MNDOT HP35s Surveying Software

User Manual, v1.0

07 May 2025

Table of Contents

Notice

This document is not a product of the Minnesota Department of Transportation (MnDOT) nor is the author affiliated with that organization. It is wholly independently written as supplemental information for MnDOT's Hewlett-Packard HP35s surveying software. The author is solely responsible for any typographic or instructional errors in this manual; corrections and feedback should be sent to me at jerry.mahun@gmail.com.

Jerry Mahun, April 2025 https://jerrymahun.com

A. Introduction

Despite the Hewlett-Packard HP35s being out of production and difficult to find, it is still a popular calculator for surveying computations. It is a programmable calculator and its biggest drawback, outside of availability, is that programs must be manually entered. Unlike HP's earlier programmable scientific calculators (e.g., 41 and 48SX/GX) it has no external communication ports. When it first appeared, a number of commercial surveying programs were available for the HP35s. Today those are rare and expensive.

The HP35s and 33s are the *only* HP calculators allowed on the NCEES[1] surveying and engineering exams, Figure 1. The NCEES Calculator Policy *does not* specifically prohibit using a programmed HP33/35 on the exams.

> To protect the integrity of its exams, NCEES limits the types of calculators examinees may bring to exam sites. The list of approved calculators is reviewed annually.
>
> The following calculator models are the only ones acceptable for use during the 2025 exams:
>
> - **Casio:** All fx-115 and fx-991 models (Any Casio calculator must have "fx-115" or "fx-991" in its model name.)
> - **Hewlett Packard:** The HP 33s and HP 35s models, but no others
> - **Texas Instruments:** All TI-30X and TI-36X models (Any Texas Instruments calculator must have "TI-30X" or "TI-36X" in its model name.)

Figure 1: NCEES Calculator Policy

The MnDOT Office of Land Management[2] has developed software for desktop computers and HP calculators. These include a pretty extensive calculator survey software package. The package consists of about 20 individual programs. Many examiners find the combination of a HP35s loaded with the Mn Dot programs a time-saver on the NCEES exams.

MnDOT's documentation includes programming information and very basic software operating instructions leaving it to the user to figure out how to use the software. This document was created to provide more detailed software operation and explanation. Each program is covered using an example problem with step-by-step solution instructions. Program limitations, where applicable, are identified.

The software is available for free, although you have to program the HP35s on your own. Entering the software in the calculator is a time-consuming task. Reading through this document can give you an idea of whether you consider the effort worth it for your particular situation. The best way to evaluate the software is to use it, which is sort of a chicken-and-egg situation: To evaluate it, you have to have access to a calculator programmed with it. Should you try to chase down a HP35s (if you don't have one), pay whatever the going rate is for it, then spend hours programming it, before you can evaluate it? A useful alternative, and one which I use all the time to answer questions about the software, is to use a Windows HP35s emulator loaded with the programs. The emulator is available for free and I have the program module for it on my website. Instructions how to obtain both are at **https://jerrymahun.com** under **Home | Software | HP Calculator Resources.** You can be up and running with the programmed emulator in a matter of minutes.

1 National Council of Examiners for Engineering and Surveying; https://ncees.org

2 Should the link change, as internet addresses do with frightening regularity, either search on "MnDOT HP35 Surveying" or let me know.

B. General Information

1. Typeface Conventions

Different fonts are used in this document to indicate various calculator and user operations. These are:

1234.5678	Calculator display
[Enter]	Calculator key
8765.4321	User entry
250.22356	Problem answer

2. Keyboard

The HP35s has roughly a bazillion functions all accessed using 41 keys. To do this the calculator uses menus and multi-function keys. Most keys have three operational functions indicated by their color and text location:

white - key face; primary function accessed by pressing key directly.

yellow - above key; secondary function accessed by pressing yellow left-arrow key, **[↰]**, first.

blue - on lower left key face; secondary function accessed by pressing blue right-arrow key, **[↱]**, first.

Many of the keys also have a red letter on their lower right face. These are labels for memories and programs.

While all these labels and operations may be initially confusing, there are initially just a handful which you will routinely use.

Figure 2: HP35s Keyboard

3. Display Format

The HP35s has two primary display lines beneath the small status line at the top.

- In normal calculations, the top display line shows the previously entered number or result, the bottom line shows the current input value or computation result.
- In a program, the top line is generally used as a label or prompt, the bottom for input or results.

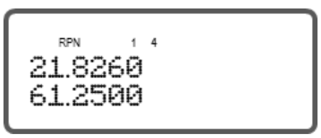


Figure 3: Calculator

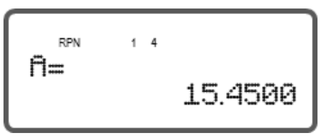


Figure 4: Program

By default, numbers are displayed with a fixed number of decimal places. Input and computation results are rounded to this format, although the calculator carries more digits internally.

To change the display format, press the **[↰] [<]** sequence. Display options are:

[1] FIX allows you to specify how many decimal places to display

[2] SCI scientific notation; can specify how may decimal places to display

[3] ENG like scientific notation except exponents are multiples of 3

[4] ALL is a floating format which shows as many decimal places as necessary

The number of decimal places needed depends on the type of calculation.

Four decimal places are sufficient to display angles in degree-minute-second to the nearest second. On the other hand, an angle in DD to four decimal places is good to roughly 0.4 seconds. Increasing the format to five decimal places minimizes display rounding.

The number of digits displayed is not necessarily the accuracy of a calculation or program result. The operator must determine to what level a result is reported based on the type of calculation and accuracy of numbers used.

The calculator defaults to the last display format used.

4. Calculation Mode

The HP35s can operate in *algebraic* or *reverse polish notation* (RPN) mode. The primary difference is how numbers and operations are entered.

In algebraic mode, expressions are entered left-to-right as they are written: number-operation-number. Pressing the **[ENTER]** key evaluates the expression.

3 times 8 is: 3 **[X]** 8 **[ENTER]**

In RPN mode, numbers are entered in the stack followed by the operation to perform on them: number-number-operation. The **[ENTER]** key pushes a number onto the stack; the operation key executes the expression on the last numbers entered. It sounds more complicated than it is.

3 times 8 is: 3 **[ENTER]** 8 **[X]**

Although initially not as intuitive as algebraic mode, RPN is more efficient for longer expressions, particularly those with nested operations.

To change the calculation mode press **[MODE]** then either **[4]** for algebraic mode or **[5]** for RPN. The display will show ALG or RPN on the status line to indicate the active calculation mode.

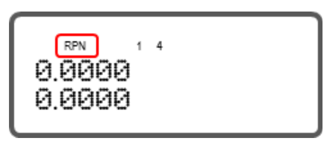


Figure 5: RPN Mode

Earlier HP calculators used RPN exclusively; later models supported algebraic and RPN modes. Which to use is a matter of preference. However, the MnDOT survey programs are written in RPN so the calculator must be in RPN mode or incorrect answers will result.

5. Angles

a. Angle Mode

The calculator must be in Degree mode, not Radians or Grads. If the calculator is in radians mode, RAD will be displayed in the status line; GRAD if in grads, and no indicator if it's in Degrees mode. To set angular mode to Degrees, press **[MODE]** then **[1]**.

b. Angle Entry & Display

(1) Conversions

Angle math and trig functions require angles be in decimal degrees (DD). The user must convert degree-minute-second (DMS) angles to DD before performing angle math.

