

Hewlett-Packard
**HP 190/HP 290C
SOLUTIONS**

FINING

INTRODUCTION

This HP-19C/HP-29C Solutions book was written to help you get the most from your calculator. The programs were chosen to provide useful calculations for many of the common problems encountered.

They will provide you with immediate capabilities in your everyday calculations and you will find them useful as guides to programming techniques for writing your own customized software. The comments on each program listing describe the approach used to reach the solution and help you follow the programmer's logic as you become an expert on your HP calculator.

You will find general information on how to key in and run programs under "A Word about Program Usage" in the Applications book you received with your calculator.

We hope that this Solutions book will be a valuable tool in your work and would appreciate your comments about it.

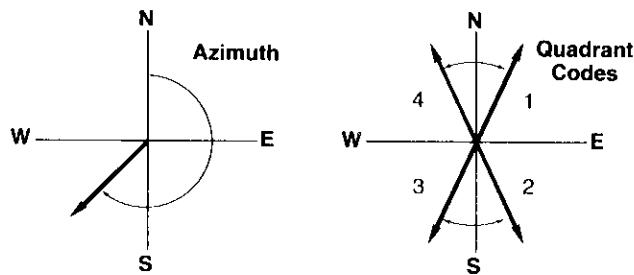
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TABLE OF CONTENTS

AZIMUTH-BEARING CONVERSIONS	1
Simple keystroke sequences and program listings for converting azimuths to bearings, and vice-versa, are provided.	
FIELD ANGLE OR BEARING TRAVERSE*	5
Reduction of field angle or bearing traverse data with closure and area calculations.	
INVERSE WITH CLOSURE	9
Calculates distances and bearings between points in a traverse, given the coordinates. Area and closure data are also calculated.	
SIDESHOTS	12
Calculates coordinates of sideshot points.	
COMPASS RULE ADJUSTMENT	15
Adjusts a traverse by the compass rule.	
CURVE SOLUTIONS	18
Calculates remaining curve parameters and sector, segment and fillet areas given a pair of parameters.	
HORIZONTAL CURVE LAYOUT*	21
Calculates various field data for layout of an horizontal circular curve.	
BEARING-DISTANCE AND BEARING-BEARING INTERSECTIONS	25
This program calculates the point of intersection of two lines given the bearing and distance, or two bearings.	
DISTANCE-DISTANCE INTERSECTION	29
This program calculates the point of intersection of two lines of known length.	
OFFSET FROM A POINT TO A LINE	32
Calculates the offset distance, point of intersection and other parameters from a point offset from a line of known bearing.	
EARTHWORK	35
Calculations of volumes by average end area and volume of borrow pit.	
COORDINATE TRANSFORMATION	39
This program translates, rotates and rescales coordinates from one grid system to another.	

* This program also appears in the HP-19C/29C Applications book, but is included here for the sake of completeness.

AZIMUTH-BEARING CONVERSIONS



Angle conventions for azimuth and quadrant bearings as used in this solution book are shown above.

Thus azimuths are measured from the north meridian following North American surveying conventions. Bearings are measured from the meridian in the quadrant in which the line falls. Quadrant codes are shown in the above sketch.

Often it is desirable to have a quick, easy method to convert to or from azimuths and bearings. In this solutions book, for example, some inputs and outputs may be in azimuths rather than bearings, or vice versa, when you desire the alternate form. The simple key-stroke routines on the following page are helpful in making these conversions: If you have a number of conversions to perform the calculator program will be more convenient and faster. Subroutine 1 converts bearings to azimuths. Subroutine 2 converts azimuths to bearings. You may want to separate the two parts and only key in one section if all your conversions are in one direction.

Example:

1. Convert bearing $S 34^{\circ} 56' 37''W$ to an azimuth.
2. Convert bearing $N 85^{\circ} 24' 47''W$ to an azimuth.
3. Convert azimuth of $162^{\circ} 15' 32''$ to bearing/quadrant.
4. Convert azimuth of $39^{\circ} 42' 26''$ to bearing/quadrant.

Solution:

1. 34.5637 ENT¹
 3.0000 GSB¹
 214.5637 *** AZ.
2. 85.2447 ENT¹
 4.0000 GSB¹
 274.3513 *** AZ.
3. 162.1532 GSB²
 17.4429 *** BRG.
 R/S
 $2.$ *** QD.
4. 39.4226 GSB²
 39.4226 *** BRG.
 R/S
 $1.$ *** QD.

KEYSTROKE ROUTINES

User Instructions

01 *LBL1	Bearing to Azimuth		
02 FIX4			
03 X#Y	Bearing		
04 +H			
05 X#Y	Quadrant		
06 ENT↑			
07 ENT↑			
08 2			
09 ÷			
10 INT			
11 1			
12 8			
13 6			
14 STOP			
15 X			
16 X#Y			
17 RCL9			
18 X			
19 COS			
20 R↓			
21 R↓			
22 R↓			
23 X			
24 -			
25 +HMS	***Azimuth		
26 R/S			
27 *LBL2	Azimuth to Bearing		
28 FIX4			
29 +H			
30 ENT↑			
31 SIN			
32 SIN-1			
33 X#0?			
34 CHS			
35 +HMS			
36 R/S	***Bearing		
37 R↓			
38 9			
39 0			
40 ÷			
41 1			
42 +			
43 INT			
44 FIX8	***Quadrant		
45 R/S			

REGISTERS

0	1	2	3	4	5
6	7	8	9 180	.0	.1
.2	.3	.4	.5	16	17
18	19	20	21	22	23
24	25	26	27	28	29

***Print x may be used with or to replace R/S

FIELD ANGLE OR BEARING TRAVERSE

This program uses angles and/or deflections turned from a reference azimuth and horizontal distances, to compute the coordinates of successive points in a traverse. For a closed traverse, the area enclosed and closure distance and azimuth are computed.

Example 1:

Field Angle Traverse
Traverse the figure below starting at

$\frac{N \ 150}{E \ 400}$

Equations:

$$N_{i+1} = N_i + HDist \cos AZ$$

$$E_{i+1} = E_i + HDist \sin AZ$$

$$\text{Area} = \sum_{k=1}^n \text{LAT}_k \left(\frac{1}{2} \text{DEP}_k + \sum_{j=1}^{k-1} \text{DEP}_j \right)$$

where:

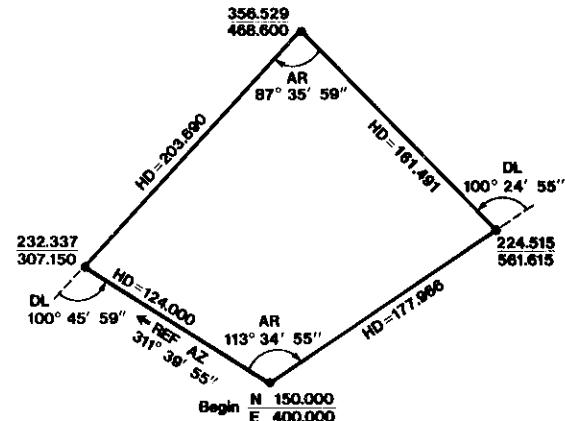
$$\text{DEP}_k = E_{k+1} - E_k \text{ and } \text{LAT}_k = N_{k+1} - N_k$$

Remarks:

If the user does not desire to do Field Angle Traverse, steps 012 through 026 may be eliminated; if he does not desire to do Bearing Traverse, steps 064 through 080 may be eliminated.

Angles left and deflections left must be entered as negative numbers.

This program assumes the calculator is set in DEG mode.



