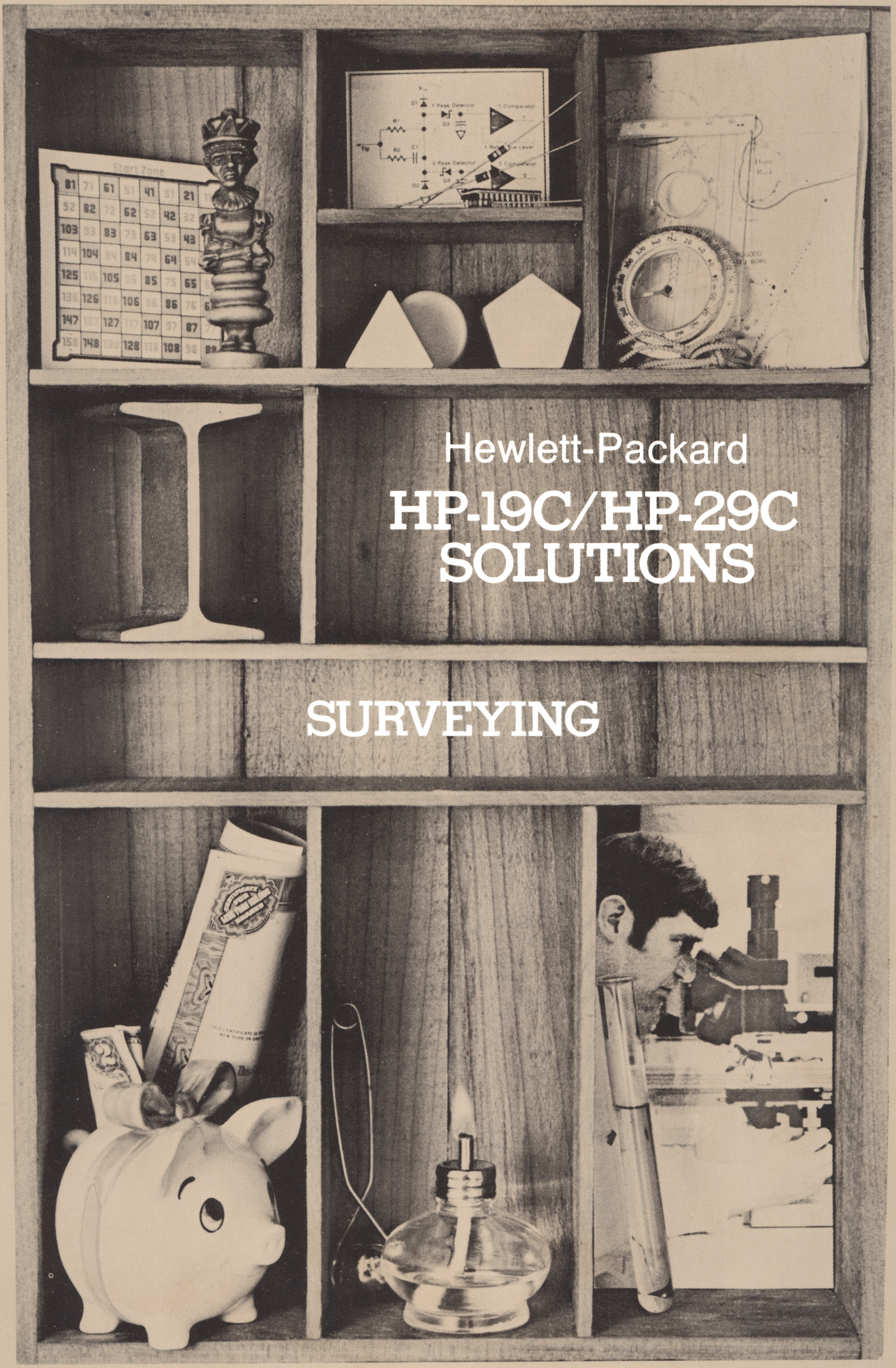

Hewlett-Packard

HP-19C/HP-29C SOLUTIONS

SURVEYING

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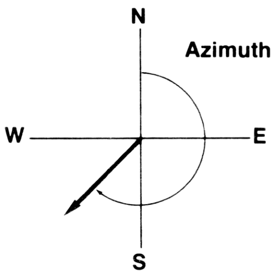
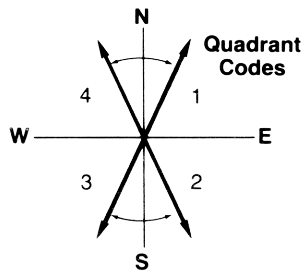
* This program also appears in the HP-19C/29C Applications book, but is included here for the sake of completeness.

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 keystroke 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° 56' 37"W to an azimuth.
2. Convert bearing N 85° 24' 47"W to an azimuth.
3. Convert azimuth of 162° 15' 32" to bearing/quadrant.
4. Convert azimuth of 39° 42' 26" to bearing/quadrant.

Solution:

```
1.    34.5637 ENT↑
           3. GSB1
     214.5637  ***    AZ.

2.    85.2447 ENT↑
       4.0000 GSB1
     274.3513  ***    AZ.

3.   162.1532 GSB2
      17.4428  ***    BRG.
               R/S
           2.  ***    QD.

4.    39.4226 GSB2
      39.4226  ***    BRG.
               R/S
           1.  ***    QD.
```

KEYSTROKE ROUTINES

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS				OUTPUT DATA/UNITS
	AZIMUTHS TO BEARINGS:						
1	Azimuth = 0° to 90°	AZ (D.MS)	NO CALCULATION				BRG (D.MS)
							QD = 1
2	Azimuth = 90° to 180°	180	ENTER↑				
		AZ (D.MS)	g	→H	-	f	
			→H.MS				BRG (D.MS)
							QD = 2
3	Azimuth = 180° to 270°	AZ (D.MS)	ENTER↑	180	-		BRG (D.MS)
							QD = 3
4	Azimuth = 270° to 360°	360	ENTER↑				
		AZ (D.MS)	g	→H	-	f	
			→H.MS				BRG (D.MS)
							QD = 4
	BEARINGS TO AZIMUTHS:						
5	Quadrant = 1	BRG (D.MS)	NO CALCULATION				AZ (D.MS)
6	Quadrant = 2	180	ENTER↑				
		BRG (D.MS)	g	→H	-	f	
			→H.MS				AZ (D.MS)
7.	Quadrant = 3	BRG (D.MS)	ENTER↑	180	+		AZ (D.MS)
8	Quadrant = 4	360	ENTER↑				
		BRG (D.MS)	g	→H	-	f	
			→H.MS				AZ (D.MS)

User Instructions

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Key in the program				
	(steps 01 thru 26 for bearing to azimuth,				
	steps 27 thru 45 for azimuth to bearing)				
2	To convert bearing to azimuth:	BRG (D.MS)	ENT↑		
	input bearing and quadrant	AD	GSB	1	AZ (D.MS)
3	To convert azimuth to bearings, input				
	azimuth.	AZ (D.MS)	GSB	2	BRG (D.MS)
			R/S		QD

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 0			
14 STO9			
15 ×			
16 X⇄Y			
17 RCL9			
18 ×			
19 COS			
20 R↓			
21 R↓			
22 R↓			
23 ×			
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 FIX0	***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.