DMS angles are entered as DDD.MMSSsss; e.g., 24°18'02.36" entered as 24.180236

The calculator displays angle results in DD which the user must convert to DMS.

To convert angles between DMS and DD:

DMS to DD **[↰] [HMS→]**

DD to DMS **[↱] [→HMS]**

Because time has the same divisions as angles, the HP calculators traditionally uses HMS (hours-minutes-seconds) nomenclature.

Enter	Press	Display
Convert 174°00'08" to DD		
174.0008	**[↰] [HMS→]**	174.0022 **174.0022°**
Convert 23.18002° to DMS		
23.18002	**[↱] [→HMS]**	23.1048 **23°10'48"**

(2) Calculations

Addition/subtraction

Angles in DMS are converted on-the-fly to DD while entering the expression.

To add 56°18'35" and 142°02'20":

56.1835 **[↰] [HMS→] [ENTER]** 142.0220 **[↰] [HMS→] [+]**

Calculator displays: 198.38661 in DD

[↱] [→HMS] to convert to D.MS

Calculator displays: 198.20550 in which is 198°20'55.0"

Trigonometric functions

Trig functions are performed on angels in DD.

sin(32°15'20"): 32.1520 **[↰] [HMS→] [SIN]**

Calculator display: 0.53370

Inverse trig functions return an angle in DD

$\cos^{-1}$(0.73216): 0.73216 **[↱] [COS]**

Calculator display: 42.9322

(3) MnDOT Programs

Angles and directions are entered and displayed in DMS format. Programs perform their own conversions internally as needed.

6. Accidental Program Loss

Nothing can be as frustrating as investing the time to manually enter the software then doing something that completely erases it. There are two primary ways this can happen, both controlled by the user:

a. Batteries

As long as the batteries have some degree of life the HP35s will retain its memory contents, including programs, whether the calculator is on or off. The calculator uses two larger coin batteries as its main power source (it has no adapter port). When the batteries are low an icon will be displayed. Change the batteries as soon as possible or risk program loss. Replace the batteries one at a time. As long as one minimally live battery is in the calculator its memory contents will be preserved. Removing both batteries at the same time will immediately wipe everything. Immediately. Everything.

b. User error

Other HP35s functions, like statistics, require that memory registers be cleared before running. Memory registers are separate from the program space. Unfortunately, the menu to clear memory registers contains the command to clear the program space also.

[↱] [←] opens the CLEAR menu. **Do not** select 3 ALL as that will delete *everything* stored in the calculator including programs.

There is no **undo** function so once erased the programs are GONE and must be painstakingly manually re-entered.

1 x   2 VARS
3 ALL 4 Σ

Figure 6: CLEAR Menu

C. Some Preliminaries

1. The Cast of Characters

a. Programs

	Program	Checksum		Program	Checksum
A	Traverse Area	B275	N	Dist-Dist Intersection	A456
B	Brng to Az	458E	O	na	- -
C	Triangle SSS	3EE3	P	na	- -
D	Triangle SAS	D75D	Q	Az to Brng	7CE8
E	Triangle SAA	57A9	R	Radial Inverse	3440
F	Triangle ASA	93A9	S	Stub	CAAF
G	Triangle SSA	6A94	T	Traverse	B397
H	Horizontal Curve	822F	U	Subroutines*	0366
I	Coord Inverse	6CEB	V	Vertical Curve	C54B
J	na	- -	W	Subroutines*	EC5D
K	na	- -	X	na	- -
L	Dir-Dir Intersection	0183	Y	na	- -
M	Dir-Dist Intersection	D8B2	Z	na	- -

*Programs U and W contain subroutines called by other programs. They are not executed directly by the user.

The letter in the column left of the program name is the label used to start it and corresponds to the red letters on the calculator keys. When the **[XEQ]** key is pressed, the next key will be one of the red letters.

Program startup key sequence is **[XEQ] [LABEL] [ENTER]**.

b. Checksum

The checksum value is used to verify a program is entered correctly. It isn't a foolproof method but it does serve as a simple check when:

Entering a program

A program isn't behaving as expected.

To check a program's checksum:

Display	Enter	Press	Comments
		[↰] [MEM]	
1VAR 2PGM 0 26,044	2	**[2]**	Check programs
LBL Q LN=54		[∧] or [∨]	Your display may vary. Use arrows keys until LBL is the desired program
LBL I LN=60		**[↰] [SHOW]**	
CK=6CEB LN=60		**[SHOW]**	CK is the checksum. Display is momentary unless **[SHOW]** is held pressed.
		[∧] or [∨]	To advance to next program
		[C]	To exit

2. Program interaction

a. Run/Stop

When prompted, the user enters numeric data followed by pressing the **[R/S]** key. **[R/S]** stands for *Run/Stop*. When a program executes, it stops when it needs data or to show a result, until the user tells it to continue running.

A common error is using the **[ENTER]** key instead of **[R/S]**. Pressing **[ENTER]** only pushes the displayed value onto the stack - it generally has no effect on program operation.

b. Data Entry

When a program prompts for input, the default value shown will either be 0.00000 or a previously entered value.

The displayed value can be accepted by pressing **[R/S]**.

A different value can be entered using the numeric keypad followed by **[R/S]**.

Default data in this document's example problems may differ from the reader's depending on the last operation performed or number entered.

c. Prompts

Most programs generaly use single-letter prompts when requesting data or showing a result. Unfortunately, the same letter can mean something different depending on the program. For example, A is

Angle in the Triangle Solutions
Azimuth in Intersection, Direction Conversion, and Traversing
Area in Area
Intersection Angle in Horizontal Curve

Often the context will make the prompt meaning apparent; familiarity will also come from repeated program use.

d. Coordinate Order

The programs prompt for, and display, coordinates in X/Y order. Many surveyors commonly work in N/E format. Be sure to adjust accordingly otherwise you will get erroneous results although they may not be obvious.

3. Much But Not All

The survey programs handle a lot of the mundane and repetitious computations but they don't do everything. Unlike a computer, the HP35s has a relatively small memory so not all surveying calculations are covered.

Most of the programs are standalone which solve a specific problem, like the triangle solutions and coordinate inverse.

Others are for more complex surveying situations having multiple parts. These compute basic information which can be used (along with one's surveying knowledge) to manually compute other things. These include **Azimuth Traverse**, **Horizontal Curve**, and **Vertical Curve**.

Program	Computes	Doesn't compute
Azimuth Traverse	Coordinates from azimuth and distance	Traverse closure, precision, adjustment
Horizontal Curve	Curve components, PC/PT stations; Areas	Deflection angle and radial chord to curve points
Vertical Curve	High/low station and elevation, elevation at curve station	PVC/PVT station and elevation; grade at any point

D. Using the Programs

Before running the programs make sure:

- Calculator is in RPN mode
- Number base is decimal
- Angle mode is Degrees
- Display format is at least 4 decimal places (5 is better and is used for the examples[3])

1. Triangle Solutions

A triangle has six parts: three angles and three sides. Three parts must be known including at least one side to geometrically define a triangle. Based on the combination of known parts and their arrangement, one of the five triangle solution programs can be used to determine the remaining parts and triangle area.

