N6 Building and Structural Surveying

Gateways to Engineering Studies - Chris Brink

HYBRID LEARNING SOLUTIONS

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Building and Structural Surveying

N6

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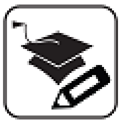
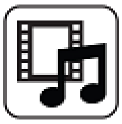
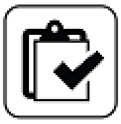
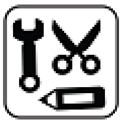
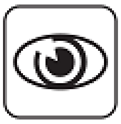
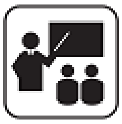
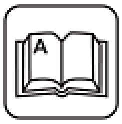
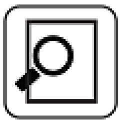
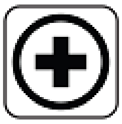
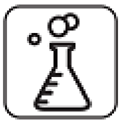
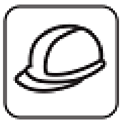
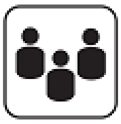
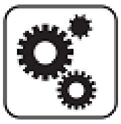
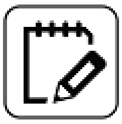
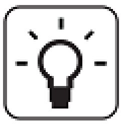
	Assessment / Activity		Multimedia
	Checklist		Practical
	Demonstration/ observation		Presentation/ Lecture
	Did you know?		Read
	Example		Safety
	Experiment		Site visit
	Group work/ discussions, role-play, etc.		Take note of
	In the workplace		Theoretical – questions, reports, case studies, etc.
	Keywords		Think about it

Module 1

Angular measurement

Learning Outcomes
On the completion of this module the student must be able to:

- Describe the temporary adjustments to optical theodolites
- Explain the following terms:
  - Transit
  - Swing
  - Face
  - Bisection of a target angle
  - Angle of direction
  - Direction measurements of angles by theodolite.
- Describe the measurement of angles of depression and elevation by theodolite.
- Describe computing of the true horizontal length from the slope distance and the angle of inclination.
- Describe operational errors and errors due to natural causes in measurement of angles

1.1 Introduction

Basic field operations performed by a surveyor involve linear and angular measurements. Through the application of mathematics and spatial information knowledge, the surveyor converts these measurements to the horizontal and vertical relationships necessary to produce maps, plans of engineering projects, or GIS/LIS.

1.2 Co-ordinates

In survey work, measured slope distances are transformed into their horizontal and vertical components.

For plotting a plan or map, only horizontal distances are used.

These horizontal distances and their directions are then transformed into co-ordinates.

In survey work the two co-ordinates of a point are measured at right angles to each other and originate from zero lines called co-ordinate axes. Thus, any point on the earth's surface can be fixed by measuring its perpendicular distance from each of the two co-ordinate axes. The intersection of these distances are known as the origin.

In mapping and survey work, the co-ordinates are usually named Y and X.
Y usually represents the measurement of the East to West distance
X usually represents the measurement of the North to South distance

In surveying, the Y co-ordinate is written first followed by the X co-ordinate as follows:

19426,13 + 314006,07

	Note: A co-ordinate without its sign is meaningless!

On the South African co-ordinate system, the Y co-ordinate is measured positive to the West of the origin and negative to the East. The X co-ordinate is measured positive from the origin in the positive direction of the X-axis and negative in the opposite direction.

As a point on the equator is the origin, it is measured positive to the South. These conventions are reversed in the Northern Hemisphere and some systems in the Southern Hemisphere.