Solution:

150.0000	ENT↑
400.0000	GSB1
180.0000	***
311.3955	R/S
131.3955	***
113.3455	GSB2
65.1450	***
177.9660	R/S
224.5150	***
	R/S (N)
561.6150	***
-180.2455	GSB3 (E)
324.4955	***
161.4910	R/S
356.5285	*** (N)
	R/S
468.6000	*** (E)
87.3559	GSB2
232.2554	***
203.6900	R/S

232.3372	***	
	R/S	(N)
307.1498	***	
-100.4559	GSB3	(E)
131.3955	***	
124.0000	R/S	
149.9048	***	(N)
	R/S	
399.7829	***	(E)
	GSB5	
26558.8204	***	(Area)
	R/S	
0.2371	***	(Error Dist.)
	R/S	
246.1844	***	(Error AZ)

Solution:

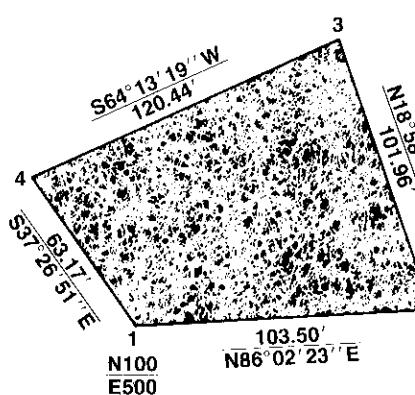
100.0000	ENT1	
500.0000	GSB1	
180.0000	***	
86.0223	ENT1	
1.0000	GSB4	
86.0223	***	
103.5000	R/S	
107.1482	***	(N)
	R/S	
603.2529	***	(E)
18.5843	ENT1	
4.0000	GSB4	
341.0117	***	
101.9600	R/S	
203.5657	***	(N)
	R/S	
570.0939	***	(E)
.64.1319	ENT1	
3.0000	GSB4	
244.1319	***	
120.4400	R/S	
151.1880	***	(N)
	R/S	
461.6395	***	(E)
37.2651	ENT1	
2.0000	GSB4	
142.3309	***	
63.1700	R/S	
101.0366	***	(N)
	R/S	
580.0490	***	(E)
	GSB5	
8855.4922	***	(Area)
	R/S	
1.0378	***	(Error Dist.)
	R/S	
2.4219	***	(Error AZ)

Example 2:

Bearing Traverse

Traverse the figure below starting at

N 100	
E 500	



User Instructions

01	*LBL1	Store starting point coordinates and 180°	50	2	***
02	FIX4		51	÷	
03	CLR6		52	RCL7	
04	ST01		53	-	
05	X#Y		54	X	
06	ST02		55	ST+8	
07	1		56	RCL6	
08	8		57	RCL2	
09	0		58	+	
10	ST03		59	R/S	
11	R/S	Reference azimuth	60	RCL7	Convert bearing and quadrant code to azimuth.
12	+H		61	RCL1	
13	RCL3		62	+	
14	+H		63	R/S	
15	+		64	*LBL4	
16	GTO8		65	X#Y	
17	*LBL2		66	ST09	
18	+H		67	X#Y	
19	RCL3		68	ENT↑	
20	+H		69	ENT↑	
21	+	Angle input	70	2	Area
22	+HMS		71	÷	
23	*LBL3		72	INT	
24	+H		73	RCL3	
25	RCL4		74	X	
26	+		75	X#Y	
27	*LBL8		76	RCL3	
28	1		77	X	
29	+R		78	COS	
30	+P		79	RCL9	
31	*LBL9	Compute azimuth	80	+H	Setup for closure
32	X#Y		81	X	
33	X>0?		82	-	
34	GTO8		83	GTO8	
35	3		84	*LBL5	
36	6		85	RCL8	
37	8		86	ABS	
38	+		87	R/S	
39	*LBL8		88	RCL7	
40	ST04		89	RCL6	
41	+HMS	Input horizontal distance	90	+P	***
42	R/S		91	R/S	
43	ST+5		92	GTO8	
44	RCL4		93	R/S	
45	X#Y				
46	+R				
47	ST+6				
48	X#Y				
49	ST+7				
		Compute next coord. and accumulate area.			

REGISTERS

0	1 Beg.	2 Beg. N	3 180	4 AZ	5 ΣHD
6 Lat.	7 Dep.	8 Area	9 Bearing	.0	.1
.2	.3	.4	.5	.16	.17
18	19	20	21	22	23
24	25	26	27	28	29

*** indicates that "Print X" may be inserted or used to replace "R/S".

INVERSE WITH CLOSURE

This program calculates the distance and azimuth of the line joining two points. For a closed inverse, the area enclosed and closure distance and azimuth are computed.

Equations:

$$HD = \sqrt{(N_i - N_{i-1})^2 + (E_i - E_{i-1})^2}$$

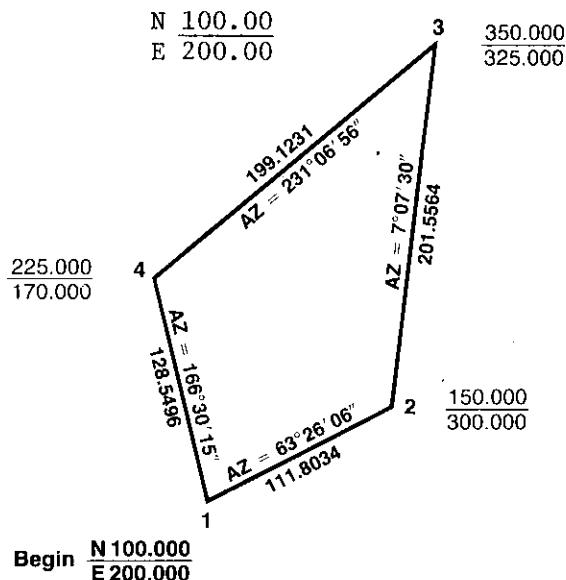
$$AZ = \tan^{-1} \frac{E_i - E_{i-1}}{N_i - N_{i-1}}$$

$$\text{Area} = \sum_{k=1}^n \text{LAT}_k \left(\frac{1}{2} \text{DEP}_k + \sum_{j=1}^{k-1} \text{DEP}_j \right)$$

where $\text{DEP}_k = E_{k+1} - E_k$ and

$$\text{LAT}_k = N_{k+1} - N_k$$

Example: Inverse the figure below starting at

Solution:

100.0000	ENT1
200.0000	GS1
150.0000	ENT1
300.0000	GS2
111.8034	*** H Dist
	R/S
63.2606	*** AZ
350.0000	ENT1
325.0000	GS2
201.5564	*** H Dist
	R/S
7.0730	*** AZ
225.0000	ENT1
170.0000	GS2
199.1231	*** H Dist
	R/S
231.0656	*** AZ
100.0000	ENT1
200.0000	GS2
128.5496	*** H Dist
	R/S
166.3015	*** AZ
	GS2
20937.5000	*** Area
	R/S
0.0000	*** Error, Dist
	R/S
360.0000	*** Error, AZ

User Instructions

01 *LBL1		50 GT00			
02 FIX4		51 R/S			
03 CLRC					
04 ST01					
05 X#Y					
06 ST02					
07 R/S					
08 *LBL2					
09 RCL7					
10 -					
11 RCL1					
12 -					
13 ST+7					
14 ST09					
15 X#Y					
16 RCL6					
17 -					
18 RCL2					
19 -					
20 ST+6					
21 ST.0					
22 X#Y					
23 2					
24 -					
25 RCL7					
26 -					
27 X					
28 ST+8					
29 RCL9					
30 RC.0					
31 *LBL0					
32 -P					
33 R/S	*** HD/Error Dist.				
34 X#Y					
35 X#00					
36 GT09					
37 3					
38 6					
39 0					
40 +					
41 *LBL9					
42 -HMS					
43 R/S	*** AZ/Error AZ				
44 *LBL3					
45 RCL8					
46 ABS					
47 R/S	***Area				
48 RCL7					
49 RCL6					