Program	Start	Name
[C]	**[XEQ] [XEQ] [ENTER]**	Side-side-side
[D]	**[XEQ] [MODE] [ENTER]**	Side-angle-side
[E]	**[XEQ] [R↓] [ENTER]**	Side-angle-angle
[F]	**[XEQ] [X◆Y] [ENTER]**	Angle-side-angle
[G]	**[XEQ] [i] [ENTER]**	Side-side-angle

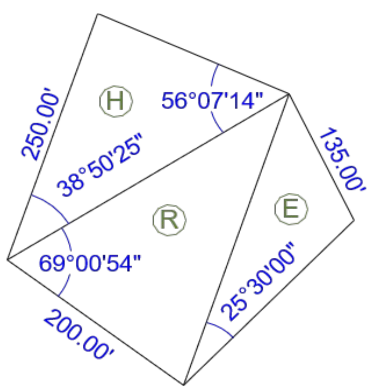
The program **Name** indicates data entry order which may be clockwise (cw) or counter-clockwise (ccw) around the triangle.

Example

Solve the missing parts of each triangle using the appropriate program.

A triangle must have at least three parts fixed in order to solve the remaining parts. Of the triangles shown, Only triangle H meets the condition.

Use Program **[E]** side-angle-angle to compute triangle H's missing parts.



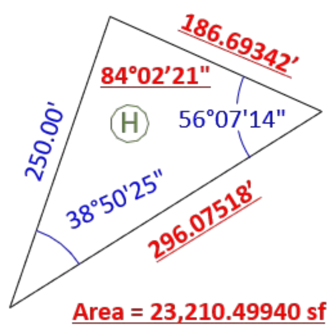
Program **[E]** Start: **[XEQ] [R↓] [ENTER]**

Display		Enter	Press	Comments
S?				Enter the distance
	0.00000	250	**[R/S]**	
A?				Enter the angle at the end of the distance
	0.00000	38.5025	**[R/S]**	

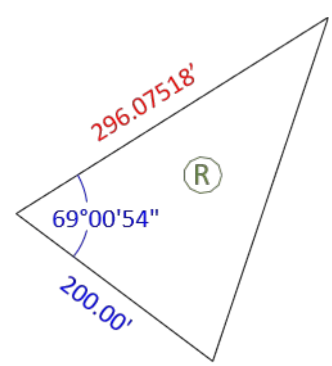
3 Even though 5 decimal places will always be shown, that does not mean the results are accurate to that level.

Display	Enter	Press	Comments
A?			Enter second angle
38.50250	57.0714	[R/S]	
56.07140 250.00000			Known angle opposite known side Known side
		[R/S]	
84.02210 296.07518			Computed third angle Opposite side
		[R/S]	
38.50250 186.69342			Second known angle Opposite side
		[R/S]	
23,210.49940			Area

Answers:



Since Triangle R shares a side with H, it can now be solved using Program **[D]** side-angle-side. Can go either cw or ccw around the triangle.



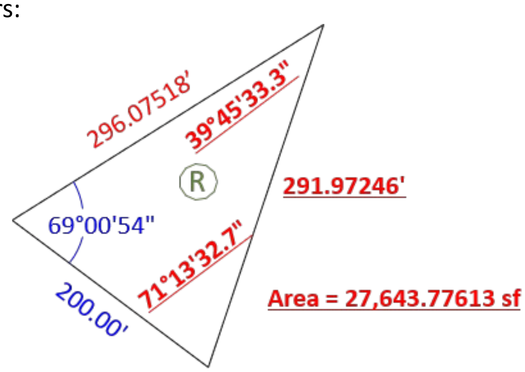
Program **[D]** Start: **[XEQ] [MODE] [ENTER]**

Going clockwise...

Display	Enter	Press	Comments
S?			Enter first side.
0.00000	296.07518	[R/S]	
A?			Enter the angle
160.90200	69.0054	[R/S]	
S?			Enter second side
296.07518	200.00	[R/S]	

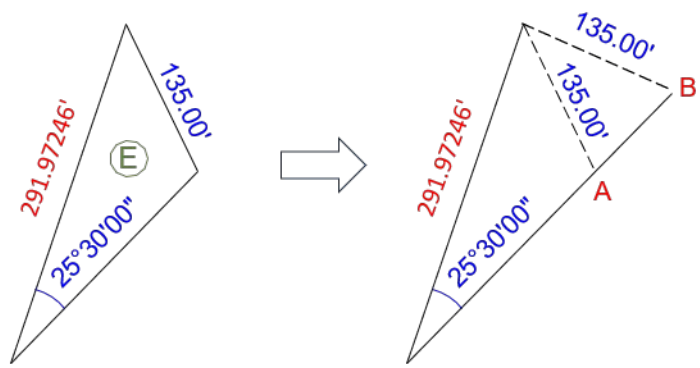
Display	Enter	Press	Comments
71.13327			Angle opposite first side.
296.07518			First side
		[R/S]	
39.45333			Angle opposite second side
200.00000			Second side
		[R/S]	
69.00540			Third angle.
291.97246			Third side.
		[R/S]	
27,643.77613			Area

Answers:



And finally triangle E can be solved because of the side shared with triangle R. Use Program **[G]**: side-side-angle.

When only a single angle is a given, there are two possible triangle solutions. The side opposite the angle serves as an arc radius intersecting the adjacent side at two locations. In triangle E the 135.00' distance creates these two intersections at A and B:



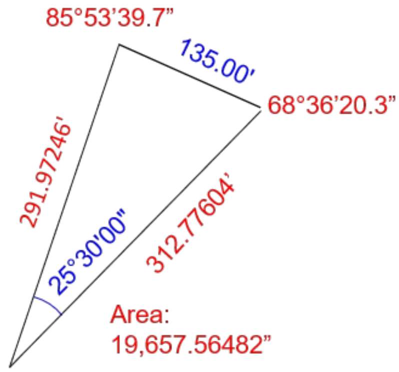
Angle A is greater than 90°, B is less than 90°. The program will compute both solutions; it's up to the user to determine which is the correct one.

Program **[G]** Start: **[XEQ] [i] [ENTER]**

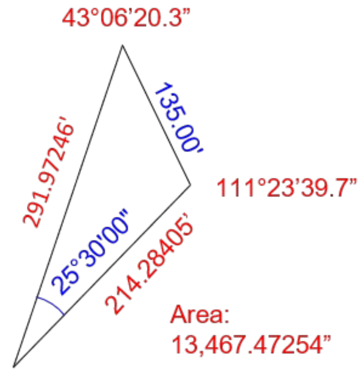
Start at 135.00' and go ccw...