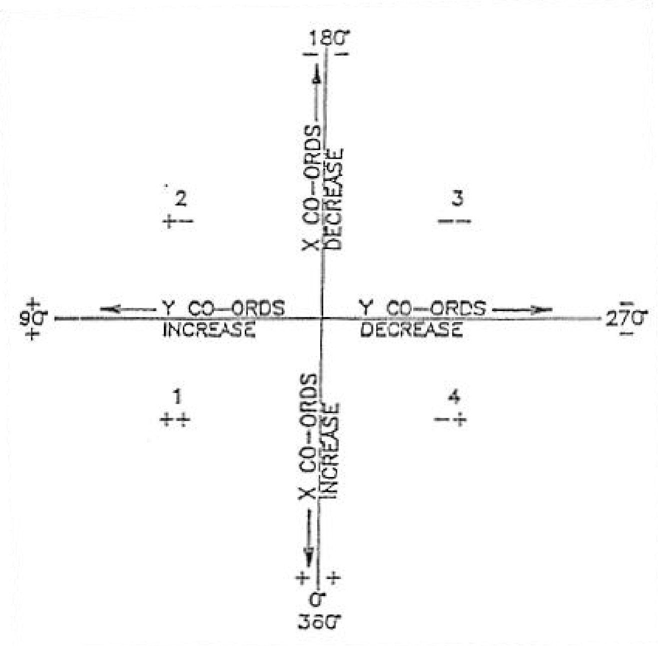


Figure 1.1

In survey work, angles are always measured in a clockwise direction. **Figure 1.1** above shows how a co-ordinate system is divided into Quadrants.

In the 1st Quadrant Y & X co-ordinates are positive -
In the 2nd Quadrant Y co-ordinates are positive and X co-ordinates are negative
In the 3rd Quadrant Y & X co-ordinates are negative
In the 4th Quadrant Y co-ordinates are negative and X co-ordinates are positive