REGISTERS

0	1 BEG E	2 BEG N	3	4	5
6 LAT	7 DEP	8 Area	9 A E	.0 AN	.1
.2	.3	.4	.5	.6	.7
18	19	20	21	22	23
24	25	26	27	28	29

*** "Print X" may replace or be used with "R/S"

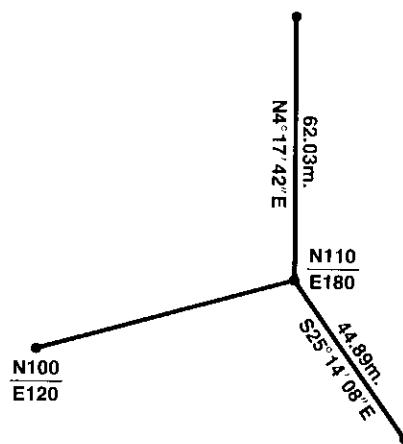
SIDESHOTS

This program is used to make sideshots or radials from a point. Two methods may be used for a sideshot, 1) input a bearing and distance and calculate the point coordinates, or 2) input the point coordinates and calculate the azimuth and distance to the point.

Equations:

$$N = N_0 + H \text{ Dist} \cos \text{AZ}$$

$$E = N_0 + H \text{ Dist} \sin \text{AZ}$$

Example:Solutions:

110.0000	ENT↑	
180.0000	GSB1	
4.1742	ENT↑	
1.0000	GSB2	
4.1742	***	AZ
62.0300	R/S	
171.8558	***	N
	R/S	
184.6455	***	E
25.1400	ENT↑	
2.0000	GSB2	
154.4552	***	AZ
44.8900	R/S	
69.3942	***	N
	R/S	
199.1384	***	E
100.0000	ENT↑	
120.0000	GSB3	
60.8276	***	H Dist
	R/S	
260.3216	***	AZ

User Instructions

01 *LBL1		50 +	***N
02 FIX4		51 R/S	
03 CLRG		52 X#Y	
04 STO1		53 RCL1	
05 X#Y		54 +	***E
06 STO2		55 R/S	
07 1		56 *LBL3	
08 0		57 RCL1	ΔE
09 0		58 -	
10 STO3		59 X#Y	
11 R/S		60 RCL2	AN ΔE
12 *LBL2	Bearing to Azimuth	61 -	Dist AZ
13 X#Y	conversion routine	62 +P	*** Dist
14 +H		63 R/S	
15 X#Y		64 GT09	
16 ENT↑		65 R/S	
17 ENT↑			
18 2			
19 2			
20 INT			
21 RCL3			
22 X			
23 R↓			
24 X#Y			
25 R↓			
26 RCL3			
27 X			
28 COS			
29 X	AZ		
30 -	make		
31 1	AZ $\leq 360^{\circ}$		
32 +R			
33 +P			
34 *LBL9	AZ		
35 X#Y			
36 X#00			
37 GT09			
38 3			
39 6			
40 0			
41 +			
42 *LBL8			
43 STO4			
44 +HMS	***AZ		
45 R/S			
46 RCL4			
47 X#Y			
48 +R			
49 RCL2			

REGISTERS

0	1 E _O	2 N _O	3 180	4	5
6	7	8	9	.0	.1
.2	.3	.4	.5	16	17
18	19	20	21	22	23
24	25	26	27	28	29

*** "Print X" may replace or be used with "R/S"

COMPASS RULE ADJUSTMENT

This program adjusts a traverse by the compass rule. It is intended to follow the program "Field Angle or Bearing Traverse" (with closure). However, if the correct coordinates of the last point and the total distance traversed are known, these parameters can be used in lieu of executing the closure program.

If this program is not used immediately after "Field Angle or Bearing Traverse" (with closure) or the storage registers have been altered since the closure program was run, enter the following data into the specified storage registers:

Register Parameter:

1. Correct closing easting.
2. Correct closing northing.
5. Total distance traversed.
6. Calculated ending northing.
7. Calculated ending easting.

The Inverse program may be used to obtain adjusted bearings, distances and area.

Equations:

$$C_L = \frac{(\Delta N) (Dist)}{\Sigma Dist}$$

$$C_D = \frac{(\Delta E) (Dist)}{\Sigma Dist}$$

Where: C_L = Correction to latitude of a course.

C_D = Correction to departure of a course.

ΔN = Closing latitude.

ΔE = Closing departure.

Dist = Length of course to be corrected.

$\Sigma Dist$ = Total length of traverse

Example:

667.147 Total distance traversed
 400.000 Correct closing easting
 150.000 Correct closing northing
 399.783 Calculated ending easting
 149.905 Calculated ending northing

POINT	UNADJUSTED
NO.	COORDINATES
2	<u>N = 224.515</u> <u>E = 561.615</u>
3	<u>N = 356.529</u> <u>E = 468.600</u>
4	<u>N = 232.337</u> <u>E = 307.150</u>

Ending & } N = 149.905
 Beginning } E = 399.783

Solution:

150.0000	ST02
400.0000	ST01
667.1476	ST05
149.9050	ST06
399.7830	ST07
6981	
224.5150	ENT†
561.6150	GSP2
224.5463	*** Adj. N
R/S	
561.6729	*** Adj. E
356.5290	ENT†
468.6000	GSP2
356.5773	*** Adj. N
R/S	
468.7104	*** Adj. E
222.3370	ENT†
307.1500	GSP2
232.4143	*** Adj. N
R/S	
387.3267	*** Adj. E
149.9050	ENT†
399.7830	GSP2
150.0000	*** Adj. N
R/S	
400.0000	*** Adj. E

User Instructions

01 *LBL1	initialize				
02 RCL1					
03 ST08					
04 RCL7					
05 -					
06 RCL5	$\frac{\Delta E}{\Sigma \text{Dist}}$				
07 ÷					
08 ST03					
09 RCL2					
10 RCL6					
11 -					
12 RCL5	$\frac{\Delta N}{\Sigma \text{Dist}}$				
13 ÷					
14 ST04					
15 RCL2					
16 ST05					
17 RTN					
18 *LBL2	(x > y)				
19 X#Y					
20 ST06					
21 RCL2					
22 -					
23 ST+5					
24 X#Y					
25 ST07					
26 RCL1					
27 -	$\sqrt{x^2 + y^2} = \text{Dist}$				
28 ST+9					
29 +P					
30 ST09					
31 RCL3	C_D				
32 X					
33 ST+8					
34 RCL9					
35 RCL4	C_L				
36 X					
37 ST+5					
38 RCL6					
39 ST02					
40 RCL7					
41 ST01					
42 RCL5	***Adj N				
43 R/S					
44 RCL8	*** Adj E				
45 R/S					
REGISTERS					
0	1 Beg E	2 Beg N	3 $\Delta E / \Sigma \text{Dist}$	4 $\Delta E / \Sigma \text{Dist}$	5 ΣHD
6 Closing LAT	7 Closing DEP	8 Adj E	9 Dist	.0	.1
.2	.3	.4	.5	16	17
18	19	20	21	22	23
24	25	26	27	28	29

***"Print X" may be used to replace "R/S"

CURVE SOLUTIONS

Given values for any of the following pairs, this program computes the remaining parameters plus the sector, segment, and fillet areas: Δ and C; Δ and R; Δ and T; R and T; R and L; R and C.