Display	Enter	Press	Comments
S?			Enter first side.
0.00000	135	**[R/S]**	
S?			Enter second side
135.00000	291.97246	**[R/S]**	
A?			Enter angle
291.97246	25.30	**[R/S]**	
SOLUTION 1			First solution will be presented
		[R/S]	
25.30000			Angle opposite first side.
135.00000			First side
		[R/S]	
68.36203			Angle opposite second side
291.97246			Second side
		[R/S]	
85.53397			Third angle.
312.77604			Third side.
		[R/S]	
19,657.56482			Area
		[R/S]	
SOLUTION 2			Second solution will be presented
		[R/S]	
25.30000			Angle opposite first side.
135.00000			First side
		[R/S]	
111.23397			Angle opposite second side
291.97246			Second side
		[R/S]	
43.06203			Third angle.
214.28405			Third side.
		[R/S]	
13,467.47254			Area
		[R/S]	

Answers:



Solution 1



Solution 2

The intersection angle is greater than 90° so **Solution 2** is correct.

2. Direction Conversions

a. Azimuth to Bearing

Convert 294°25'47" Az

Program **[Q]** Start: **[XEQ] [EQN] [ENTER]**

Display	Enter	Press	Comments
A?			Enter azimuth
0.0000	294.2547	**[R/S]**	
B=			
65.34130			Bearing angle
		[R/S]	
Q=			
4.00000			Quadrant 4 = NW

Answer: **N 65°34'13.0"W**

b. Bearing to Azimuth

Convert S 18°40'22" E bearing

Program **[B]** Start: **[XEQ] [GTO] [ENTER]**

Display	Enter	Press	Comments
B?			Enter bearing angle.
0.0000	18.4022	**[R/S]**	

Q?	2		Enter bearing quadrant.
0.0000		[R/S]	
A=			
161.19380			Azimuth

Answer: **161°19'38.0"**

3. Coordinate Inverse

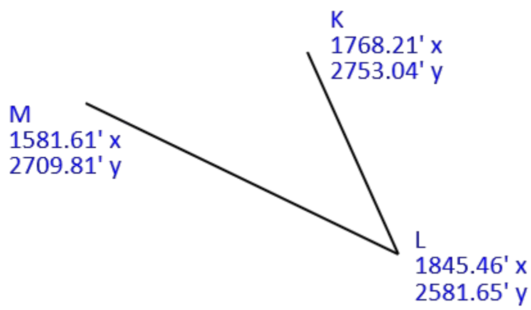
An inverse uses coordinate pairs to compute the distance and direction between them. There are two inverse routines in the software.

a. Point to point

Used for a line. Can compute successive lines: coordinates of the first line's second point became default values for the first point of the next line.

Example

Determine distances and directions of the two traverse legs starting at K.



Program **[I]** Start: **[XEQ] [COS] [ENTER]**

Display	Enter	Press	Comments
First PT			
X?			Enter first point's X
0.00000	1768.21	[R/S]	
Y?			
0.00000	2753.04	[R/S]	Enter first point's Y
NEXT PT			
X?			Last entered X is shown.
1,768.21000	1845.46	[R/S]	Enter next X.
Y?			Last entered Y is shown.
2,753.04000	2581.65	[R/S]	Enter new Y.
D=			
187.99493			Distance
		[R/S]	
A=			
155.44155			Azimuth
		[R/S]	

Display	Enter	Press	Comments
FIRST PT			
X?			Last entered X is shown.
1,845.46000		[R/S]	Accept.
Y?			Last entered Y is shown.
2581.65000		[R/S]	Accept.
NEXT PT			
X?			Last entered X is shown.
1,845.46000	1581.61	[R/S]	Enter next X.
Y?			Last entered X is shown.
2,581.65000	2709.81	[R/S]	Enter next Y.
D=			
293.32884			Distance.
		[R/S]	
A=			
295.54261			Azimuth.

Answers

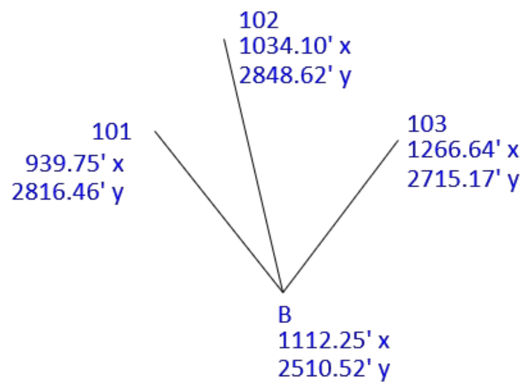
Line	Length	Azimuth
KL	187.99493’	155°44’15.5”
LM	293.32884’	295°54’26.1”

b. Radial from fixed point

Inverse from a single stationary point and to multiple points. The stationary point position is entered once, then the other points are entered in turn.

Example

Determine the distances and directions from point B to points 101, 102, and 103.



Program **[R]** Start: **[XEQ] [7] [ENTER]**

Display	Enter	Press	Comments
FIRST PT	1112.25		Enter coordinates of point B.

Display		Enter	Press	Comments
X?				
	0.0000		[R/S]	X
Y?				
	0.0000	2510.52	[R/S]	Y
NEXT PT				First radial point.
X?				Last entered X is shown.
	1,112.25000	939.75	[R/S]	Enter next X.
Y?				Last entered Y is shown.
	2,510.52000	2816.46	[R/S]	Enter next Y.
D=				
	357.78420			Distance.
			[R/S]	
A=				
	328.46134			Azimuth.
			[R/S]	
NEXT PT				Next radial point.
X?				Last entered X is shown.
	939.75000	1034.10	[R/S]	Enter next X.
Y?				Last entered Y is shown.
	2,816.46000	2848.62	[R/S]	Enter next Y.
D=				
	350.12129			Distance.
			[R/S]	
A=				
	344.54434			Azimuth.

Distance and diretion from point B to point 103 is computed the same.

Answers

Display	Enter	Press
B-101	357.78420	328°46’13.4”
B-102	350.12129	344°54’43.4”
B-103	248.74235	34°38’24.3”

4. Traversing

Traversing starts with a coordinate pair and computes a second pair given a distance and direction. It is the opposite of an inverse computation.

a. Sequential Lines

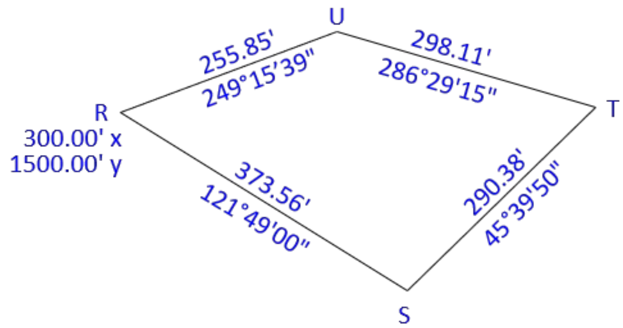
Point coordinates are computed along sequential traverse legs. The end point of one traverse leg becomes the first point of the next leg. The traverse can be a loop or link.

The program does not compute misclosure, precision, nor adjust the traverse.

Example

Starting at R compute point coordinates going around the traverse.

The azimuth values indicate the travel direction is ccw around the traverse.



Program **[T]** Start: **[XEQ] [9] [ENTER]**

Display	Enter	Press	Comments
FIRST PT X? 0.00000	300	**[R/S]**	Enter first X.
Y? 0.00000	1500	**[R/S]**	Enter first Y.
A? 0.00000	121.4900	**[R/S]**	Enter azimuth to next point.
D? 0.00000	373.56	**[R/S]**	Enter distance to next point.
X= 617.42864			Next point X is displayed.
		[R/S]	
Y= 1,303.05805			Next point Y is displayed.
		[R/S]	
First PT X? 617.42864		**[R/S]**	Last point is first point of next line. Last computed X is shown; accept it.
Y? 1,303.05805		**[R/S]**	Last computed Y is shown; accept it.
A? 121.49000	45.3950	**[R/S]**	Last entered azimuth is shown. Enter azimuth to next point.
D? 373.56000	290.38	**[R/S]**	Last entered distance is shown. Enter distance to next point.
X= 825.12363			Next point X is displayed.