Equations:

$$N_{i+1} = N_1 + \text{HDist} \cos AZ$$

$$E_{i+1} = E_1 + \text{HDist} \sin AZ$$

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

where:

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

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.

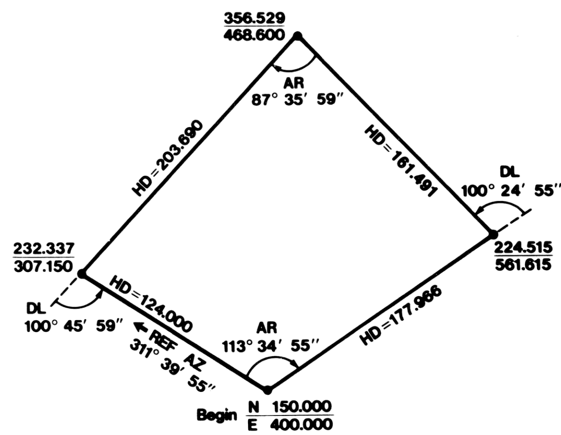
Angles left and deflections left must be entered as negative numbers.

This program assumes the calculator is set in DEG mode.

Example 1:

Field Angle Traverse
Traverse the figure below starting at

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



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  ***   (N)
           R/S
 561.6150  ***   (E)
-100.2455 GSB3
 324.4955  ***
 161.4910  R/S
 356.5285  ***   (N)
           R/S
 468.6000  ***   (E)
  87.3559 GSB2
 232.2554  ***
 203.6900  R/S
```

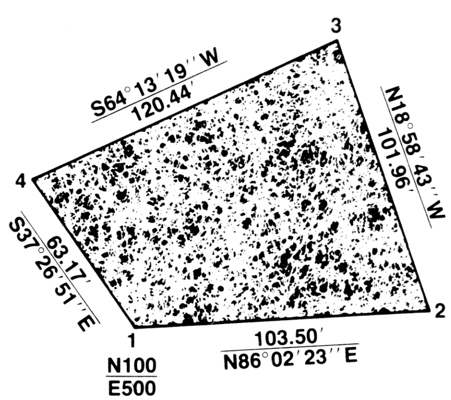
```
     232.3372  ***   (N)
               R/S
     307.1498  ***   (E)
    -100.4559 GSB3
     131.3955  ***
     124.0000  R/S
     149.9048  ***   (N)
               R/S
     399.7829  ***   (E)
              GSB5
   26558.8204  ***   (Area)
               R/S
       0.2371  ***   (Error Dist.)
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

Example 2:

Bearing Traverse

Traverse the figure below starting at

$\frac{N\ 100}{E\ 500}$



Solution:

```
    100.0000 ENT↑
    500.0000 GSB1
    180.0000  ***
     86.0223 ENT↑
      1.0000 GSB4
     86.0223  ***
    103.5000  R/S
    107.1482  ***   (N)
              R/S
    603.2529  ***   (E)
     18.5843 ENT↑
      4.0000 GSB4
    341.0117  ***
    101.9600  R/S
    203.5657  ***   (N)
              R/S
    570.0939  ***   (E)
     64.1319 ENT↑
      3.0000 GSB4
    244.1319  ***
    120.4400  R/S
    151.1880  ***   (N)
              R/S
    461.6395  ***   (E)
     37.2651 ENT↑
      2.0000 GSB4
    142.3309  ***
     63.1700  R/S
    101.0366  ***   (N)
              R/S
    500.0490  ***   (E)
             GSB5
   8855.4922  ***   (Area)
              R/S
      1.0378  ***   (Error Dist.)
              R/S
      2.4219  ***   (Error AZ)
```

User Instructions

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Key in the program.				
2	Key in beginning coordinates	BEG N	ENT↑		
		BEG E	GSB	1	180.00
	For Field Angle Traverse:				
3	Key in reference azimuth away	REF AZ	R/S		AZ (D.MS)
	from beginning point.				
4	Key in field angle:				
	Angle right	ang. right	GSB	2	AZ (D.MS)
	or Angle left (-)	-ang. left	GSB	2	AZ (D.MS)
	or Deflection right	deflect.rt	GSB	3	AZ (D.MS)
	or Deflection left (-)	-deflectlf	GSB	3	AZ (D.MS)
5	Key in horizontal distance and compute				
	coordinates	HDist	R/S		N
			R/S		E
	or				
	For Bearing Traverse:				
3'	Key in bearing*and quadrant code.	BRG (D.MS)	ENT↑		
		QD	GSB	4	AZ (D.MS)
4'	Key in horizontal distance and compute				
	coordinates.	HDist	R/S		N
			R/S		E
	Repeat steps 3,4,5, or 3',4' for successive				
	courses.				
6	For closed figure: Compute area, error				
	distance, and error azimuth.		GSB	5	Area
			R/S		Error Dist
	* If azimuth is known rather than bearing,		R/S		Error AZ
	enter azimuth with QD = 1.				