Equations

$$\begin{aligned}\frac{1}{2}\Delta &= \tan^{-1} (T/R) = \sin^{-1} (\frac{1}{2}C/R) = 90L/\pi R \\ T &= R \tan (\frac{1}{2}\Delta) \\ C &= 2T \cos (\frac{1}{2}\Delta) \\ R &= T/\tan (\frac{1}{2}\Delta) = C/(2 \sin (\frac{1}{2}\Delta)) \\ L &= \Delta \pi R/180\end{aligned}$$

$$\text{Sector area} = LR/2$$

$$\text{Segment area} = \text{Sector area} - \frac{1}{2}CR \cos (\frac{1}{2}\Delta)$$

$$\text{Fillet area} = T R - \text{Sector area}$$

Where: T = Tangent distance

C = Chord length

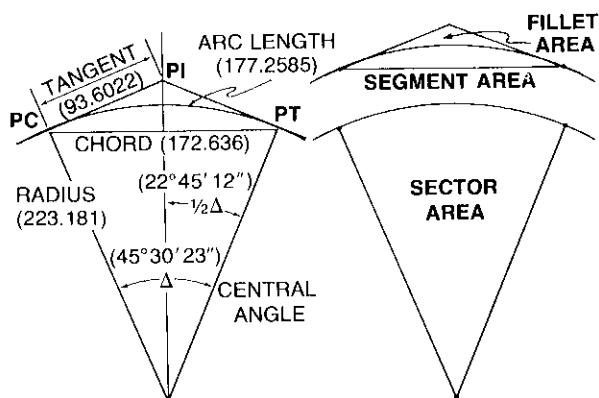
L = Arc length

R = Radius

Δ = Central angle

Solution:

CLRG		
223.1810	ST02	R
172.6360	ST03	C
93.6022	***	T
22.7532	***	$\Delta/2$
177.2584	***	L
19780.3563	***	Sector Area
2014.9959	***	Segment Area
1109.8705	***	Fillet Area



$$R = 223.181$$

$$\Delta = 45^\circ 30' 23''$$

$$\frac{1}{2}\Delta = 22^\circ 45' 11''$$

$$C = 172.636$$

$$T = 93.602$$

$$L = 177.258$$

$$\text{Sector area} = 19780.36$$

$$\text{Segment area} = 2015.00$$

$$\text{Fillet area} = 1109.87$$

User Instructions

81 *LBL1		50 X	
82 RCL1		51 RCL2	
83 X		52 X	
84 2		53 R/S	***L
85 ÷		54 RCL2	
86 ST01		55 STX4	
87 X#0?		56 X	
88 GT09		57 2	
89 RCL3	have Δ , calculate R	58 ÷	
10 RCL1		59 R/S	***Sector area
11 SIN		60 -	
12 2		61 CHS	
13 X		62 R/S	***Segment area
14 ÷	R = f (C, Δ)	63 RCL4	
15 X#0?		64 LSTX	
16 ST02		65 -	
17 RCL4		66 R/S	***Fillet area
18 RCL1		67 *LBL9	have R, calculate Δ
19 TAN		68 RCL5	
20 ÷		69 RCL2	
21 X#0?	R = f (T, Δ)	70 ÷	
22 ST02		71 9	
23 *LBL5		72 0	
24 RCL2		73 X	
25 R/S	*** R	74 PI	
26 RCL1		75 ÷	$\Delta = f (L, R)$
27 R/S	*** $\Delta/2$	76 X#0?	
28 TAN		77 ST01	
29 X		78 RCL3	
30 ST04		79 RCL2	
31 R/S	*** T	80 2	
32 2		81 X	
33 X		82 ÷	
34 RCL1		83 SIN ⁻¹	$\Delta = f (C, R)$
35 COS		84 X#0?	
36 X		85 ST01	
37 R/S	*** C	86 RCL4	
38 RCL2		87 RCL2	
39 X		88 ÷	
40 RCL1		89 TAN ⁻¹	$\Delta = f (T, R)$
41 COS		90 X#0?	
42 X		91 ST01	
43 2		92 GT05	
44 ÷		93 R/S	
45 PI			
46 2			
47 0			
48 ÷			
49 RCL1			

REGISTERS

0	1 $\Delta/2$	2 R	3 C	4 T	5 L
6	7	8	9	.0	.1
.2	.3	.4	.5	16	17
18	19	20	21	22	23
24	25	26	27	28	29

***"PrintX" may be inserted or used to replace "R/S"

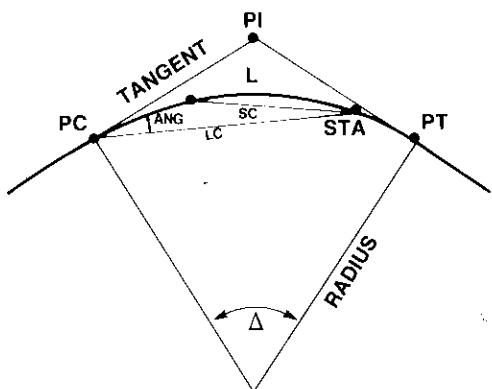
HORIZONTAL CURVE LAYOUT

This program calculates various field data for layout of an horizontal circular curve. The required information on the curve is the PC station and the radius or degree of curve. With this data one computes successively the arc length, deflection angle from tangent to chord, the long chord from PC to current station, and the short chord from previous station to current station. In addition, the tangent offset and tangent distance are available if desired.

If the central angle is known the program also will compute the total arc length from PC to PT, the station PT and the length of the tangent from PC to PI.

In the program, stations are entered in the form XXXX.XX for station XX+XX.XX. For example: 20 + 10.00 is entered as 2010.00. The degree of curve D, (or central angle subtending an arc of 100 ft.) is entered in degrees with a negative sign, always.

PC Deflections



Field data output for PC deflections consist of:
 STA-current station
 ANG-deflection angle from tangent to long chord.
 LC-long chord from PC to current station

SC-Short chord from previous station to current station

Δ-A-central angle

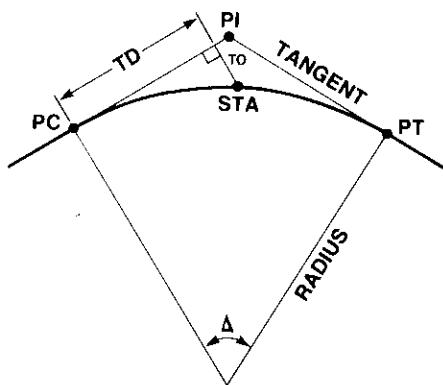
PI-point of intersection of tangents

PC, PT-ends of curve

L-Arc length

R-radius

Tangent Offsets and Distances



Field data output for tangent offsets consist of:

STA-current station

TD-tangent distance

TO-tangent offset

T-distance from PC to PI

(HORIZONTAL CURVE LAYOUT)

Example:

Compute field data for a curve with a central angle of $35^{\circ}30'$ and degree of curve of $12^{\circ}30'$. The PC station is $7 + 85.40$.