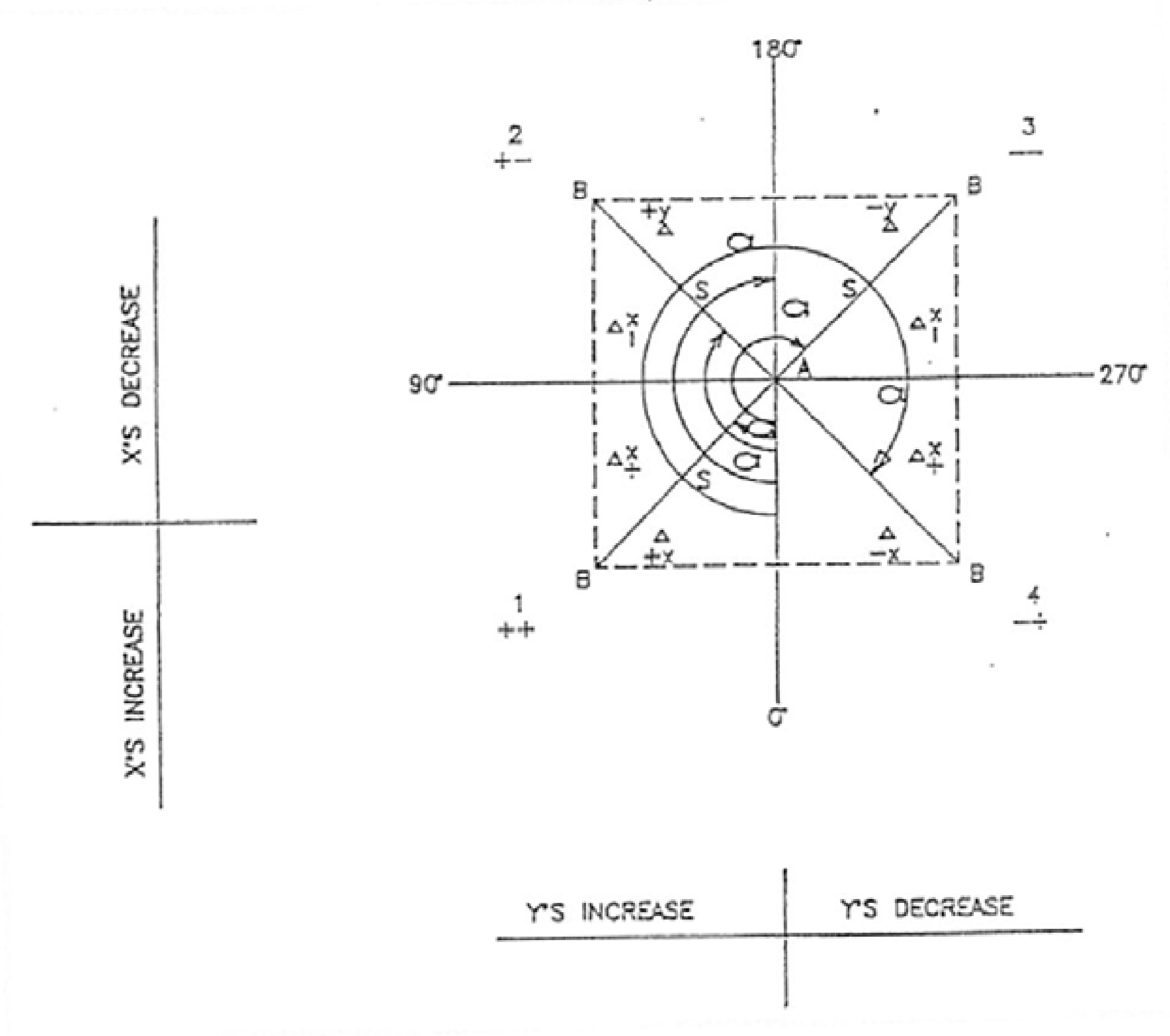


Figure 1.2

In **Figure 1.2** above, the point B is shown as it might be in each Quadrant. The Y and X coordinates of B in each case are the lengths of the two perpendiculars to the X and Y axes as shown by the broken lines and symbols ΔY and ΔX.

The lines AB represent the direction from A to B and the directions are shown as α. It can be seen that α is always measured from 0° thus determining into which quadrant the line falls and thus the quadrant signs. The distance of line A→B is shown as S.

From **Figure 1.2** we can then derive the formulae for the join and polar calculations etc as shown.

Formulae used in join and polar calculations:

Formulae used in join and polar calculations:
Y_A = Co-ordinate (A) - Y
X_A = Co-ordinate (A) - X
Δ_Y = Diff in Y co-ordinate
Δ_X = Diff in X co-ordinate
S = Distance in metre
α = Direction

To find direction:

First Quadrant

$$\alpha = \tan^{-1}\frac{\Delta Y}{\Delta X} + 0^\circ$$

Second Quadrant

$$\alpha = \tan^{-1}\frac{\Delta Y}{\Delta X} + 90^\circ$$

Third Quadrant

$$\alpha = \tan^{-1}\frac{\Delta Y}{\Delta X} + 180^\circ$$

Fourth Quadrant

$$\alpha = \tan^{-1}\frac{\Delta Y}{\Delta X} + 270^\circ$$

To find distance:

$S = \frac{\Delta Y}{\sin \alpha}$ or $S = \frac{\Delta \alpha}{\cos \alpha}$

To find ∆Y and ∆X:

$\Delta Y = S.\sin \alpha$ or $\Delta X = S.\cos \alpha$

1.3 Joins

To calculate the distance and direction between two known points is known as a Join. To calculate the join use the formulae given.

Worked Example 1.1

Calculate the join between co-ordinate points A and B.

Co-ordinates

	Y	X
ΔA =	-6	+8
ΔB	-2	+1

Simple figures have been used in the example to help you understand the join calculation.

The co-ordinates A and B are plotted (**Figure 1.3**) to assist in the join calculation. Unless asked for it is not necessary to plot the co-ordinates.