[R/S]

Y=
1505.99482

Next point Y is displayed.

Continue…

With a closed loop traverse, compute back into the first point as a check.
If the traverse has been adjusted the end and start coordinates will be the same.
If they differ that means either the traverse data is unadjusted or there was an entry error.

Answers

Point	X	Y
S	617.42864	1,303.05805
T	825.12363	1,505.99482
U	539.27142	1,590.60027
R	299.99994	1,500.00015

Rounding error closing back to R. Matches when rounded to a reasonable 2-3 decimal places.

b. Radial (Stub)

Positions are computed radially from an instrument location. Data input starts with a coordinate pair at the instrument, then continue with an azimuth and distance to each radial point.

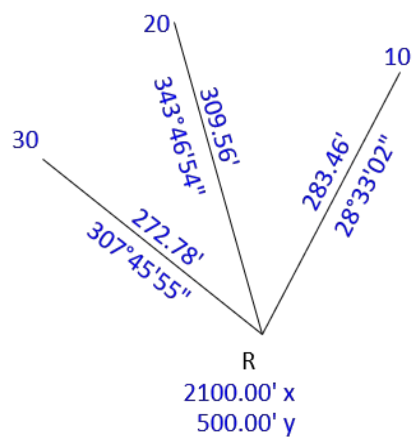
Program **[S]** Start: **[XEQ] [8] [ENTER]**

Example

The instrument is located at point R.

Compute the coordinates of points 10, 20, and 30.

Because azimuths are used, it doesn't matter in which order the point coordinates are computed.



Program **[S]** Start: **[XEQ] [8] [ENTER]**

Display	Enter	Press	Comments
FIRST PT			
X?			Last entered X is shown.
0.00000	2100	[R/S]	Enter X.
Y?			Last entered Y is shown.
0.00000	500	[R/S]	Enter Y.
A?			
0.00000	28.3302	[R/S]	Enter azimuth to first point.
D?			
0.00000	283.46	[R/S]	Enter distance to first point.
X=			
2,235.47517			X coordinate.
		[R/S]	
Y=			
748.99006			Y coordinate.
		[R/S]	
A?			
28.33020	343.4654	[R/S]	Enter azimuth to next point.
D?			
283.46000	309.56	[R/S]	Enter distance to next point.
X=			
2,013.54040			X coordinate.
		[R/S]	
Y=			
767.24086			Y coordinate.

Continue...

Answers

Point	X	Y
10	**2,235.47517**	**748.99006**
20	**2,013.54040**	**767.24086**
30	**1,884.36024**	**667.05814**

5. Traverse Area

The area of a closed loop traverse is computed by coordinates entered in sequence around the traverse The first coordinate pair must be repeated at the end at which point the area will be displayed.

It doesn't matter which point you start with or which direction (cw/ccw) you go around the traverse - pick one, go in sequence , and re-enter the first point at the end.

The area is calculated using a basic mathematic polynomial equation. As long as coordinates are entered it will calculate an area even of the area doesn't make any sense. For example, a crossing traverse, Figure 7, doesn't have a consistent "interior" so it does not have a realistic area. But the program will compute a value for it.

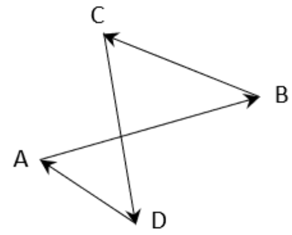
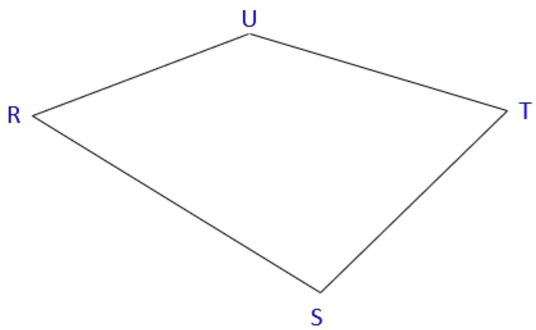


Figure 7: Crossing Traverse

Example

Compute the area of the traverse shown.



Point	*X*	*Y*
R	300.00	1,500.00
S	617.43	1,303.06
T	825.12	1,505.99
U	539.27	1,590.60

Program **[A]** Start: **[XEQ] [R/S] [ENTER]**

Start at point R and travel ccw

Display	Enter	Press	Comments
FIRST PT			
X?			Last entered X is shown.
0.00000	300	**[R/S]**	Enter next X.
Y?			Last entered Y is shown.
0.00000	1500	**[R/S]**	Enter next Y.
NEXT PT			
X?			Last entered X is shown.
300.00000	617.43	**[R/S]**	Enter next X.
Y?			Last entered Y is shown.
1,500.00000	1303.06	**[R/S]**	Enter next Y.

Display	Enter	Press	Comments
NEXT PT			
X?			Last entered X is shown.
617.43000	825.12	[R/S]	Enter next X.
Y?			Last entered Y is shown.
1,303.06000	1505.99	[R/S]	Enter next Y.
NEXT PT			
X?			Last entered X is shown.
825.12000	539.27	[R/S]	Enter next X.
Y?			Last entered Y is shown.
1,505.99000	1590.60	[R/S]	Enter next Y.
NEXT PT			
X?			Last entered X is shown.
539.27000	300	[R/S]	Enter first X.
Y?			Last entered Y is shown.
1590.60000	1500	[R/S]	Enter first Y.
F=			
75,730.59160			Area, sq ft
		[R/S]	
A=			
1.73854			Area, acres
		[R/S]	
P=			
1,217.88956			Perimeter

Answer: **39,840.09160 sq ft = 0.91460 acres**
Perimeter is 1,720.10047'

Your result may be a negative area - not to worry. The coordinate area equation takes the difference between cross-multiplication sums. Depending on the computation direction around the traverse the result could be positive or negative. Simply use the absolute value.

6. Intersections

Intersections are used to determine the horizontal position of a remote point using a single measurement (distance or direction) from each of two control points. The two control points form a baseline, one side of a triangle. There are three different intersections depending on the measurement type at each control point.

Direction-direction
Distance-distance
Direction-distance

Every other type of intersection is just a variation of one of these three.

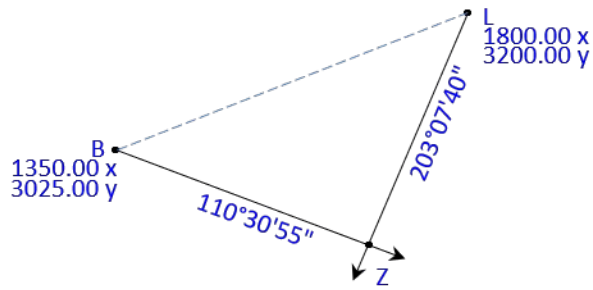
The intersection results include the computed coordinates and the missing data (distance or direction) from each control point.

a. Direction-Direction

Example

Given the two azimuths from points B and L, determine the position of point Z.