Solution:

785.4000	ENT↑	1000.0000	GSB2	(For STA. 10)
-12.3000	GSB1	214.6000	***	(L)
785.4000	***	13.2445	***	(ANG)
	(PC)		R/S	
	RCL1		R/S	
458.3662	***	212.6454	***	(LC)
	(R)		R/S	
800.0000	GSB2	99.8018	***	(SC)
14.6000	***	49.3252	***	(TO)
	(L)		RCL8	
	R/S		RCL9	
0.5445	***	206.8455	***	(TD)
	(ANG)		35.3000	GSB3
	R/S		284.0000	***
14.5994	***		(L)	
	(LC)		R/S	
	R/S		1069.4000	***
14.5994	***		(PT)	
	(SC)		R/S	
	RCL8		146.7242	***
0.2325	***		(T)	
	(TO)			
	RCL9			
14.5975	***			
	(TD)			
900.0000	GSB2	1069.4000	GSB2	(Field data: PT)
114.6000	***	284.0000	***	(L)
	(L)		R/S	
	R/S		17.4500	***
7.0945	***		(ANG)	
	(ANG)		R/S	
114.3018	***	279.4790	***	(LC)
	(LC)		R/S	
	R/S		69.3337	***
99.8018	***		(SC)	
	(SC)			
	RCL8			
14.2516	***			
	(TO)			
	RCL9			
113.4098	***			
	(TD)			

User Instructions

01 *LBL1		58 SIN	Calculate TO
02 CLRG		51 x	
03 FIX4	Store R&D	52 ST08	Calculate TD
04 X ²		53 RCL5	
05 GSB8		54 RCL7	
06 ST01		55 COS	
07 PI		56 x	
08 x		57 ST09	dsp LC
09 S		58 RCL5	***
10 0		59 R/S	
11 %		60 RCL4	
12 ST02	Input PC	61 RCL2	
13 R4		62 -	
14 ST03		63 GSB9	
15 ST04		64 x	
16 RTN		65 SIN	
17 *LBL8		66 RCL1	
18 CHS		67 2	
19 →H	Calculate R from D	68 x	***Calculate SC
20 PI		69 x	
21 x		70 RTN	
22 1/X		71 *LBL9	
23 1		72 9	
24 8		73 8	
25 EEX		74 PI	
26 3		75 %	
27 x		76 RCL1	Input Δ
28 RTN		77 %	
29 *LBL2	Input station	78 RTN	
30 RCL4		79 *LBL3	
31 ST.2		80 →H	
32 R4		81 2	
33 ST04		82 %	
34 RCL3		83 ST06	
35 -		84 GSB9	
36 R/S	*** Calculate L	85 %	Calculate L
37 GSB9		86 R/S	***
38 x		87 RCL3	
39 ST07		88 +	Calculate PT
40 →HMS		89 R/S	***
41 R/S		90 RCL6	
42 RCL7	*** Calculate ANG	91 TAN	
43 SIN		92 RCL1	
44 RCL1		93 x	***
45 x		94 R/S	Calculate T
46 2			
47 x	Calculate LC		
48 ST05			
49 RCL7			

REGISTERS

0	1 R	2 Ft/Deflect	3 PC	4 STA Current	5 LC
6 Δ/2	7 ANG	8 TO	9 TD	.0	.1
.2 Prev. Sta.	.3	.4	.5	.16	.17
18	19	20	21	.22	.23
24	25	26	27	.28	.29

*** indicates that "Print X" may be inserted or used to replace "R/S".

BEARING-DISTANCE AND BEARING-BEARING INTERSECTION

This program computes the coordinates of the point of intersection of two lines:

1) one of known bearing through known coordinates and the other of known length from a point of known coordinates; or 2) when the bearing of each line is known and the coordinates of a point on each line are known. For the first case, both solutions may be computed.

Equations:

Bearing-Distance

$$AZ_{12} = \tan^{-1} \frac{E_2 - E_1}{N_2 - N_1}$$

$$h = Dist_{12} \sin \phi$$

$$b = \sqrt{Dist_{12}^2 - h^2}$$

$$N = N_1 + ((Dist_{12} \cos \phi) + b) \cos (AZ_1)$$

$$E = E_1 + ((Dist_{12} \cos \phi) + b) \sin (AZ_1)$$

where:
 AZ_{12} = Azimuth of line from point 1 to point 2
 AZ_1 = Azimuth of line 1
 ϕ = Angle between line 1 and line from point 1 to point 2
 h = Perpendicular distance from point 2 to line 1
 b = Distance from point of intersection to the point where the perpendicular (h) intersects line 1
 $Dist_{12}$ = Length of line 2 (the known distance)
 $N_1 E_1$ = Northing, easting of point 1
 $N_2 E_2$ = Northing, easting of point 2
 $Dist_{12}$ = Distance from point 1 to point 2

Bearing-Bearing

$$N = N_1 + Dist (\cos AZ_1)$$

$$E = E_1 + Dist (\sin AZ_1)$$

$$Dist = \frac{Dist_{12} \sin (AZ_2 - AZ_{12})}{\sin (AZ_2 - AZ_1)}$$

where:

$$AZ_{12} = \text{Azimuth of line from point 1 to point 2}$$

$$AZ_1 = \text{Azimuth of line 1}$$

$$AZ_2 = \text{Azimuth of line 2}$$

$$N_1 E_1 = \text{Northing, easting of point 1}$$

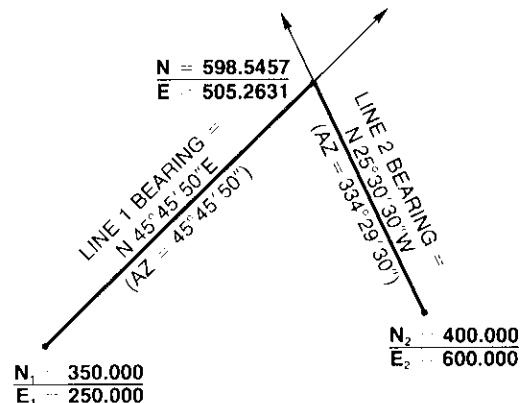
$$N_2 E_2 = \text{Northing, easting of point 2}$$

$$N, E = \text{Northing, easting of intersect point}$$

$$Dist = \text{Distance from point 1 to intersection}$$

$$Dist_{12} = \text{Distance from point 1 to point 2}$$

Example 1:



Solution:

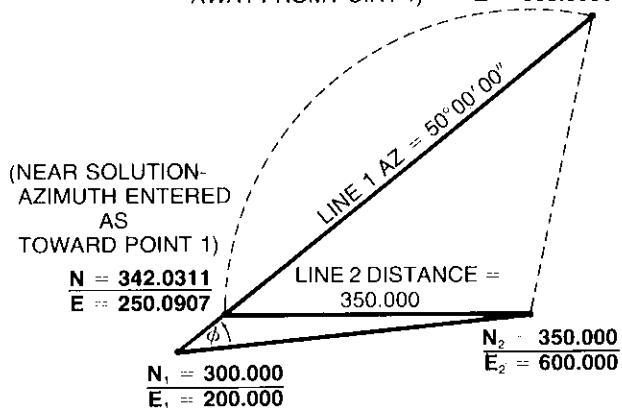
750.0000 ENT↑
 250.0000 GSB1
 400.0000 ENT↑
 600.0000 R/S
 45.4550 ENT↑
 1.0000 GSB2
 25.3020 ENT↑
 4.0000 GSB3
 GSB4
 598.5457 *** N
 R/S
 505.2631 *** E

Solution:

300.0000 ENT↑
 200.0000 GSB1
 350.0000 ENT↑
 600.0000 R/S
 50.0000 ENT↑
 1.0000 GSB2
 350.0000 ST07
 GSB5
 693.2096 *** N₁
 R/S
 668.6089 *** E₁

Example 2:

(FAR SOLUTION-
AZIMUTH ENTERED AS
AWAY FROM POINT 1) $\frac{N}{E} = \frac{693.2096}{668.6089}$



User Instructions

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Key in the program			
2	Enter coordinates of point 1	N1 E1	ENT↑ GSB 1	
3	Enter coordinates of point 2	N2 E2	ENT↑ R/S	
4	Enter bearing and quadrant of line 1 (or store the azimuth of line 1)	BRG 1 QD 1* AZ* (D.d)	ENT↑ GSB 2 STO 5	AZ 1 (D.d)
5a	For bearing-bearing: enter bearing and quadrant of line 2 (or store the azimuth of line 2); and compute intersect coordinates	BRG 2 QD 2 AZ 2 (D.d)	ENT↑ GSB 3 STO 6 GSB 4	AZ 2 (D.d)
5b	For bearing-distance*: store the distance of line 2; and compute intersect coordinates	Dist 2	R/S STO 7 GSB 5 R/S	N E N E
<p>*Two solutions are possible in the bearing-distance case. To obtain the near solution enter the bearing as into point 4; for the far solution, enter the bearing as away from point 4.</p>				