01 *LBL1	Store starting point coordinates and 180°	50 2	
02 FIX4		51 ÷	
03 CLRG		52 RCL7	
04 STO1		53 -	
05 X⇄Y		54 x	
06 STO2		55 ST+8	
07 1		56 RCL6	
08 8		57 RCL2	
09 0		58 +	
10 STO3		59 R/S	***
11 R/S		60 RCL7	
12 →H		61 RCL1	
13 RCL3	Reference azimuth	62 +	
14 →H		63 R/S	***
15 +		64 *LBL4	
16 GTO0		65 X⇄Y	
17 *LBL2		66 STO9	
18 →H	Angle input	67 X⇄Y	Convert bearing and quadrant code to azimuth.
19 RCL3		68 ENT↑	
20 →H		69 ENT↑	
21 +		70 2	
22 →HMS		71 ÷	
23 *LBL3	Deflection angle input	72 INT	
24 →H		73 RCL3	
25 RCL4		74 x	
26 +		75 X⇄Y	
27 *LBL0		76 RCL3	
28 1		77 x	
29 →R		78 COS	
30 →P	Compute azimuth	79 RCL9	
31 *LBL9		80 →H	
32 X⇄Y		81 x	
33 X>0?		82 -	
34 GTO8		83 GTO0	
35 3		84 *LBL5	Area
36 6		85 RCL8	
37 0		86 ABS	
38 +		87 R/S	***
39 *LBL8		88 RCL7	
40 STO4		89 RCL6	
41 →HMS		90 →P	Setup for closure ***
42 R/S	***	91 R/S	
43 ST+5		92 GTO9	
44 RCL4	Input horizontal distance	93 R/S	
45 X⇄Y			
46 →R			
47 ST+6			
48 X⇄Y	Compute next coord. and accumulate area.		
49 ST+7			

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:

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

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

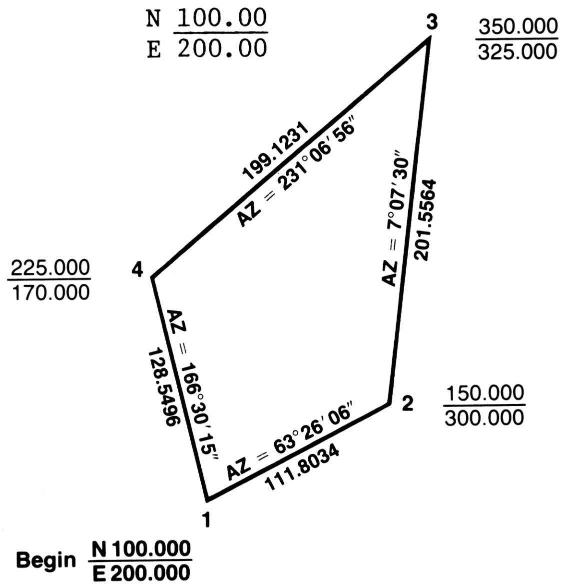
$$\text{Area} = \sum_{k=1}^{n} LAT_k \left(\tfrac{1}{2}DEP_k + \sum_{j=1}^{k-1} DEP_j \right)$$

where $DEP_k = E_{k+1} - E_k$ and

$LAT_k = N_{k+1} - N_k$

Example: Inverse the figure below starting at

N 100.00
E 200.00



Solution:

```
  100.0000 ENT↑
  200.0000 GSB1
  150.0000 ENT↑
  300.0000 GSB2
  111.8034  ***     H Dist
            R/S
   63.2606  ***     AZ
  350.0000 ENT↑
  325.0000 GSB2
  201.5564  ***     H Dist
            R/S
    7.0730  ***     AZ
  225.0000 ENT↑
  170.0000 GSB2
  199.1231  ***     H Dist
            R/S
  231.0656  ***     AZ
  100.0000 ENT↑
  200.0000 GSB2
  128.5496  ***     H Dist
            R/S
  166.3015  ***     AZ
           GSB7
20937.5000  ***     Area
            R/S
    0.0000  ***     Error, Dist
            R/S
  360.0000  ***     Error, AZ
```

User Instructions

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Key in program				
2	Enter beginning coordinates	BEG N	ENT↑		
		BEG E	GSB	1	
3	Enter coordinates of next point and	N	ENT↑		
	compute horizontal distance and azimuth	E	GSB	2	H Dist
			R/S		AZ (DMS)
4	Repeat step 3 for successive courses				
5	For closed figure, compute area, error		GSB	3	Area
	distance, and error azimuth		R/S		Error Dist.
			R/S		Error AZ

```
01 *LBL1
02  FIX4
03  CLRG
04  STO1
05   X⇄Y
06  STO2
07   R/S
08 *LBL2
09  RCL7
10    -
11  RCL1
12    -
13  ST+7
14  STO9
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>0?
36  GTO9
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
50  GTO0
51   R/S
```

REGISTERS

0	1 BEG E	2 BEG N	3	4	5
6 LAT	7 DEP	8 Area	9 Δ E	.0 ΔN	.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"

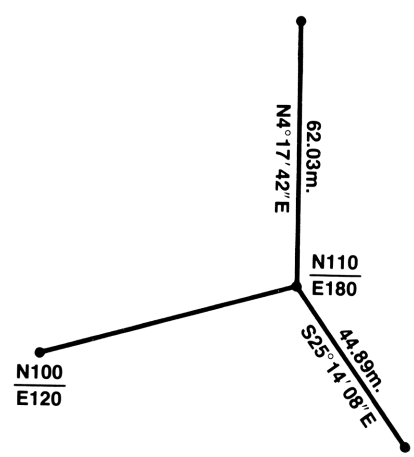
SIDESHOTS

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:

$$N = N_0 + H\ Dist\ \cos AZ$$
$$E = N_0 + H\ Dist\ \sin AZ$$

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
 25.1408 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

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Key in the program				
2	Enter hub coordinates	N	ENT↑		
		E	GSB	1	
3a	For bearing sideshot:* Enter bearing and quad-	BRG (D.MS)	ENT↑		
	rant;	QD	GSB	2	AZ (D.MS)
	enter horizontal distance and compute point	H Dist	R/S		N
	coordinates.		R/S		E
	*If azimuth is known rather than bearing,				
	enter azimuth with QD = 1.				
3b	For inverse sideshot: enter coordinates of	N	ENT↑		
	sideshot point and compute horizontal distance	E	GSB	3	H Dist
	azimuth		R/S		AZ (D.MS)
4	Repeat step 3 for all desired sideshots.				

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 8		57 RCL1	ΔE
09 0		58 -	
10 STO3		59 X⇄Y	
11 R/S		60 RCL2	ΔN 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 GTO9	
16 ENT↑		65 R/S	
17 ENT↑			
18 2			
19 ÷			
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	$\lvert AZ \rvert \leq 360^{o}$		
32 →R			
33 →P			
34 *LBL9	AZ		
35 X⇄Y			
36 X>0?			
37 GTO8			
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_0	2 N_0	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:

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

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

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.