A direction-direction intersection results in a single solution.

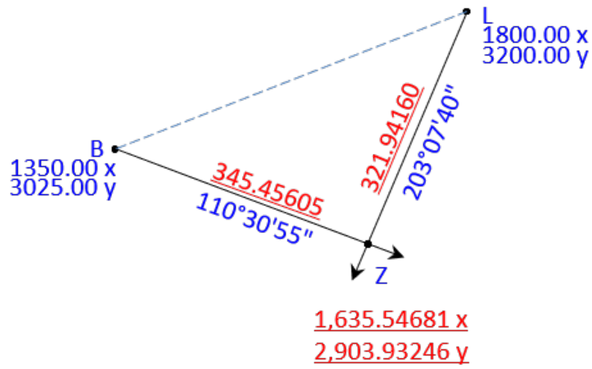


Program **[L]** Start: **[XEQ] [y^x] [ENTER]**

Either point can be entered first.

Display	Enter	Press	Comments
FIRST PT			
X?			Start with point B
0.00000	1350	**[R/S]**	Enter X.
Y?			
0.00000	3025	**[R/S]**	Enter Y.
A?			
-999.00000	110.3055		Azimuth from first point.
NEXT PT			Enter point L
X?			Last entered X is shown.
1,350.00000	1800	**[R/S]**	Enter next X.
Y?			Last entered Y is shown.
3,025.00000	3200	**[R/S]**	Enter next Y.
A?			
-999.00000	203.0740	**[R/S]**	Azimuth from second point.
X=			
1,673.54681			Intersection X
		[R/S]	
Y=			
2903.93246			Intersection Y
		[R/S]	
D=			
345.45605			Distance from first point
		[R/S]	
D=			
321.94160			Distance from second point

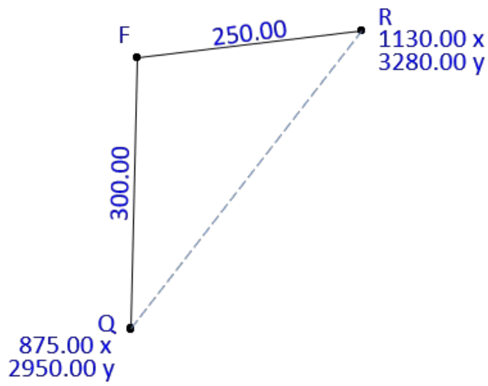
Answers



b. Distance-Distance

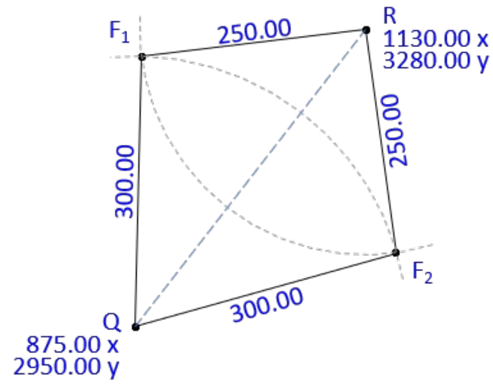
Example

Determine the position of point F.



A distance-distance intersection results in two identical triangles mirrored about the base line. That means there are two possible locations for the intersection point. The software will compute and display both (SOL1 and SOL2).

A circle-circle or arc-arc intersection is the same as a distance-distance intersection. The base line connects the curvature center of each arc and the radii are the intersecting distances.

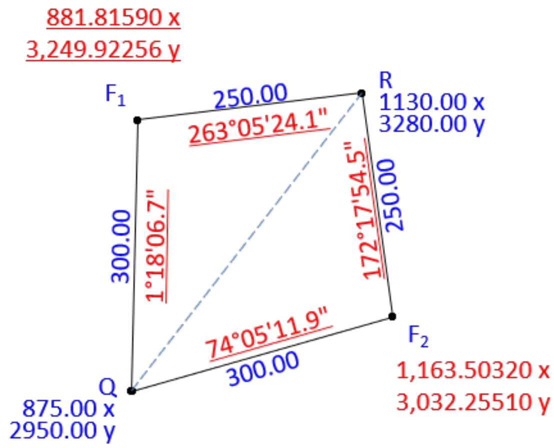


Program **[N]** Start: **[XEQ] [+/-] [ENTER]**

Either point can entered first.

Display	Enter	Press	Comments
FIRST PT			
X?			Start with point R
0.00000	1130	[R/S]	Enter X.
Y?			
0.00000	3280	[R/S]	Enter Y.
R?			
0.00000	250	[R/S]	Enter the distance from first point.
NEXT PT			
X?			Last entered X is shown.
1,130.00000	875	[R/S]	Enter next X.
Y?			Last entered Y is shown.
3,280.00000	2950	[R/S]	Enter next Y.
R?			
250.00000	300	[R/S]	Enter distance from second point.
SOL 1			First solution
		[R/S]	
X=			
881.81590			Intersection X
		[R/S]	
Y=			
3,249.92256			Intersection Y
		[R/S]	
Z=			
263.05241			Azimuth from first point
		[R/S]	
Z=			
1.18067			Azimuth from second point
		[R/S]	
SOL 2			
		[R/S]	
X=			
1,163.50320			Intersection X
		[R/S]	
Y=			
3,032.25510			Intersection Y
		[R/S]	
Z=			
172.17545			Azimuth from first point
		[R/S]	
Z=			
74.05119			Azimuth from second point

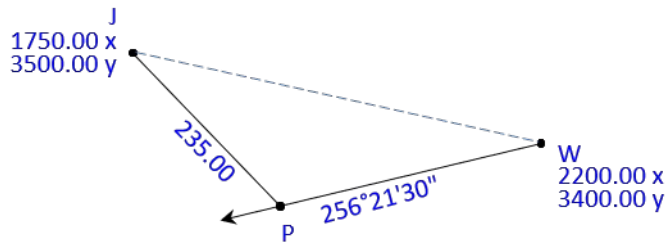
Answers



c. Direction-Distance

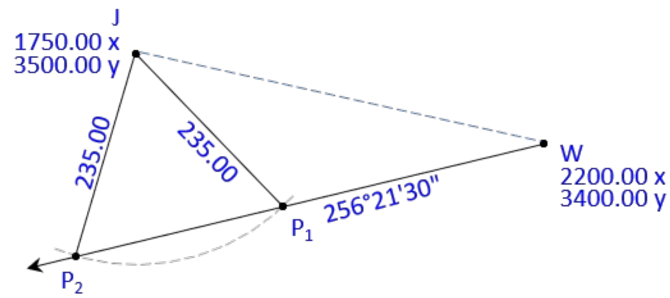
Example

Determine the position of point P.



A direction-distance intersection results in two possible locations for the intersection point. Two different triangles are formed which share two side lengths and one angle. The interior angle at the intersection point is <90° for one triangle and >90° for the other.

The software will compute and display both (SOL1 and SOL 2) intersections.



A direction-circle or direction-arc intersection is the same as a direction-distance intersection. The base line connects the center of curvature to the direction point; the radius is the intersecting distance.