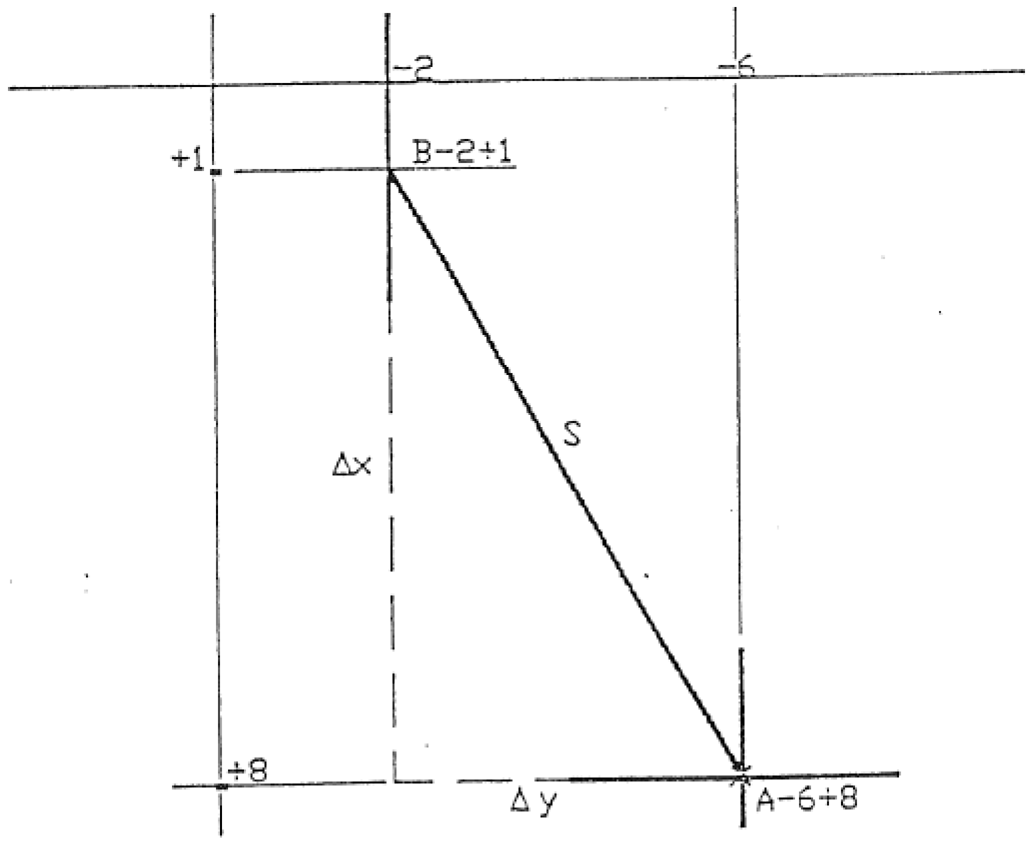


Figure 1.3

Solution:

In **Figure 1.3** a join is to be calculated from ΔA to ΔB. We can see that B is in the 2nd quadrant of A. The formula is applied to calculate the join. The join calculation is recorded in a standard method.

ΔA ΔB	(Φ ← CHS) -6 -2	(CHS → θ) +8 +1		150:15:18 8,062m
ΔA	ΔY +4	ΔX -7	-6 +4	+8 -7
150:15:18 8,062 ΔB			-2	+1

Table 1.1

Step 1: Calculate direction

$$\alpha = \tan^{-1}\frac{\Delta X}{\Delta Y} + 90°$$
$$\alpha = \tan^{-1}\frac{-2}{+4} + 90°$$
$$= 150:15:18$$

Step 2: Calculate distance

$$S = \frac{\Delta X}{\cos\alpha}$$
$$S = \frac{-7}{\cos 150:15:18}$$
$$S = 8{,}062\ m$$

Step 3: Check ΔY & ΔX

$$\Delta X = S.\cos\alpha$$
$$\Delta X = 8{,}602\ .\cos 150:15:18$$
$$\Delta X = -7$$

$$\Delta Y = S.\sin\alpha$$
$$\Delta Y = 8{,}602\ .\sin 150:15:18$$
$$\Delta Y = +4$$

Worked Example 1.2

Find the distance and direction from the following two sets of co-ordinates.