ΣDist = 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 NO.	UNADJUSTED COORDINATES
2	N = 224.515
	E = 561.615
3	N = 356.529
	E = 468.600
4	N = 232.337
	E = 307.150

$\left.\begin{array}{l}\text{Ending \&}\\ \text{Beginning}\end{array}\right\}\begin{array}{l}N = 149.905\\ E = 399.783\end{array}$

Solution:

```
150.0000 STO2
400.0000 STO1
667.1470 STO5
149.9050 STO6
399.7830 STO7
         GSB1
224.5150 ENT↑
561.6150 GSB2
224.5403  ***    Adj. N
          R/S
561.6729  ***    Adj. E
356.5290 ENT↑
468.6000 GSB2    Adj. N
356.5773  ***
          R/S
469.7104  ***    Adj. E
232.3370 ENT↑
307.1500 GSB2
232.4143  ***    Adj. N
          R/S
307.3267  ***    Adj. E
149.9050 ENT↑
399.7830 GSB2
150.0000  ***    Adj. N
          R/S
400.0000  ***    Adj. E
```

User Instructions

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Key in the program				
2	Store data	Beg N	STO	2	
	Note: If this program is run immediately	Beg E	STO	1	
	following "Field Angle or Bearing Traverse",	ΣHDist	STO	5	
	these values are already stored in the	C1 LAT	STO	6	
	correct registers.	C1 DEP	STO	7	
3	Initialize		GSB	1	
4	Compute adjusted coordinates	Unadj N	ENT↑		
		Unadj E	GSB	2	Adj N
			R/S		Adj E
	*N.E. Coordinates must be reentered in the				
	same sequence as originally traversed,				
	starting at the second point.				

01 *LBL1	initialize		
02 RCL1			
03 STO8			
04 RCL7			
05 -			
06 RCL5	$\frac{\Delta E}{\Sigma Dist}$		
07 ÷			
08 STO3			
09 RCL2			
10 RCL6			
11 -			
12 RCL5	$\frac{\Delta N}{\Sigma Dist}$		
13 ÷			
14 STO4			
15 RCL2			
16 STO5			
17 RTN			
18 *LBL2			
19 X⇄Y	$(x \gtrless y)$		
20 STO6			
21 RCL2			
22 -			
23 ST+5			
24 X⇄Y			
25 STO7			
26 RCL1			
27 -			
28 ST+8	$\sqrt{x^2 + y^2 = Dist}$		
29 →P			
30 STO9			
31 RCL3	C_D		
32 ×			
33 ST+8			
34 RCL9			
35 RCL4	C_L		
36 ×			
37 ST+5			
38 RCL6			
39 STO2			
40 RCL7			
41 STO1			
42 RCL5	***Adj N		
43 R/S			
44 RCL8	*** Adj E		
45 R/S			

REGISTERS

0	1 Beg E	2 Beg N	3 $\Delta E/\Sigma Dist$	4 $\Delta E/\Sigma Dist$	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

$\frac{1}{2}\Delta = \tan^{-1}(T/R) = \sin^{-1}(\frac{1}{2}C/R) = 90L/\pi R$

$T = R \tan(\frac{1}{2}\Delta)$

$C = 2T \cos(\frac{1}{2}\Delta)$

$R = T/\tan(\frac{1}{2}\Delta) = C/(2 \sin(\frac{1}{2}\Delta))$

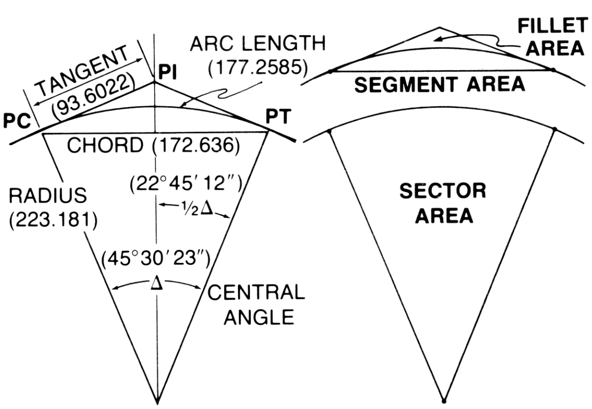
$L = \Delta\pi R/180$

Sector area = LR/2

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

Fillet area = T R-Sector area

Where: T = Tangent distance
C = Chord length
L = Arc length
R = Radius
Δ = Central angle



R = 223.181
$\Delta = 45^o\ 30'\ 23''$
$\frac{1}{2}\Delta = 22^o\ 45'\ 11''$
C = 172.636
T = 93.602
L = 177.258
Sector area = 19780.36
Segment area = 2015.00
Fillet area = 1109.87

Solution:

	CLRG	
223.1810	STO2	R
172.6360	STO3	C
	GSB1	
223.1810	***	R
	R/S	
22.7532	***	Δ/2
	R/S	
93.6022	***	T
	R/S	
172.6360	***	C
	R/S	
177.2584	***	L
	R/S	
19780.3563	***	Sector Area
	R/S	
2014.9959	***	Segment Area
	R/S	
1109.8705	***	Fillet Area

User Instructions

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Key in the program				
2	Initialize		f	REG	
3	Store data for any one of the following pairs:	Δ	STO	1	
	Δ, C	R	STO	2	
	Δ, R	C	STO	3	
	Δ, T	T	STO	4	
	R,T	L	STO	5	
	R,L				
	R,C				
4	Run		GSB	1	R
			R/S		Δ/2
			R/S		T
			R/S		C
			R/S		L
			R/S		Sector A
			R/S		Segment A
			R/S		Fillet A
5	For a new case, go to step 2.				

01 *LBL1		50 x	
02 RCL1		51 RCL2	
03 →H		52 x	
04 2		53 R/S	***L
05 ÷		54 RCL2	
06 STO1		55 ST×4	
07 X=0?		56 x	
08 GTO9		57 2	
09 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 STO2		65 -	
17 RCL4		66 R/S	***Fillet area
18 RCL1		67 *LBL9	have R, calculate Δ
19 TAN		68 RCL5	
20 ÷	R = f (T,Δ)	69 RCL2	
21 X≠0?		70 ÷	
22 STO2		71 9	
23 *LBL5		72 0	
24 RCL2		73 x	
25 R/S	*** R	74 PI	
26 RCL1		75 ÷	Δ = f (L,R)
27 R/S	***Δ/2	76 X≠0?	
28 TAN		77 STO1	
29 x		78 RCL3	
30 STO4		79 RCL2	
31 R/S	*** T	80 2	
32 2		81 x	
33 x		82 ÷	
34 RCL1		83 SIN-1	Δ = f (C,R)
35 COS		84 X≠0?	
36 x		85 STO1	
37 R/S	*** C	86 RCL4	
38 RCL2		87 RCL2	
39 x		88 ÷	
40 RCL1		89 TAN-1	Δ = f (T,R)
41 COS		90 X≠0?	
42 x		91 STO1	
43 2		92 GTO5	
44 ÷		93 R/S	
45 PI			
46 9			
47 0			
48 ÷			
49 RCL1			