01 *LBL1	Store Coordinates	50 X#Y	
02 ST02		51 X>Y	
03 R↓		52 RTN	
04 ST01		53 3	
05 1		54 6	
06 8		55 0	
07 0		56 +	
08 ST08		57 RTN	
09 R/S		58 *LBL4	
10 ST04		59 GSB6	
11 R↓		60 RCL6	
12 ST03		61 -	
13 RTN		62 CHS	AZ ₁₂ - AZ ₁₁
14 *LBL2		63 SIN	
15 GSB0		64 X	
16 ST05		65 RCL6	
17 RTN		66 RCL5	
18 *LBL3		67 -	
19 GSB0		68 SIN	
20 ST06		69 ÷	Dist
21 RTN		70 ST08	
22 *LBL0	Bearing → Azimuth	71 *LBL9	
23 X#Y	Conversion	72 RCL5	
24 →H		73 RCL8	
25 X#Y		74 →R	X cos AZ ₁ , X sin AZ ₁
26 ENT↑		75 RCL1	
27 ENT↑		76 +	
28 2		77 R/S	***N
29 ÷		78 X#Y	
30 INT		79 RCL2	
31 RCL0		80 +	***E
32 X		81 R/S	
33 R↓		82 *LBL5	
34 X#Y		83 GSB6	
35 R↓		84 RCL5	
36 RCL0		85 -	
37 X		86 CHS	AZ ₁ - AZ ₁₂ = Ø
38 COS		87 X#Y	
39 X	AZ	88 →R	
40 -		89 X#Y	
41 RTN		90 X ²	h ²
42 *LBL6		91 RCL7	
43 RCL4		92 X ²	
44 RCL2		93 -	
45 -		94 CHS	
46 RCL3		95 CX	b
47 RCL1		96 +	
48 -		97 ST08	
49 →P	-Dist ₁₂ AZ ₁₂	98 GT09	

REGISTERS

0 180	1 N ₁	2 E ₁	3 N ₂	4 E ₂	5 AZ ₁
6 AZ ₂	7 Dist 2	8 used	9	.0	.1
.2	.3	.4	.5	16	17
18	19	20	21	22	23
24	25	26	27	28	29

***"Print X" may replace or be used with "R/S"

DISTANCE-DISTANCE INTERSECTION

Given two lines, each of known length and originating from two known points, this program computes the intersection coordinates. There are two possible solutions; this program calculates the one found by proceeding in a clockwise direction from the first known point to the second known point. The other solution is found by reversing the entry of the known point coordinates.

Equations:

$$\phi = \cos^{-1} \frac{Dist_{12}^2 + Dist_1^2 - Dist_2^2}{2(Dist_1)(Dist_{12})}$$

$$AZ = \tan^{-1} \frac{E_2 - E_1}{N_2 - N_1}$$

$$N = N_1 + Dist_1 \cos (AZ - \phi)$$

$$E = E_1 + Dist_1 \sin (AZ - \phi)$$

where: ϕ = Angle between line 1 and line 1-2

$Dist_{12}$ = Distance from point 1 to point 2

$Dist_1$ = Known distance along line 1

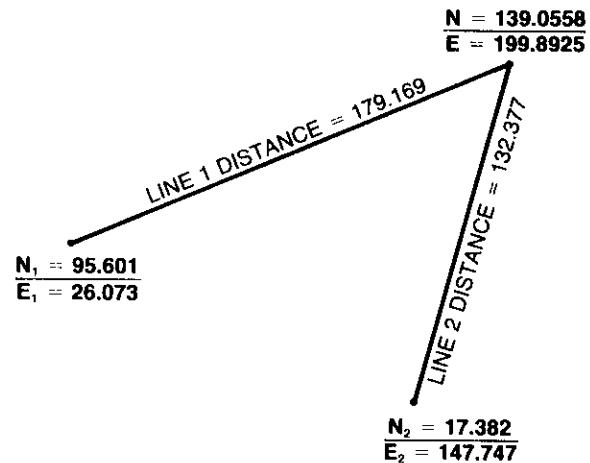
$Dist_2$ = Known distance along line 2

$N_{1,E}$ = Northing, easting of point 1

N, E = Northing, easting of intersection point

AZ = Azimuth of line from point 1 to point 2

Example:



Solution:

CLRS	
179.1690	ENT1
132.3770	GSB1
95.6010	ENT1
26.0730	GSB2
17.3820	ENT1
147.7470	GSB3
139.0558	*** N
	R 3
199.8925	*** E

User Instructions

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Key in the program			
2	Enter distances	Dist 1	ENT↑	
		Dist 2	GSB 1	
3	Enter points 1 and 2* and calculate intersection	N 1	ENT↑	
		E 1	GSB 2	
		N 2	ENT↑	
		E 2	GSB 3	N
			R/S	E
<p>* Two solutions are possible. For the alternate solutions reverse the order of entering points 1 and 2</p>				

01 *LBL1				
02 ST06				
03 R4				
04 ST05				
05 RTN				
06 *LBL2				
07 ST02				
08 X*Y				
09 ST01				
10 RTN				
11 *LBL3				
12 ST04				
13 R4				
14 ST03				
15 RCL4				
16 RCL2				
17 -				
18 RCL3				
19 RCL1				
20 -				
21 →P	Dist ₁₂ AZ			
22 ST07				
23 X ²				
24 RCL5				
25 X ²				
26 +				
27 RCL6				
28 X ²				
29 -				
30 2				
31 ÷				
32 RCL7				
33 RCL5				
34 X				
35 ÷				
36 COS ⁴	φ AZ			
37 -				
38 RCL5				
39 →R				
40 RCL1				
41 +				
42 R/S	*** N			
43 X*Y				
44 RCL2				
45 +				
46 R/S	*** E			

REGISTERS

0	1 N ₁	2 E ₁	3 N ₂	4 E ₂	5 Dist 1
6 Dist 2	7 Dist 12	8	9	.0	.1
.2	.3	.4	.5	16	17
18	19	20	21	22	23
24	25	26	27	28	29

*** "Print X" may be used to replace "R/S"

OFFSET FROM A POINT TO A LINE

Given the point of known coordinates with a line of known bearing passing through it and a second point of known coordinates, this program calculates the offset distance from the second point to the line, the distance from the intersection to the first known point, the coordinates of the intersection, and the azimuth from the point of intersection to the second point.