ΔA = Y_A – 1429,68 X_A + 3462,89

ΔB Y_B – 1679,80 X_B + 3143,64

Solution:

ΔA ΔB	 -1429,68 -1679,80	 +3462,89 +3143,64		218:04:38 405,56
ΔA 218:04:38 405,56 ΔB	ΔY +4	ΔX -7	-1429,68 -250,12	+3462,89 -319,25
			-1679,80	+3143,64

Table 1.2

Step 1: Calculate direction

$$\alpha = \tan^{-1}\frac{\Delta Y}{\Delta x} + 180°$$

$$\alpha = \tan^{-1}\frac{-250{,}12}{-319{,}25} + 180°$$

$$= 218{:}\,04{:}\,38$$

Step 2: Calculate distance

$$S = \frac{\Delta X}{\cos\alpha}$$

$$S = \frac{-319{,}25}{\cos 218{:}04{:}38}$$

$$S = 405{,}56\ m$$

Step 3: Check ΔY & ΔX

$$\Delta X = S.\cos\alpha$$

$$\Delta X = 406{,}56\ .\cos 218{:}\,04{:}\,38$$

$$\Delta X = -319{,}25$$

$$\Delta Y = S.\sin\alpha$$

$$\Delta Y = 405{,}\,56\ .\sin 218{:}\,04{:}\,38$$

$$\Delta Y = -250{,}12$$

1.4 Polar

The calculation of co-ordinates of an unknown point by distance and direction from a known point is known as a polar calculation; the same formulae given in the Co-ordinates section for join calculations are used.

Worked Example 1.3

ΔA $Y - 6X + 8$
α = 150:15:18
S = 8,620

Solution:

<table>
<tr><td rowspan="3">ΔA
150:15:18
8,062
ΔB
ΔA
ΔB</td><td rowspan="2">-6
-2</td><td rowspan="2">+8
+1</td><td>-6
+4</td><td>+8
-7</td></tr>
<tr><td rowspan="2">-2</td><td rowspan="2">+1

150:15:18
8,062</td></tr>
<tr><td>+4</td><td>-7</td></tr>
</table>

Table 1.3

Step 1: Calculate

ΔY

$\Delta Y \ = S.\sin\alpha$

$\Delta Y \ = 8{,}062\ .\sin 150{:}\ 15{:}\ 18$

$\Delta Y \ = +4{,}0\ m$

Step 2 Calculate

ΔX

$\Delta X \ = S.\cos\alpha$

$\Delta X \ = 8{,}062\ .\cos 150{:}\ 15{:}\ 18$

ΔX = -7 m

Step 3: Direction check

$\alpha \ = \tan^{-1}\frac{\Delta X}{\Delta Y} + 90°$

$\alpha \ = \tan^{-1}\frac{-7}{+4} + 90°$

$\alpha \ = 150{:}\ 15{:}\ 18$

Step 4: Distance check

$S \ = \frac{\Delta X}{\cos\alpha}$

$S \ = \frac{-7}{\cos 150{:}15{:}18}$

$S \ = 8{,}062\ m$

Worked Example 1.4

Calculate the polar given

ΔA $-2144{,}9\ +6981{,}43$

α = 157:33:36

S = 202,79

Solution:

ΔA				+6981,43
157:33:36			-2144,69	-187,44
8,062			+77,41	
ΔB			-2067,28	+6793,99
ΔA	-2144,69	+6981,43		
ΔB	-2067,28	+6793,99		
				157:33:39
	+77,41	-187,44		202,79

Table 1.4

Step 1: Calculate ΔY & ΔX

$\Delta Y \ = S.\sin\alpha$

$\Delta Y \ = 202{,}79\ .\sin 157{:}\,33{:}\,39$

$\Delta Y \ = +77{,}41\ m$

$\Delta X \ = S.\cos\alpha$

$\Delta X \ = 202{,}79\ .\cos 157{:}\,33{:}\,39$

ΔX = -187,44 m

Step 2: Check direction

$\alpha \ = \tan^{-1}\frac{\Delta X}{\Delta Y} + 90°$

$\alpha \ = \tan^{-1}\Delta Y$

$\alpha \ = 157{:}\,33{:}\,36$

Step 3: Check distance

$S \ = \frac{\Delta X}{\cos\alpha}$

$S \ = \frac{-187{,}44}{\cos 157{:}33{:}36}$

$S \ = 202{,}79\ m$

Orientation of a direction

In this section observations are made from a fixed or known station to several known stations and unknown stations. The direction from the fixed station to the unknown station is to be orientated and the co-ordinates of the unknown station is to be calculated. Forward or (Circle left; ⊙ L) and backward or (Circle right; ⊙ R) observation must be made to each station.