REGISTERS

0	1 Δ/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"

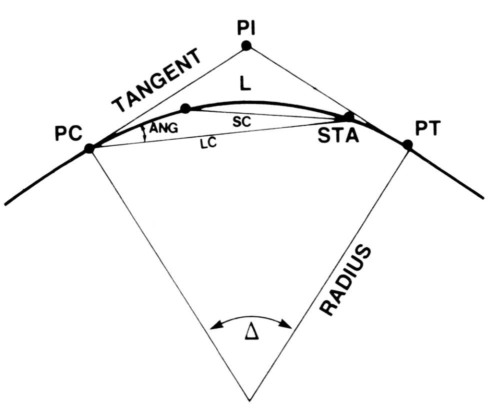
HORIZONTAL CURVE LAYOUT

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.

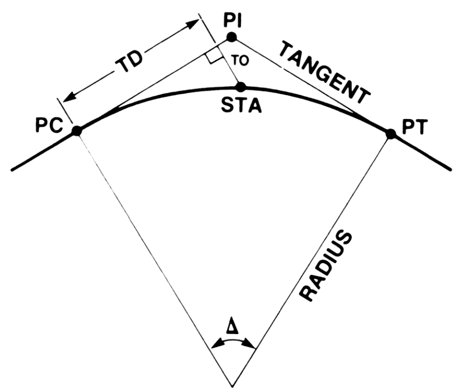
In the program, stations are entered in the form XXXX.XX for station XX+XX.XX. For example: 20 + 10.00 is entered as 2010.00. The degree of curve D, (or central angle subtending an arc of 100 ft.) is entered in degrees with a negative sign, always.

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 Δ-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°30' and degree of curve of 12°30'. The PC station is 7 + 85.40.

Solution:

```
 785.4000 ENT↑
 -12.3000 GSB1
 785.4000  ***   (PC)
          RCL1
 458.3662  ***   (R)

 800.0000 GSB2   (For STA. 8)
  14.6000  ***   (L)
           R/S
   0.5445  ***   (ANG)
           R/S
  14.5994  ***   (LC)
           R/S
  14.5994  ***   (SC)
          RCL8
   0.2325  ***   (TO)
          RCL9
  14.5975  ***   (TD)

 900.0000 GSB2   (For STA. 9)
 114.6000  ***   (L)
           R/S
   7.0945  ***   (ANG)
           R/S
 114.3018  ***   (LC)
           R/S
  99.8018  ***   (SC)
          RCL8
  14.2516  ***   (TO)
          RCL9
 113.4098  ***   (TD)
```

```
1000.0000 GSB2   (For STA. 10)
 214.6000  ***   (L)
           R/S
  13.2445  ***   (ANG)
           R/S
 212.6454  ***   (LC)
           R/S
  99.8018  ***   (SC)
          RCL8
  49.3252  ***   (TO)
          RCL9
 206.8455  ***   (TD)
  35.3000 GSB3
 284.0000  ***   (L)
           R/S
1069.4000  ***   (PT)
           R/S
 146.7242  ***    (T)

1069.4000 GSB2    (Field data: PT)
 284.0000  ***    (L)
           R/S
  17.4500  ***    (ANG)
           R/S
 279.4790  ***    (LC)
           R/S
  69.3337  ***    (SC)
```

User Instructions

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Key in the program.				
2	Input beginning station of curve	PC	ENT↑		PC
3	Input radius	R	GSB	1	
	or degree of curve (as a negative number)	-D(D.MS)	GSB	1	
3'	Radius or degree of curve are available if		RCL	1	R
	desired.		RCL	2	D
4	Input station	STA	GSB	2	L(Arc.leng)
			R/S		def. angle
			R/S		long chord
			R/S		short chord
4'	Tangent offset, TO, and tangent distance,				
	TD, are available if desired.		RCL	8	TO
			RCL	9	TD
5	Input central angle	Δ(D.MS)	GSB	3	Arc. length
			R/S		station PT
			R/S		T, length

Step	Key	Comment
01	*LBL1	
02	CLRG	
03	FIX4	Store R&D
04	X<0?	
05	GSB0	
06	STO1	
07	Pi	
08	x	
09	9	
10	0	
11	÷	
12	STO2	Input PC
13	R↓	
14	STO3	
15	STO4	
16	RTN	
17	*LBL0	
18	CHS	
19	→H	Calculate R from D
20	Pi	
21	x	
22	1/X	
23	1	
24	8	
25	EEX	
26	3	
27	x	
28	RTN	
29	*LBL2	Input station
30	RCL4	
31	ST.2	
32	R↓	
33	STO4	
34	RCL3	
35	-	
36	R/S	***
37	GSB9	Calculate L
38	x	
39	STO7	
40	→HMS	
41	R/S	***
42	RCL7	Calculate ANG
43	SIN	
44	RCL1	
45	x	
46	2	
47	x	Calculate LC
48	STO5	
49	RCL7	
50	SIN	Calculate TO
51	x	
52	STO8	
53	RCL5	Calculate TD
54	RCL7	
55	COS	
56	x	
57	STO9	dsp LC
58	RCL5	
59	R/S	***
60	RCL4	
61	RC.2	
62	-	
63	GSB9	
64	x	
65	SIN	
66	RCL1	
67	2	
68	x	
69	x	***Calculate SC
70	RTN	
71	*LBL9	
72	9	
73	0	$\frac{90}{\pi R}$
74	Pi	
75	÷	
76	RCL1	Input Δ
77	÷	
78	RTN	
79	*LBL3	
80	→H	
81	2	
82	÷	
83	STO6	
84	GSB9	
85	÷	Calculate L
86	R/S	***
87	RCL3	
88	+	Calculate PT
89	R/S	***
90	RCL6	
91	TAN	
92	RCL1	
93	x	***
94	R/S	Calculate T

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

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

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

$$b = \sqrt{Dist_2^2 - h^2}$$

$$N = N_1 + ((Dist_{12} \cos\phi)+b) \cos (Az_1)$$

$$E = E_1 + ((Dist_{12} \cos\phi)+b) \sin (Az_1)$$

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
- $Dist_2$ = Length of line 2 (the known distance)
- N_1E_1 = Northing, easting of point 1
- N_2E_2 = Northing, easting of point 2
- $Dist_{12}$ = Distance from point 1 to point 2