Equations:

$$\text{Dist}_{BO} = \sqrt{(N_0 - N_B)^2 + (E_0 - E_B)^2}$$

$$\text{Dist}_{BI} = \sqrt{(N_0 - N_I)^2 + (E_0 - E_I)^2}$$

$$N_I = \frac{E_0 - E_B + N_0 \text{ctn}(\text{Az}_{BI}) + N_B \tan(\text{Az}_{BI})}{\text{ctn}(\text{Az}_{BI}) + \tan(\text{Az}_{BI})}$$

$$E_I = E_B + (N_I - N_B) \tan(\text{Az}_{BI})$$

Where: Dist_{BO} = Distance from point to offset point

Dist_{BI} = Distance from base point to intersection point

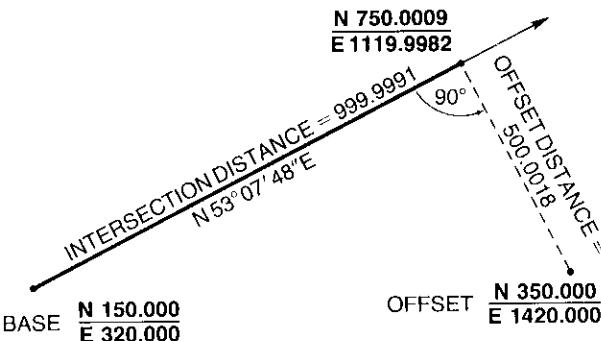
Dist_{IO} = Distance from intersection point to offset point

N_0, E_0 = Northing, easting of offset point

N_B, E_B = Northing, easting of base point

N_I, E_I = Northing, easting of intersection point

Az_{BI} = Known AZ from base point to intersection point

Example:Solution:

150.0000	ST01
320.0000	ST02
350.0000	ST03
1420.0000	ST04
53.8748	ST05 AZ
1.0000	ST06
180.0000	ST07
750.0009	GSB1 N _I
1119.9982	*** R/S
500.0018	*** E _I
999.9991	*** R/S
143.8748	*** O. AZ

User Instructions

01 *LBL9	bearing to azimuth conversion routine	50 +		
02 RCL7		51 CHS		
03 RCL6		52 ÷		
04 2		53 ST.0		
05 ÷		54 R/S	***N ₁	
06 INT		55 RCL8		
07 x		56 x		
08 RCL6		57 RCL9		
09 RCL7		58 +		
10 x		59 ST.1		
11 COS		60 R/S	***E ₁	
12 RCL5		61 RCL3		
13 +H		62 RC.0		
14 x		63 -		
15 -	AZ	64 RCL4		
16 *LBL8		65 RC.1		
17 1		66 -		
18 +R	make AZ ≤ 360°	67 +P		
19 +P		68 R/S	***offset distance	
20 X#Y		69 RCL1		
21 X>0?		70 RC.0		
22 GT07		71 -		
23 3		72 RCL2		
24 6		73 RC.1		
25 0		74 -		
26 +		75 +P		
27 *LBL7		76 R/S	***intersect distance	
28 ST05		77 X#Y	0 I.D. O.D.	
29 +HMS		78 R↓		
30 RTN	***azimuth	79 +P		
31 *LBL1		80 X#Y		
32 GSB9		81 RCL5		
33 RCL2		82 +		
34 RCL1		83 X#Y		
35 RCL5		84 +R	N E	
36 TAN		85 X#Y	E _B	
37 ST08		86 RCL2		
38 x		87 +		
39 -		88 RCL4	E ₀ E calculated	
40 ST09		89 X=Y?		
41 RCL4		90 GT00		
42 RCL3		91 RCL7	180	
43 RCL8		92 ST-5	AZ-180 results	
44 ÷		93 *LBL0		
45 +		94 RCL5		
46 -		95 9		
47 RCL8		96 6		
48 ENT1		97 +	AZ ± 90	
49 1/X		98 GT08		

REGISTERS

0	1 N _B	2 E _B	3 N _O	4 E _O	5 BRG/AZ
6 QD	7 180	8 tan AZ	9 used	.0 N ₁	.1 E ₁
.2	.3	.4	.5	.16	.17
18	19	20	21	22	23
24	25	26	27	28	29

*** "Printx" may be inserted or used to replace "R/S".

EARTHWORK

VOLUME BY AVERAGE END AREA

Routines labeled 1 and 2 calculate the end area for any station, volume from previous station, and accumulated volume to the present station. Inputs are the elevations and distances from the centerline for all points of a cross section and the interval from the previous station.

Equations:

$$V_{avg} = (|Area_i| + |Area_{i-1}|) \frac{I}{2}$$

$$Area = \frac{1}{2} [Elev_1 (H\ Dist_2 - H\ Dist_n) + \\ Elev_2 (H\ Dist_3 - H\ Dist_1) + \\ \dots + Elev_n (H\ Dist_1 - H\ Dist_n)]$$

Where: V_{avg} = Average volume between two stations

Area = Cross sectional area at a station

H Dist = Horizontal distance from centerline at cross section

Elev = Elevation at a point on the cross section

I = Interval between stations

Subscript i refers to current point

Subscript n refers to last point

Numeric subscript refers to point number

VOLUME OF BORROW PIT

Routines labeled 3-6 calculate the volume of fill which can be taken from a borrow pit given grid dimensions and elevations at the grid intersections. Volume is available for each grid section and also as an accumulative volume for all previous sections.

If several grid blocks have the same horizontal dimensions, the sum of the volumes of all these blocks can be calculated at once. For example, if three rectangular blocks have the same dimensions, the 12 elevations are entered before pressing GSB 6.

Equations:

$$Vol_{\Delta} = \frac{1}{2} (\text{Base})(\text{Ht})(\text{Elev})$$

$$Vol = (\text{Width})(\text{Length})(\text{Elev})$$

Where: Vol_{Δ} = Volume of triangular grid section

Base = Base of triangle

Ht = Height of triangle

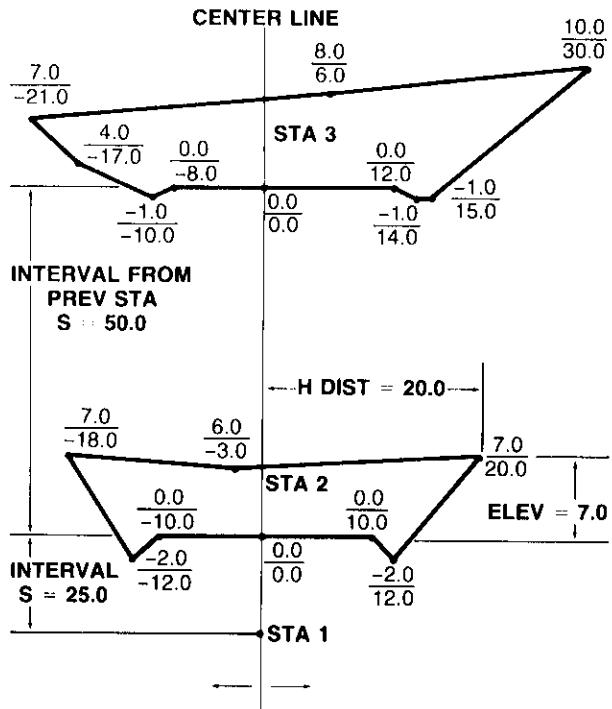
Elev = Elevation of grid section (depth of cut)

Vol = Volume of rectangular grid section

Width = Width of rectangle

Length = Length of rectangle

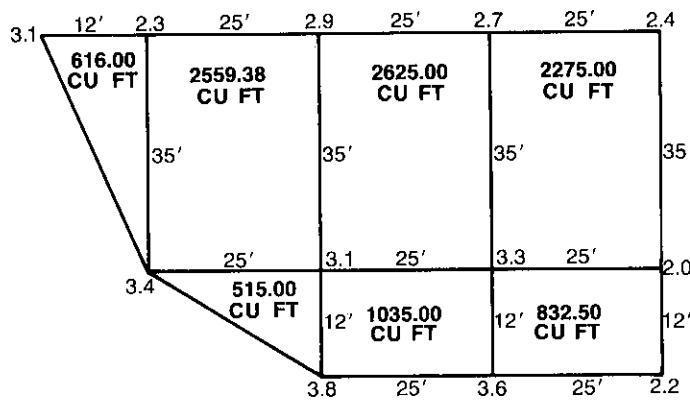
Example 1:



Solution:

CLRG
 0.0000 GSB2 1st Sta.
 0.0000 ENT↑ Starting at 0/0 &
 0.0000 GSB1 Going CCW.
 0.0000 ENT↑
 10.0000 GSB1
 -2.0000 ENT↑
 12.0000 GSB1
 7.0000 ENT↑
 20.0000 GSB1
 6.0000 ENT↑
 -3.0000 GSB1
 7.0000 ENT↑
 -18.0000 GSB1
 -2.0000 ENT↑
 -12.0000 GSB1
 0.0000 ENT↑
 -10.0000 GSB1
 0.0000 ENT↑ Reinput 1st Elev &
 0.0000 GSB1 Dist.
 25.0000 GSB2 1st INT.
 100.0000 *** Vol. (total)
 RCL5
 100.0000 *** Vol. (internal)
 RCL4
 216.0000 *** Area

 0.0000 ENT↑
 0.0000 GSB1
 0.0000 ENT↑
 12.0000 GSB1
 -1.0000 ENT↑
 14.0000 GSB1
 -1.0000 ENT↑
 15.0000 GSB1
 10.0000 ENT↑
 30.0000 GSB1
 8.0000 ENT↑
 6.0000 GGB1
 7.0000 ENT↑
 -21.0000 GSB1
 4.0000 ENT↑
 -17.0000 GSB1
 -1.0000 ENT↑
 -10.0000 GSB1
 8.0000 ENT↑
 -8.0000 GSB1
 8.0000 ENT↑
 0.0000 GSB1
 50.0000 GSB2 2nd INT.
 597.6852 *** Vol. (total)
 RCL5
 497.6852 *** Vol. (internal)
 RCL4
 321.5000 *** Area

Example 2:

CLΣ
 12.0000 ENT↑
 35.0000 GSB3
 2.3000 GSB5
 3.1000 GSB5
 3.4000 GSB5
 GSB6
 616.0000 *** G. Vol.

 25.0000 ENT↑ 12.0000 ENT↑
 35.0000 GSB4 25.0000 GSB4
 2.3000 GSB5 3.8000 GSB5
 3.4000 GSB5 3.1000 GSB5
 3.1000 GSB5 3.6000 GSB5
 2.9000 GSB5 3.6000 GSB5
 2.9000 GSB5 3.3000 GSB5
 3.1000 GSB5 3.3000 GSB5
 3.3000 GSB5 2.0000 GSB5
 3.3000 GSB5 2.2000 GSB5
 2.7000 GSB5 GSB6
 2.7000 GSB5 1867.5000 *** G.Vol.
 2.4000 GSB5 R/S
 2.8000 GSB5 10457.8750 *** A.Vol.
 GSB6
 7459.3750 *** G. Vol.

 25.0000 ENT↑
 12.0000 GSB3
 3.1000 GSB5
 3.4000 GSB5
 3.8000 GSB5
 GSB6
 515.0000 *** G. Vol.

User Instructions

37

01 *LBL1	Avg. End Area	50 0	prepare for sub-
02 STX1	routines	51 ENT↑	routine 5
03 RCL1		52 RTN	
04 ST-2		53 *LBL5	
05 R↓		54 +	
06 X2Y		55 R/S	
07 STX0		56 *LBL6	
08 RCL0		57 RC.3	
09 ST+2		58 X	
10 R↓		59 S+.2	
11 ST01		60 R/S	***grid section
12 R↓		61 RC.2	volume
13 ST00		62 R/S	***accumulated
14 RCL2			volume
15 2			
16 =			
17 ST03			
18 RTN			
19 *LBL2			
20 RCL4			
21 RCL3			
22 ABS			
23 ST04			
24 +			
25 5			
26 4			
27 =			
28 X	interval Volume		
29 ST05			
30 ST+6			
31 0	Clear registers		
32 ST00			
33 ST01			
34 ST02			
35 ST03			
36 RCL6	Total Volume		
37 RTN			
38 *LBL3			
39 X	Borrow Pit routines		
40 6			
41 =			
42 ST.3			
43 GT00			
44 *LBL4			
45 X			
46 4			
47 =			
48 ST.3			
49 *LBL0			

REGISTERS

0 used	1 used	2 used	3 used	4 Area	5 Int. vol.
6 Tot vol	7	8	9	.0	.1
.2 Σ Vol.	.3 used	.4	.5	16	17
18	19	20	21	22	23
24	25	26	27	28	29

***"PrintX" may be used in place of "R/S"

COORDINATE TRANSFORMATION

This program translates, rotates, and rescales coordinates. Traverse rotation angle is entered as a negative value for counterclockwise rotation and positive for clockwise rotation. The translation factors are calculated by entering old and new grid system coordinates for the same point; rotation is also about this point.

Equations:

$$\Delta Z_R = \phi + \tan^{-1} \frac{E_i - E_p}{N_i - N_p}$$

$$H \text{ Dist}_s = S \sqrt{(N_i - N_p)^2 + (E_i - E_p)^2}$$

$$N = H \text{ Dist}_s \cos (AZ_R) + N_{T_1}$$

$$E = H \text{ Dist}_s \sin (AZ_R) + E_{T_1}$$

Where: AZ_R = Rotated azimuth

ϕ = Rotation angle

N_i, E_i = Northing, easting of current point before transformation

N_p, E_p = Original northing, easting of pivot point

$H \text{ Dist}_s$ = Scaled horizontal distance

S = Scale factor

N, E = Northing, easting after transformation

N_{T_1}, E_{T_1} = Northing, easting of pivot point after transformation

Note: The scale factor is taken as one, unless the new grid system is to a different scale.

Example:

Coordinates before transformation are those computed by Compass Rule

Adjustment.

COORDINATES IN OLD SYSTEM	COORDINATES IN NEW SYSTEM
------------------------------	------------------------------

<u>N</u> 150.000*	<u>N</u> 100.00*
<u>E</u> 400.000	<u>E</u> 350.00

<u>N</u> 224.540	
<u>E</u> 561.673	

<u>N</u> 356.577	
<u>E</u> 468.710	

<u>N</u> 232.414	
<u>E</u> 307.327	

* Rotated about this point

Rotation Angle = $-3^\circ 00' 00''$

Scale Factor = 1.00

Solution:

-3.0000 STOP

1.0000 STOP

150.0000 ENT↑

400.0000 ENT↑

100.0000 ENT↑

350.0000 ENT↑

224.5400 ENT↑

561.6730 ENT↑

165.9765 *** N

E/S

515.3526 *** E

356.5570 ENT↑

468.7100 ENT↑

302.6770 *** N

E/S

429.4262 *** E

232.4140 ENT↑

307.3270 ENT↑

187.1512 *** N

E/S

261.7672 *** E

User Instructions

01	*LBL1				
02	ST02				
03	X#Y				
04	ST01				
05	RTN				
06	*LBL2				
07	ST04				
08	X#Y				
09	ST03				
10	RTN				
11	*LBL3				
12	RCL2				
13	-				
14	X#Y				
15	RCL1				
16	-				
17	+P				
18	RCL6				
19	X	H Dist _S			
20	X#Y				
21	RCL5				
22	+H	AZ _R Note sign			
23	-	convention			
24	X#Y				
25	+R				
26	RCL3				
27	+	*** N			
28	R/S				
29	X#Y				
30	RCL4				
31	+	*** E			
32	R/S				

REGISTERS

0	1 N _P	2 E _P	3 N _{T₁}	4 E _{T₁}	5 Ø
6 S	7	8	9	.0	.1
.2	.3	.4	.5	16	17
18	19	20	21	22	23
24	25	26	27	28	29

NOTES

In the Hewlett-Packard tradition of supporting HP programmable calculators with quality software, the following titles have been carefully selected to offer useful solutions to many of the most often encountered problems in your field of interest. These ready-made programs are provided with convenient instructions that will allow flexibility of use and efficient operation. We hope that these Solutions books will save your valuable time. They provide you with a tool that will multiply the power of your HP-19C or HP-29C many times over in the months or years ahead.

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Surveying Solutions
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