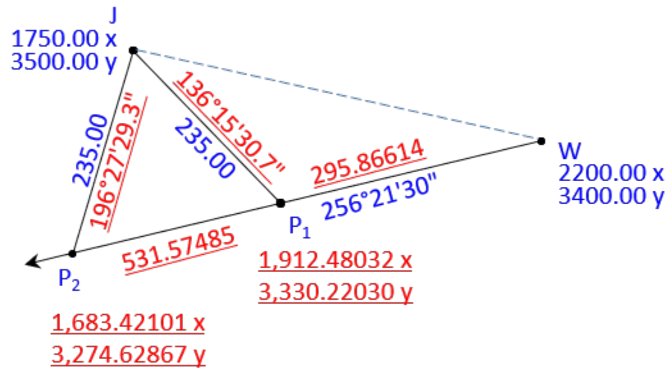
The direction point is entered first.

Program **[M]** Start: **[XEQ] [1/x] [ENTER]**

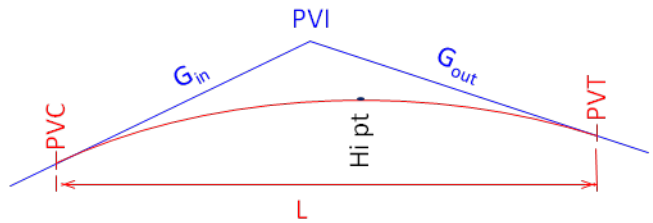
Display	Enter	Press	Comments
FIRST PT			
X?			Point W
0.00000	2200	**[R/S]**	Enter X.

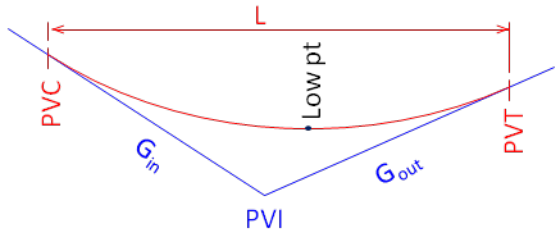
Display	Enter	Press	Comments
Y? 0.00000	3400	[R/S]	Enter Y.
A? -999.00000	256.2130	[R/S]	Azimuth from first point.
NEXT PT X? 2,200.00000	1750	[R/S]	Last entered X is shown. Enter next X.
Y? 3,400.0000	3500	[R/S]	Last entered Y is shown. Enter next Y.
R? -999.0000	235	[R/S]	Distance from second point.
SOL 1			First solution.
		[R/S]	
X= 1,912.48032			Intersection X
		[R/S]	
Y= 3,330.22030			Intersection Y
		[R/S]	
Z= 136.15307			Azimuth from second point
		[R/S]	
S= 295.86614			Distance from first point
		[R/S]	
SOL 2			
		[R/S]	
X= 1,683.42101			Intersection X
		[R/S]	
Y= 3,274.62867			Intersection Y
		[R/S]	
Z= 196.27293			Azimuth from second point
		[R/S]	
S= 531.57485			Distance from first point

Answers



7. Vertical Curve





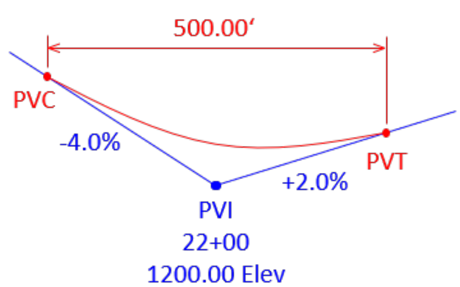
This program computes basic vertical curve information.

Input: PVI station and elevation, grades in and out, curve length.

Output: High/Low point elevation and station; elevation at user provided station

The program **does not** compute the stations and elevations of the PVC and PVT.

Example



Because the program does not compute endpoints, manually compute the PVC and PVT stations:

$Sta_{PVC} = Sta_{PVI} - L/2 = [22+00] - 500.00/2 = [19+50]$

$Sta_{PVT} = Sta_{PVI} + L/2$= [22+00] + 500.00/2 = [24+50]

Input these in the program to get their elevations.

Program **[V]** Start: **[XEQ] [5] [ENTER]**

Display	Enter	Press	Comments
PVI STA	2200	**[R/S]**	
PVI ELE	1200	**[R/S]**	
GR IN	4	**[+/-][R/S]**	
GR OUT	2	**[R/S]**	
VC LEN	500	**[R/S]**	
1,203.33333 2,283.33333			Elevation and station of hi/lo point
		[R/S]	
STA INC	100	**[R/S]**	see below*
S? 2550.00000			Enter a sta at which to compute elev
	1950	**[R/S]**	Enter the pre-computed BVC station
E= 1,210.000000			Elev at the PVC
		[R/S]	
S? 2,050.00000		**[R/S]**	The station will increment by STA INC Accept or enter any other station.
E= 1,206.60000			Elev at 20+50
		[R/S]	
S? 2,150.0000		**[R/S]**	Continue every 100 ft...
E= 1,204.40000			Elev at 21+50 Repeat as needed.
S? 2450			Enter the pre-computed PVT sta.
E= 1205.00000		**[R/S]**	Elev at the PVT

* STA INC is the amount S (station) will automatically increase each time an elevation is computed. Press **[R/S]** to accept the station, its elevation will be computed, and the next station will be displayed. This allows you to quickly step through the curve.

If the PVC station is not a full (or half) station, then for S? enter the first full (half) station on the curve and the program will increment from there.

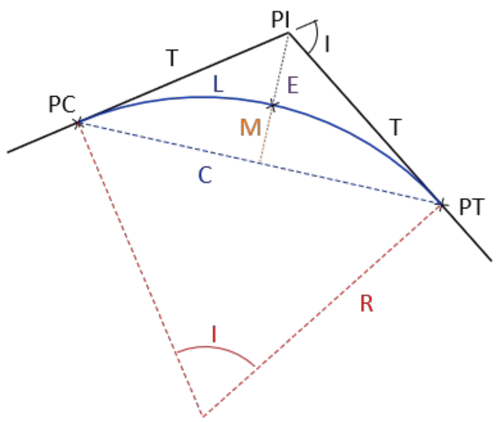
Answers:

Sta	*Elev*	
22+83.33333	1,203.33333	Low point
19+50	1,210.00000	PVC
20+50	1,206.60000	
21+50	1,204.40000	
22+50	1,203.40000	
23+50	1,203.60000	
24+50	1,205.00000	PVT

8. Horizontal Curve

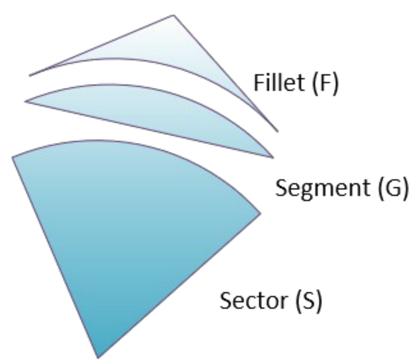
This program solves the geometric elements and areas of a circular curve.

Curve elements:



Two geometric curve elements must be entered; the software will compute the others.
Enter 0's for the unknown components.

The program is set up for the arc definition degree of curvature.