Bearing-Bearing

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

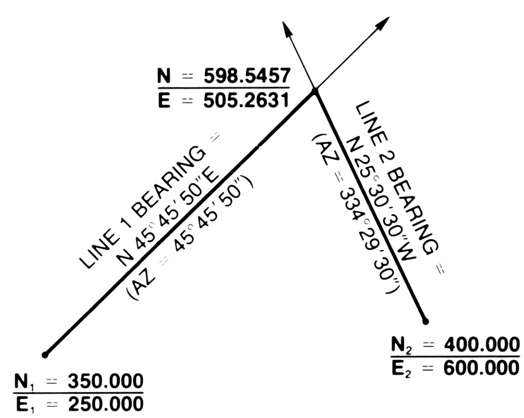
$$E = E_1 + Dist (\sin AZ_1)$$

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

where:

- AZ_{12} = Azimuth of line from point 1 to point 2
- AZ_1 = Azimuth of line 1
- AZ_2 = Azimuth of line 2
- N_1E_1 = Northing, easting of point 1
- N_2E_2 = Northing, easting of point 2
- N,E = Northing, easting of intersect point
- $Dist$ = Distance from point 1 to intersection
- $Dist_{12}$ = Distance from point 1 to point 2

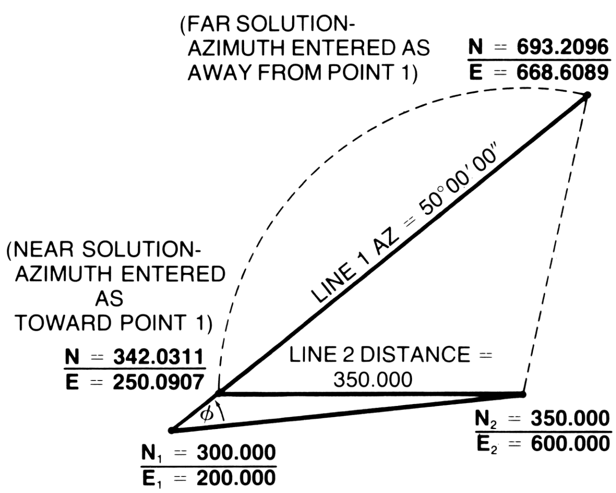
Example 1:



Solution:

```
750.0000 ENT↑
250.0000 GSB1
400.0000 ENT↑
600.0000  R/S
 45.4550 ENT↑
  1.0000 GSB2
 25.3070 ENT↑
  4.0000 GSB3
         GSB4
598.5457  ***   N
          R/S
505.2631  ***   E
```

Example 2:



Solution:

```
300.0000 ENT↑
200.0000 GSB1
350.0000 ENT↑
600.0000  R/S
 50.0000 ENT↑
  1.0000 GSB2
350.0000 STO7
         GSB5
693.2096  ***   N1
          R/S
668.6089  ***   E1

300.0000 ENT↑
200.0000 GSB1
350.0000 ENT↑
600.0000  R/S
 50.0000 ENT↑
  3.0000 GSB2
350.0000 STO7
         GSB5
342.0311  ***   N2
          R/S
250.0907  ***   E2
```

User Instructions

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Key in the program				
2	Enter coordinates of point 1	N1	ENT↑		
		E1	GSB	1	
3	Enter coordinates of point 2	N2	ENT↑		
		E2	R/S		
4	Enter bearing and quadrant of line 1	BRG 1	ENT↑		
		QD 1*	GSB	2	AZ 1 (D.d)
	(or store the azimuth of line 1)	AZ* (D.d)	STO	5	
5a	For bearing-bearing: enter bearing and	BRG 2	ENT↑		
	quadrant of line 2	QD 2	GSB	3	AZ 2 (D.d)
	(or store the azimuth of line 2); and	AZ 2 (D.d)	STO	6	
	compute intersect coordinates		GSB	4	N
5b	For bearing-distance*: store the distance		R/S		E
	of line 2; and compute intersect coordinates	Dist 2	STO	7	
			GSB	5	N
			R/S		E
	*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.				

01 *LBL1	Store Coordinates	50 X⇄Y	
02 STO2		51 X>0?	
03 R↓		52 RTN	
04 STO1		53 3	
05 1		54 6	
06 8		55 0	
07 0		56 +	
08 STO0		57 RTN	
09 R/S		58 *LBL4	
10 STO4		59 GSB6	
11 R↓		60 RCL6	
12 STO3		61 -	
13 RTN		62 CHS	AZ_{12} $-AZ_{12}$
14 *LBL2		63 SIN	
15 GSB0		64 ×	
16 STO5		65 RCL6	
17 RTN		66 RCL5	
18 *LBL3		67 -	
19 GSB0		68 SIN	
20 STO6		69 ÷	Dist
21 RTN		70 STO8	
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 ×		81 R/S	
33 R↓		82 *LBL5	
34 X⇄Y		83 GSB6	
35 R↓		84 RCL5	
36 RCL0		85 -	
37 ×		86 CHS	$AZ_1 - AZ_{12} = Ø$
38 COS		87 X⇄Y	
39 ×	AZ	88 →R	
40 -		89 X⇄Y	
41 RTN		90 X²	h^2
42 *LBL6		91 RCL7	
43 RCL4		92 X²	
44 RCL2		93 -	
45 -		94 CHS	
46 RCL3		95 √X	b
47 RCL1		96 +	
48 -		97 STO8	
49 →P	$-Dist_{12}$ AZ_{12}	98 GTO9	

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:

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

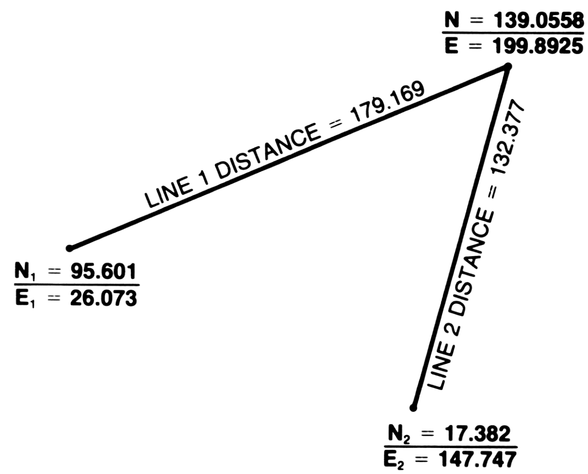
$$AZ = \tan^{-1} \frac{E_2 - E_1}{N_2 - N_1}$$

