONS	DISPLAY	REMARKS
1.		6 0 STO		
2.	Angle B Degrees	ENT		
3.	Minutes	ENT		
4.	Seconds	RCL ÷ +		
5.		RCL ÷ + TAN 1/X		
6.	Angle A Degrees	ENT		
7.	Minutes	RCL ÷ +		
8.	Seconds	RCL ÷ RCL ÷ +		
9.		TAN 1/X STO R↓		
10.		ENT ENT		

11.	E_A	X		
12.	N_A	− RCL		
13.	E_B	X +		
14.	N_B	+ X⇄Y ENT ENT RCL		
15.		+ X⇄Y R↓ ÷	E_C	Record
16.		R↓ R↓ ENT ENT		
17.	E_A	X⇄Y		
18.	N_A	X +		
19.	E_B	−		
20.	N_B	RCL X + X⇄Y		
21.		RCL + ÷	N_C	Record

TRIANGLE SOLUTION - GIVEN THREE SIDES

Example:

A =	2489.621	a =	48° 00' 00"
B =	2543.150	b =	49° 23' 13"
C =	3322.312	c =	82° 36' 47"



$$c = 2\,TAN^{-1}\left(\frac{r}{S-C}\right)$$

$$r = \sqrt{\frac{(S-A)\,(S-B)\,(S-C)}{S}}$$

$$S = \frac{1}{2}\,(A + B + C)$$

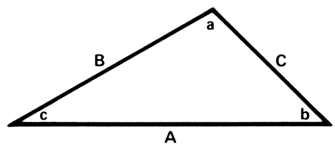
LINE	DATA	OPERATIONS	DISPLAY	REMARKS
1.	Side A	ENT ENT		
2.	Side B	ENT R↓ +		
3.	Side C	STO + 2 ÷ RCL		
4.		X⇄Y STO X⇄Y − ENT		
5.		R↓ R↓ RCL X⇄Y −		
6.		X⇄Y RCL X⇄Y −		
7.		X X RCL ÷ √X		
8.		X⇄Y ÷ ARC TAN 2		
9.		X	Decimal Angle c	See Note 1
10.	Integer Degrees		Degrees	Record
11.		− 6 0 X		
12.	Integer Minutes		Minutes	Record
13.		− 6 0 X	Seconds	Record

Note 1: Angle b may be obtained by reversing the data entries at lines 2 and 3.

TRIANGLE SOLUTION - GIVEN TWO ANGLES AND INCLUDED SIDE

Example:

A = 2489.621 a = 48° 00' 00"
B = 2543.150 b = 49° 23' 13"
C = 3322.312 c = 82° 36' 47"



$$A = \frac{B \sin a}{\sin b}$$

$$C = \frac{B \sin c}{\sin b}$$

(LAW OF SINES)

LINE	DATA	OPERATIONS	DISPLAY	REMARKS
1.		CLR 6 0 STO		
2.	Angle a Degrees	ENT		
3.	Minutes	ENT		
4.	Seconds	RCL ÷ +		
5.		RCL ÷ +		
6.	Angle c Degrees	ENT		
7.	Minutes	RCL ÷ +		
8.	Seconds	RCL ÷ RCL ÷ +		
9.		ENT R↓ + SIN		
10.	Side B	X⇄Y ÷ X⇄Y SIN X⇄Y		
11.		ENT R↓ X	Side A	Record
12.		R↓ SIN X	Side C	Record

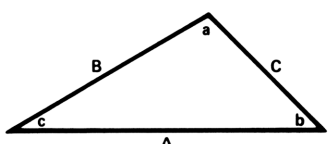
TRIANGLE SOLUTION
GIVEN TWO SIDES & ANGLE OPPOSITE ONE OF THEM

Example:

A = 6.00	a = 30° 23' 17"	A = 6.00	a = 30° 23' 17"
B = 10.70	b = 64° 26'11"	B = 10.70	b = 115° 33' 49"
C = 11.82	c = 85° 10' 32"	C = 6.64	c = 34° 02' 54"

$$b = \sin^{-1}\left(\frac{B \sin a}{A}\right)$$

Acute Angle b

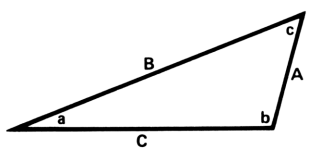


$$c = 180 - (a + b)$$

$$C = \frac{A \sin c}{\sin a}$$

(LAW OF SINES)

Obtuse Angle b



LINE	DATA	OPERATIONS	DISPLAY	REMARKS
1.		CLR 6 0 STO		
2.	Angle a Degrees	ENT		
3.	Minutes	RCL ÷ +		
4.	Seconds	RCL ÷ RCL ÷ +		
5.		STO SIN		
6.	Side B	ENT R↓ X X⇄Y +		
7.	Side A	÷ ENT ARC SIN	Angle b Decimal	See Note 1/Record
8.		RCL +	Angle b + a Decimal	See Note 2
9.		1 8 0 X⇄Y −	Angle c Decimal	Record
10.		SIN X⇄Y ÷ X	Side C	Record

Note 1: To solve the problem where angle b is obtuse, press:
180, x⇄y, − before proceeding to line 8.