Three different areas are computed
- Fillet (F) - between the curve and tangents.
- Segment (G) - between the chord and curve.
- Sector (S) - bounded by curve and radii.

The program only computes curve elements, PC and PT stations, and areas. It **does not** compute deflection angles or chords to curve points. Those must be manually computed.

Example

600 ft radius curve whose PI station is at 42+50 with a 35°30' intersection angle.

Program **[H]** Start: **[XEQ] [SIN] [ENTER]**

Display	Enter	Press	Comments
A?			Intersection angle
0.00000	35.30	[R/S]	
D?			Deg of curvature
0.00000		[R/S]	
R?			Radius
0.00000	600.00	[R/S]	
A=			Intersection angle
35.30000		[R/S]	
D=			Deg of curve
9.32575		[R/S]	
T=			Tangent dist
192.06151		[R/S]	
L=			Length
371.75513		[R/S]	
R=			Radius
600.00000		[R/S]	
C=			Long chord
365.83716		[R/S]	
M=			Middle ordinate
28.56252		[R/S]	
E=			External
29.99018		[R/S]	
S=			Sector area
111,526.53920		[R/S]	
G=			Segment area
7,000.00717		[R/S]	
F=			Fillet area
3,710.36933		[R/S]	
			Enter PI station
PI STA	4250	[R/S]	
4,057.93849			PC STA
4,429.69362			PT STA

Note: In traditional horizontal curve stationing, there are two ways to determine the PT station:

PT Sta = PC Sta + L

PT Sta = PI Sta + T

The former is the *PT Back* because it is with respect to back along the curve.
The latter is the *PC Ahead* because it is with respect to the alignment ahead of the curve.
Older plans will show these as the Station Equation; *Sta Eqn: PT Back = PT Ahead*
This program calculates the *PT Back*.

Answers

Degree of Curvature	9°32’57.5”	Sector area	111,526.53920
Tangent	192.06151	Segment area	7,000.00717
Curve Length	371.75513	Fillet area	3,710.36933
Long Chord	365.83716	PI Sta	42+50
Middle Ordinate	28.56252	PC sta	40+57.93849
External Dist	29.99018	PT sta	44+29.69362

Appendix A: Basic Statistics

1. Statistical Functions

The HP35s has built-in statistical analysis functions allowing quick determination of mean and standard deviation for a set of numbers.

The two keys located at the right end of the bottom row are used for data entry and statistical analyses in conjunction with the yellow-left and blue-right shift keys.

Keystroke	Function	Action
[Σ+]	[Σ+]	Add to set
[↰] [Σ+]	[Σ-]	Remove from set
[↰] [+]	[x̄.ȳ]	Mean (average) for each data set
[↱] [+]	[s,σ]	standard deviation (s), standard error (σ)

The calculator is able to work with two data sets simultaneously, x and y. It supports analysis of two independent data sets or dependent bi-variate data. Using a single set (e.g., x) is sufficient for typical survey measurements.

2. Population vs Sample

Depending in what is analyzed, either all the data (population) or a representative subset (sample) is used. As an example, consider a bushel basket of oranges. If we want to know the average weight of an orange we can:

- weight each orange in the bushel basket (population) and from those compute the average weight and its spread
- close our eyes and randomly grab a representative handful of oranges (sample) and weigh just those. Their average weight and spread would be used as a prediction for all the oranges in the entire bushel.

The distribution difference is the *Standard Error* (σ, population) and *Standard Deviation* (s, sample). The first is an indicator of *accuracy*, the latter an indicator of *precision*.

The general equations are:

$$MPV = \frac{\Sigma m}{n}$$

$$v = MPV - m$$

$$SE = \sqrt{\frac{\Sigma v^2}{n}}$$

$$SD = \sqrt{\frac{\Sigma v^2}{n-1}}$$

m	individual measurement
n	number of measurements
MPV	Most probable value; mean
v	residual
SE	Standard error (population)
SD	Standard deviation (sample)

As the number of measurements (n) increases, SD becomes closer to SE - sample size begins to approach entire population size.

Surveying is a measurement science that attempts to determine the most likely value of an unknown quantity. To collect an entire population would require an infinite number of measurements, which isn't feasible. Instead, we repeat the measurement enough times for a degree of certainty. Ours is a sample set used that to predict the most probable value. For statistical analysis we use the Standard Deviation. The smaller the standard deviations, the more precise the measurement set.

3. Example

a. Data

A student survey crew taped a distance four times with these results: 231.65 ft, 231.33 ft, 231.54 ft, and 231.57 ft. What s the most probable length of the line and the standard deviation of the measurements?

b. Clear statistical memory

The statistical functions use a special non-volatile memory which must be cleared before new data is entered. Be very careful as this is a way to delete software from Sha

Display	Enter	Press	Comments
0.00000 0.00000		[↱] [←]	Clear the statistical variables
1 x 2 VARS 3 ALL 4 Σ			DO NOT select **3** or the programs will be deleted.
	4		This clears the statistics memory

c. Enter data

An erroneous entry will be included to demonstrate how it is corrected

Display	*Enter*	*Press*	**Comments**
0.00000 0.00000			
	231.65	[Σ+]	Enter first measurement.
0.00000 1.00000			Counter.
	231.33	[Σ+]	Enter second measurement.
0.00000 2.00000			Counter.
	231.54	[Σ+]	Enter third measurement.
0.00000 3.00000			Counter.
	231.75	[Σ+]	Enter fourth measurement.
0.00000 4.00000			Counter.

The last entry was incorrect.

Display	*Enter*	*Press*	**Comments**
	231.75	[↰] [Σ+]	Re-enter the value to remove it
0.00000 3.00000			Counter.
	231.57	[Σ+]	Enter correct value
0.00000 4.00000			Counter.

d. Results

Display	*Enter*	*Press*	**Comments**
		[↰] [+]	Call up the statistics
$\bar{x}$ $\bar{y}$ $\bar{x}$ w 231.52250			x is the mean.
		[↱] [+]	
Sx Sy σx σy 0.13647			Sx is the sample standard deviation

Most probable length is 231.522 ± 0.136

Appendix B: Windows HP35s Emulator

Once The HP35s emulator in installed, it can be operated in one of two ways:

Using the mouse

The keys on the calculator screen image are active and can be selected by clicking with the mouse/touchpad or by touch on a touch screen computer,

This is the digital equivalent of manually using a HP35s.

Using the PC keyboard

The HP35s and standard PC keyboards share many similarities but each also has unique keys. For example: there is no **[ESC]** on the HP35s nor does the PC have a **[R/S]** key.

HP35s keys are mapped to PC keys; where possible, the same keys are used. Unique keys are mapped to others, some that make mnemonic sense, some that don't

HP35s key	PC Key	
[0]-[9]	**[0]-[9]**	
[A]-[Z]	**[a]-[z]**	After **[XEQ]** is pressed
[R/S]	**[a]**	
[XEQ]	**[c]**	
[ENTER]	**[ENTER]**	
[←]	**[BackSpace]**	
[C]	**[ESC] or [Delete]**	
[↰]	**[Shift]**	
[↱]	**[Ctrl]**	
[+/-]	**[n]**	

You are not limited to using one method or the other: you can use both. Somethings are quicker to do on a PC keyboard while others more efficiently done using the mouse.