Worked Example 1.5

The following observations were taken in the field of ΔDairy.

	@DAIRY	
STATION	⊙L	⊙R
ΔCHEST	91:19:00	271:20:00
ΔBEND	164:06:20	344:06:00
ΔREK	18:39:09	198:39:20
ΔTATE	265:46:10	85:46:20
ΔCHEST	91:19:20	271:19:00

In this case the theodolite was orientated from Δ dairy to Δ chest and once the observations to the other stations were completed a closure onto the station on which the theodolite was orientated (Δ Chest in this case must be made). The following co-ordinates are given:

ΔDAIRY	+4073,39	+302749,45
ΔCHEST	+5320,64	+302720,63
ΔBEND	+4551,19	+301070,93
ΔREK	+4954,77	+305359,61

The distance Δ Dairy to Tate was measured as 1413,25 m. In the example the direction from Dairy to Tate has to be orientated and the co-ordinates of Tate are to be calculated.

The following steps are used to orientate and obtain the co-ordinates of the unknown station:
Step 1 → Calculate the join directions
Step 2 → Calculate the ⊙L and ⊙R mean direction
Step 3 → Calculate the orientated direction
Step 4 → Calculate the polar

Solution:
Step 1 → Calculate the joins

∆DAIRY ∆CHEST	+4073,39 +5320,64	+302749,45 +302720,63		
∆DAIRY 91:19:25 1247,58 ∆CHEST	+1247,15	-28,82	+4073,39 +1247,25	+302749,45
			+5320,64	+302720,63
∆DAIRY ∆BEND	+4073,39 +4551,19	+302749,45 +301070,93		164:06:39 1745,20
∆DAIRY 164:06:39 1745,20 ∆BEND			+4073,39 +477,80	+302749,45 -1678,52
			+4551,19	+301070,93
∆DAIRY ∆REK	+4073,39 +4943,77	+302749,45 +301359,61		18:39:30 3754,953
∆DAIRY 18:39:30 2754,95 ∆REK	+881,38	+2610,16	+4073,39 +881,38	+302749,45 +2610,16
			+4954,77	+305359,61

Table 1.5

Use The formulae for join calculations

Step 2: Calculate ⊙ l & ⊙ R mean direction

⊙L	⊙R	MEAN	CORRECTION	CORRECTED
∆CHEST 91:19:00	271:20:00	91:19:30	0	91:19:30
∆BEND 164:06:20	366:06:00	164:06:10	5	164:06:10
∆REK 18:39:09	198:39:20	18:39:25	10	18:39:25
⊙TATE 265:46:10	85:46:20	265:46:15	15	265:46:15
∆CHEST 91:19:20	271:19:00	91:19:10	20	91:19:10

Table 1.6

To obtain the mean of ⊙L & ⊙R

a) If ⊙R readings are more than 180° then subtract 180° and add ⊙L and divide by 2.

eg ∆CHEST ⊙R 271:20:00 - 180 = 91:20:00
ADD ⊙L = 91:19:00
= 182:39:00
Divide by 2 = 91:19:30

b) If ⊙R readings are less than 180° then add 180° and add ⊙L and divide by 2.

eg. ⊙TATE ⊙R 85:46:20 + 180 = 265:46:20
Add ⊙L = 265:46:10
= 531:32:30
Divide by 2 = 265:46:15

To obtain the correction

Subtract the last mean observed direction to ∆Chest from the first observed direction ∆Chest, 91:19:30 - 91:19:10 = 20"

Divide this correction by No of stations $= \frac{20"}{4}$
= 5"

We see that we have to add 20" to 91:19:10 to obtain the first direction observed to be ∆Chest therefore the corrections are to be added.