Note 2: Since the sum of angles of a triangle must be 180°, the sum of angles b and a cannot be greater than 180. If the display exceeds 180° there is only one solution, with angle b acute.

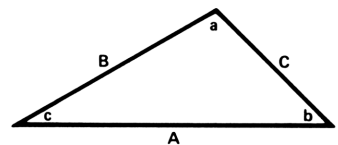
AREA OF A TRIANGLE - GIVEN THREE SIDES

Example:

$$\text{Area} = \sqrt{S(S-A)(S-B)(S-C)}$$

$$\text{Where } S = \frac{1}{2}(A + B + C)$$

A, B, C = Lengths of Individual Sides



A = 2489.621
B = 2543.150
C = 3322.312

Area = 3139465.857

LINE	DATA	OPERATIONS	DISPLAY	REMARKS
1.	Side A	ENT		
2.	Side B	ENT		
3.	Side C	STO $X\rightleftarrows Y$ ENT $R\downarrow$ +		
4.		$X\rightleftarrows Y$ ENT $R\downarrow$ + 2		
5.		÷ RCL $X\rightleftarrows Y$ STO $X\rightleftarrows Y$		
6.		− RCL X RCL $X\rightleftarrows Y$		
7.		$R\downarrow$ $X\rightleftarrows Y$ − $X\rightleftarrows Y$ RCL		
8.		$X\rightleftarrows Y$ − X X $\sqrt{X}$	Area	Record

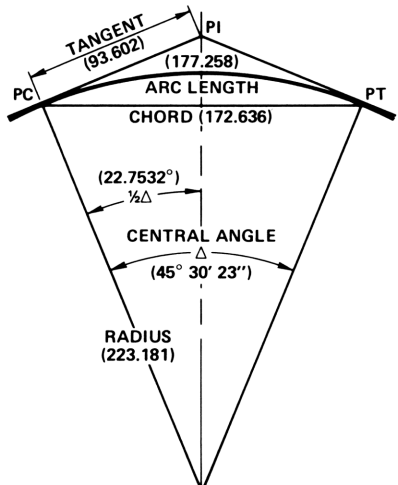
CURVE SOLUTION - GIVEN CENTRAL ANGLE AND TANGENT DISTANCE

Example:

R = Tangent/tan $(\Delta/2)$

Chord = 2R sin $(\Delta/2)$

Arc Length = R $\Delta \pi/180$

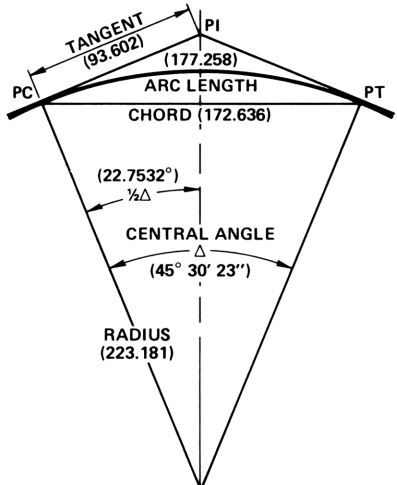


LINE	DATA	OPERATIONS	DISPLAY	REMARKS
1.		6 0 STO		
2.	Δ Degrees	ENT		
3.	Minutes	ENT		
4.	Seconds	RCL ÷ + RCL ÷		
5.		+ 2 ÷ STO	Decimal ½ Δ	
6.	Tangent Distance	ENT RCL TAN ÷	Radius	Record
7.		ENT ENT RCL SIN X		
8.		2 X	Chord	Record
9.		R↓ RCL X		
10.		π X 9 0 ÷	Arc	Record

CURVE SOLUTION - GIVEN CENTRAL ANGLE & RADIUS

Example:

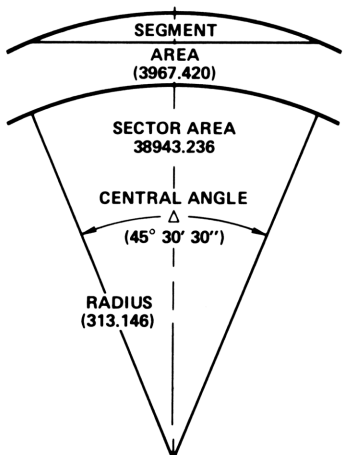
Chord = 2 R sin ($\Delta/2$)
Tangent = R tan ($\Delta/2$)
Arc Length = RΔ $\pi/180$