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

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

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_1 = Northing, easting of point 1
- N,E = Northing, easting of intersection point
- AZ = Azimuth of line from point 1 to point 2

Example:



Solution:

```
              CLRG
179.1690  ENT↑
132.3770  GSB1
 95.6010  ENT↑
 26.0730  GSB2
 17.3820  ENT↑
147.7470  GSB3
139.0558  ***     N
               R/S
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

* Two solutions are possible. For the alternate solutions reverse the order of entering points 1 and 2

Program			
01 *LBL1			
02 STO6			
03 R↓			
04 STO5			
05 RTN			
06 *LBL2			
07 STO2			
08 X⇄Y			
09 STO1			
10 RTN			
11 *LBL3			
12 STO4			
13 R↓			
14 STO3			
15 RCL4			
16 RCL2			
17 -			
18 RCL3			
19 RCL1			
20 -			
21 →P	$Dist_{12}$ AZ		
22 STO7			
23 X²			
24 RCL5			
25 X²			
26 +			
27 RCL6			
28 X²			
29 -			
30 2			
31 ÷			
32 RCL7			
33 RCL5			
34 x			
35 ÷			
36 COS⁻¹	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:

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

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

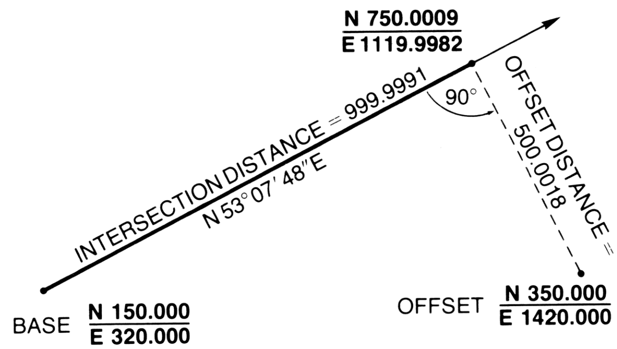
$$N_1 = \frac{E_O - E_B + N_O \operatorname{ctn}(Az_{BI}) + N_B \tan(Az_{BI})}{\operatorname{ctn}(Az_{BI}) + \tan(Az_{BI})}$$

$$E_1 = E_B + (N_I - N_B)\tan(Az_{BI})$$

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_O, E_O = 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	
53.0748	ST05	AZ
1.0000	ST06	
180.0000	ST07	
	GSB1	N_I
750.0009	***	
	R/S	
1119.9982	***	E_I
	R/S	
500.0018	***	O.D.
	R/S	
999.9991	***	I.D.
	R/S	
143.0748	***	O. AZ

User Instructions

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Key in the program				
2	Store data	N_B	STO	1	
		E_B	STO	2	
		N_O	STO	3	
		E_O	STO	4	
		BRG**	STO	5	
		QD**	STO	6	
		180	STO	7	
3	Run		GSB	1	N_I
			R/S		E_I
			R/S		O.D.
			R/S		I.D.
			R/S		O.AZ*
	*Offset azimuth may be incorrect for bearings of 0, but for these cases, the offset azimuth may be obtained by inspection				
	**If azimuth is known rather than bearing	Az(H.MS)	STO	5	
		1	STO	6	

01 *LBL9	bearing to azimuth	50 +	
02 RCL7	conversion routine	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 $\vert AZ \vert \leq 360^{o}$	67 →P	
19 →P		68 R/S	***offset distance
20 X⇄Y		69 RCL1	
21 X>0?		70 RC.0	
22 GTO7		71 -	
23 3		72 RCL2	
24 6		73 RC.1	
25 0		74 -	
26 +		75 →P	
27 *LBL7		76 R/S	***intersect distance
28 STO5		77 X⇄Y	θ 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	
37 STO8		86 RCL2	E_B
38 x		87 +	
39 -		88 RCL4	E_O E calculated
40 STO9		89 X=Y?	
41 RCL4		90 GTO0	
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 0	
48 ENT↑		97 +	
49 1/X		98 GTO8	AZ ± 90

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_I	.1 E_I
.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:

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

$$Area = \tfrac{1}{2}[Elev_1\ (H\ Dist_2 - H\ Dist_n) + Elev_2\ (H\ Dist_3 - H\ Dist_1) + \ldots + Elev_n\ (H\ Dist_1 - H\ Dist_{n-1})]$$

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.

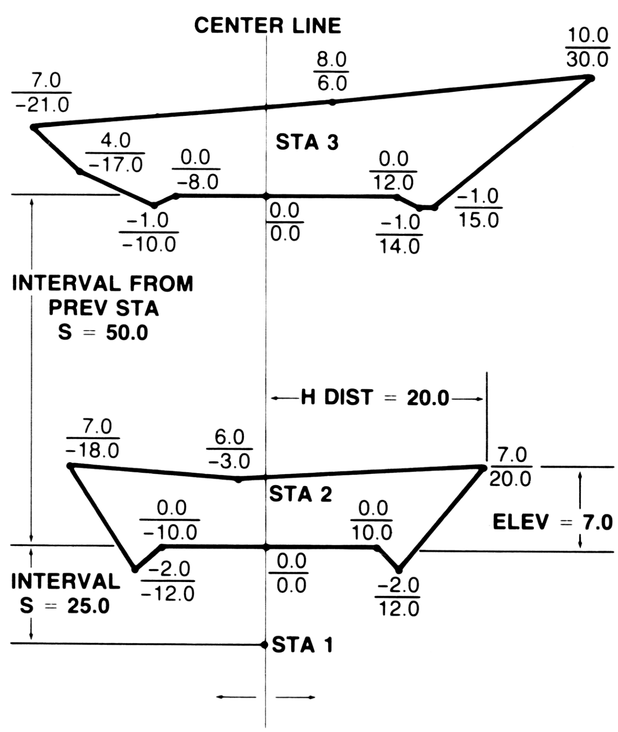
Equations:

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

$$Vol = (Width)(Length)(Elev)$$

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:

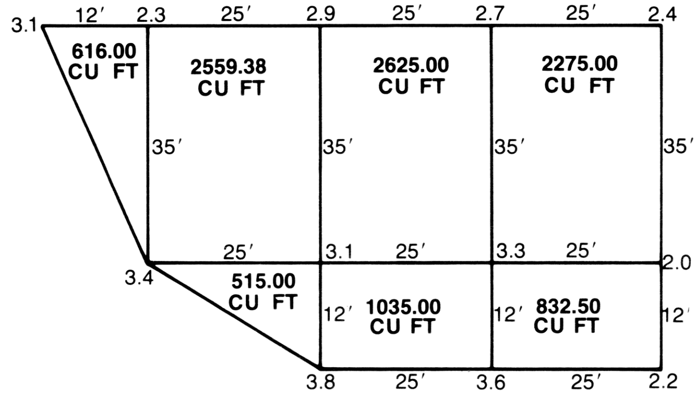


Solution:

```
                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    GSB1
      7.0000    ENT↑
    -21.0000    GSB1
      4.0000    ENT↑
    -17.0000    GSB1
     -1.0000    ENT↑
    -10.0000    GSB1
      0.0000    ENT↑
     -8.0000    GSB1
      0.0000    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↑
     35.0000    GSB4
      2.3000    GSB5
      3.4000    GSB5
      3.1000    GSB5
      2.9000    GSB5
      2.9000    GSB5
      3.1000    GSB5
      3.3000    GSB5
      3.3000    GSB5
      2.7000    GSB5
      2.7000    GSB5
      2.4000    GSB5
      2.0000    GSB5
                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.
```

```
     12.0000    ENT↑
     25.0000    GSB4
      3.8000    GSB5
      3.1000    GSB5
      3.6000    GSB5
      3.6000    GSB5
      3.3000    GSB5
      3.3000    GSB5
      2.0000    GSB5
      2.2000    GSB5
                GSB6
   1867.5000    ***    G.Vol.
                R/S
  10457.8750    ***    A.Vol.
```

User Instructions

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Key in the program				
	VOLUME BY AVERAGE END AREA:				
2	Initialize		f	REG	
3	If station has zero end area go to step 6				
4	Input elevation and distance from the	Elev	ENT↑		
	centerline	Dist	GSB	1	
5	Repeat step 4 working around the section until				
	first Elev. and Dist. have been reinput				
6	Input interval from previous station and				
	calculate total volume	Int. (ft)	GSB	2	Total vol. (yds^3)
	(Note: input 0 interval if first station)				
7	For volume of interval		RCL	5	Int. vol. (yds^3)
8	For area of cross section		RCL	4	Area (ft^2)
9	Go to step 3 for a new section, Step 2 for a				
	new case				
	VOLUME OF BORROW PIT				
10	Initialize		f	Σ	
11a	For triangular area	Base	ENT↑		
		Height	GSB	3	
11b	For rectangular area	Width	ENT↑		
		Length	GSB	4	
12	Input as many elevations as needed to describe				
	each corner, pressing GSB 5 after each entry	Elev	GSB	5	
13	Calculate grid section volume		GSB	6	G.Vol (ft^3)
14	Calculate accumulated volume		R/S		A.Vol (ft^3)
	(To convert cubic feet to cubic yards divide				
	by 27.)				

Step	Key	Comment
01	*LBL1	Avg. End Area routines
02	STx1	
03	RCL1	
04	ST-2	
05	R↓	
06	X⇄Y	
07	STx0	
08	RCL0	
09	ST+2	
10	R↓	
11	STO1	
12	R↓	
13	STO0	
14	RCL2	
15	2	
16	÷	
17	STO3	
18	RTN	
19	*LBL2	
20	RCL4	
21	RCL3	
22	ABS	
23	STO4	
24	+	
25	5	
26	4	
27	÷	
28	x	interval Volume
29	STO5	
30	ST+6	
31	0	Clear registers
32	STO0	
33	STO1	
34	STO2	
35	STO3	
36	RCL6	Total Volume
37	RTN	
38	*LBL3	
39	x	Borrow Pit routines
40	6	
41	÷	
42	ST.3	
43	GTO0	
44	*LBL4	
45	x	
46	4	
47	÷	
48	ST.3	
49	*LBL0	
50	0	prepare for sub-routine 5
51	ENT↑	
52	RTN	
53	*LBL5	
54	+	
55	R/S	
56	*LBL6	
57	RC.3	
58	x	
59	S+.2	
60	R/S	***grid section volume
61	RC.2	***accumulated volume
62	R/S	

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:

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

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

$$N = H\ Dist_s \cos(AZ_R) + N_{T_1}$$

$$E = H\ Dist_s \sin(AZ_R) + E_{T_1}$$

Where:
- AZ_R = Rotated azimuth
- ϕ = Rotation angle
- N_iE_i = Northing, easting of current point before transformation
- N_pE_p = Original northing, easting of pivot point
- $H\ Dist_s$ = 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
N 150.000*	N 100.00*
E 400.000	E 350.00
N 224.540	
E 561.673	
N 356.577	
E 468.710	
N 232.414	
E 307.327	

* Rotated about this point

Rotation Angle = −3° 00' 00"
Scale Factor = 1.00

Solution:

```
 -3.0000 STOE
  1.0000 STO5
150.0000 ENT↑
400.0000 GSB1
100.0000 ENT↑
350.0000 GSB2
224.5400 ENT↑
561.6730 GSB3
165.9765  ***    N
          R/S
515.3526  ***    E
356.5770 ENT↑
468.7100 GSB3
302.6779  ***    N
          R/S
429.4262  ***    E
232.4140 ENT↑
307.3270 GSB3
197.1512  ***    N
          R/S
261.7672  ***    E
```

User Instructions

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Key in the program				
2	Store rotation angle and scale factor	Ø (H.MS)	STO	5	
	(scale factor usually = 1)	S	STO	6	
3	Input N and E of pivot point in old system	N	ENT↑		
		E	GSB	1	
4	Input N and E of pivot point in new system	N	ENT↑		
		E	GSB	2	
5	Calculate transformed coordinates	N	ENT↑		
		E	GSB	3	N
			R/S		E
6	Repeat step 4 for all points				

01 *LBL1 02 STO2 03 X⇄Y 04 STO1 05 RTN 06 *LBL2 07 STO4 08 X⇄Y 09 STO3 10 RTN 11 *LBL3 12 RCL2 13 - 14 X⇄Y 15 RCL1 16 - 17 →P 18 RCL6 19 x 20 X⇄Y 21 RCL5 22 →H 23 - 24 X⇄Y 25 →R 26 RCL3 27 + 28 R/S 29 X⇄Y 30 RCL4 31 + 32 R/S	H $Dist_s$ (line 19) AZ_R Note sign convention (line 22) *** N (line 27) *** E (line 31)		

REGISTERS

0	1 N_P	2 E_P	3 N_{T_1}	4 E_{T_1}	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

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