LINE	DATA	OPERATIONS	DISPLAY	REMARKS
1.	Δ Degrees	ENT		
2.	Minutes	ENT		
3.	Seconds	ENT 6 0 STO		
4.		÷ + RCL ÷ +		
5.		2 ÷	Decimal ½ Δ	
6.		ENT ENT TAN		
7.	Radius	STO X	Tangent Distance	Record
8.		R↓ SIN RCL X 2		
9.		X	Chord	Record
10.		R↓ RCL X π X		
11.		9 0 ÷	Arc Length	Record

CURVE AREA - GIVEN CENTRAL ANGLE & RADIUS

Example:



$$\text{Segment Area} = \pi R^2 \left(\frac{\Delta^\circ}{360^\circ}\right) - \frac{1}{2} R^2 \sin(\Delta^\circ)$$

$$\text{Sector Area} = \pi R^2 \left(\frac{\Delta^\circ}{360^\circ}\right)$$

LINE	DATA	OPERATIONS	DISPLAY	REMARKS
1.		6 0 STO		
2.	Δ Degrees	ENT		
3.	Minutes	ENT		
4.	Seconds	RCL ÷ + RCL ÷		
5.		+ ENT ENT π X		
6.		3 6 0 ÷		
7.	Radius	ENT X ENT R↓ X	Sector Area	Record
8.		X⇄Y SIN X⇄Y R↓ X		
9.		2 ÷ X⇄Y R↓ −	Segment Area	Record

CURVE LAYOUT - DEFLECTION ANGLES FROM TANGENT

Deflection/ft = $180/(2\pi R)$

Deflection Angle = Arc X Deflection/ft.

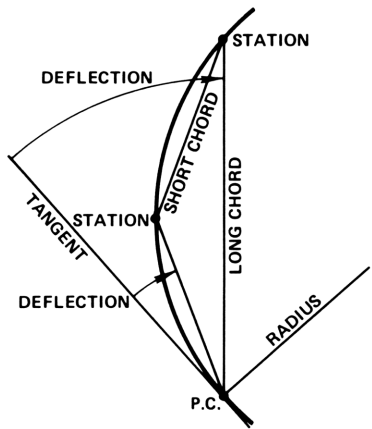
Long Chord = 2 Radius Sin (Deflection Angle)

Example:

Radius = 900.00 Ft.

Station	Arc Length	Deflection	Long Chord
12 + 57.00	(Point of Curvature, P.C.)		
12 + 75.00	18.00	00°34′23″	18.00
12 + 88.50	31.50	01°00′10″	31.50
13 + 00.00	43.00	01°22′07″	43.00
13 + 25.00	68.00	02°09′52″	67.98
13 + 50.00	93.00	02°57′37″	92.96

Arc Length = Difference in Stations



LINE	DATA	OPERATIONS	DISPLAY	REMARKS
1.	Radius	ENT 2 X ENT ENT		
2.		1 8 0 ENT π		
3.		÷ X⇄Y ÷ STO		
4.		RCL		
5.	Arc Length From P.C.	X	Decimal Deflection	
6.		ENT ENT		
7.	Integer Degrees		Deflection Degrees	Record
8.		– 6 0 X		
9.	Integer Minutes		Deflection Minutes	Record
10.		– 6 0 X	Deflection Seconds	Record
11.		R↓		
12.		SIN X	Long Chord	See Note 1
13.		CLX		Return to Line 4

Note 1: Computation of the long chord can be omitted if regular intervals are used for which the short chord remains constant. Calculation then only needed for odd intervals.

ELEVATIONS ALONG A VERTICAL CURVE

$$E_s = E_o + G_1(\text{Distance in Stations}) + \left[\frac{50(G_2 - G_1)}{L}\right](\text{Distance in Stations})^2$$

Example:

Beginning Grade (G_1) = -1.065%

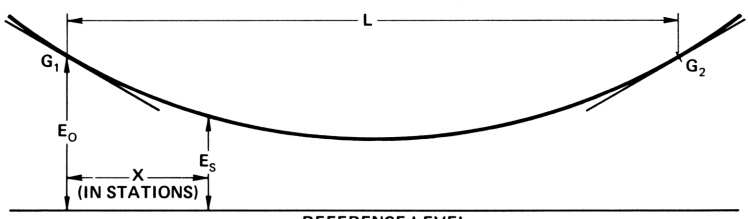
Ending Grade (G_2) = +1.600%

Elevation at Beginning (E_0) = 614.00 Ft.

Length of Curve (L) = 340 Ft.

Stationing Intervals = 100 Ft.

STATION	ELEVATION (E_S)
17 + 00.00	614.000
18 + 00.00	613.327
19 + 00.00	613.438
20 + 00.00	614.332
20 + 40.00	614.910



LINE	DATA	OPERATIONS	DISPLAY	REMARKS
1.	G_2	ENT		Grades in %
2.	G_1	− 5 0 X		
3.	Length of Curve (L)	÷ STO		
4.	Beginning Elevation (E_O)	ENT		
5.	Distance in Stations	ENT ENT X RCL X		
6.		X⇄Y		
7.	G_1	X + +	Elevation (E_S)	Record
8.		CLX		Return to step 5

NOTES

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