Step 3 → Calculate the orientated direction

NAME	CORRECTED	ORIENTATED DIRECTION	CORRECTION	JOIN DIRECTION
∆CHEST 91:19:00	91:19:30		-5"	91:19:25
∆BEND 164:06:20	164:06:15		+24"	164:06:39
∆REK 18:39:09	18:39:25		+5"	18:39:25
⊙TATE 265:46:10	265:46:30	265:46:38		

Table 1.7

$= \frac{+24}{3}$
= +8

To obtain the corrections subtract the corrected observed directions from the join directions.

Add the corrections and divide by the No of known stations observed. Add or subtract this depending on the sign of the correction to the corrected observed direction to the unknown point. This is the orientated direction to the unknown station.

We now have the direction and distance to ⊙Tate and the co-ordinates of ⊙ Dairy. Therefore to calculate co-ords of ⊙Tate we calculate the polar.

Step 4 → Calculate the polar (co-ordinates of TATE)

ΔCHEST			-4073,39	+302749,45
265:46:38			-1409,41	-104,06
1413,25				
ΔTATE			+2663,98	+302645,39
ΔDAIRY	+4073,39	+302749,45		
ΔTATE	-2663,98	+302645,39		
	-1409,41	-104,06		

Table 1.8

Activity 1.1

1. Calculate the following joints and check them from the co-ordinates from the data given in **Table 1.9**.
   i) ΔA → ΔB
   ii) ΔA → ΔC
   iii) ΔA → ΔB
   iv) ΔA → ΔE
   v) ΔD → ΔB
   vi) ΔB → ΔE

ΔA	-26116,83	+57174,20
ΔB	-26233,02	+57107,80
ΔC	-26479,22	+57242,74
ΔD	-26472,80	+57371,22
ΔE	-26100,27	+57342,72

Table 1.9

2. Calculate the direction and distance from B to A and check the calculations from the following data:
   A -2042,99 +5189,02
   B -2643,67 +4754,66
3. From the data given in **Table 1.10**, calculate the directions and distances PQ, PR, PM and PL and check the calculations.

ΔP	-84357,02	+77840,96
ΔQ	-82587,20	+85416,12
ΔR	-86060,83	+74358,14

ΔM	-86790,60	+78996,93
ΔL	-80442,18	+76908,67

Table 1.10

Activity 1.2

1. Calculate the polar between ΔA & ΔB given:
   Direction ΔA to ΔB 225:37:14
   Distance A to B 6813,96 m
   Co-ordinates 0 = ΔA -24610,34 +9826,42
2. Direction the polar between ΔA & ΔC
   Distance A to C 98:41:32
   Distance A to C 741,42 m
   Co-ordinates of A -2463,68 +9827,99
3. Calculate the polar between ΔA to ΔB, ΔC, ΔD, ΔZ, given:
   Co-ordinates of A -293641,91 +307689,70
   Direction A to B 98:64:33
   Distance AB 6821,31
   Direction A to C 180:00:30
   Distance A to C 341 ,22m
   Direction A to ΔD 359:59:59
   Distance A to D 682,40
   Direction A to Z 00:00:01
   Distance A to Z 342,68 m

Activity 1.3

1. Calculate the co-ordinates of ⊙Dog given:
   Join directions

   ΔSPITSKOP → ΔKROMRIVIER α = 291:21: 10
   ΔSPITSKOP → ΔROOIKRAANS α = 320:21:26

   OBSERVED DIRECTIONS →

	AT SPITSKOP	
	⊙L	⊙R
ΔKROMRIVIER	291:27:01	111:27:05
ΔROOIKRANS	320:21:12	140:21:10
ΔDOG	302:32:32	122:32:36
ΔKROMRIVIER	291:27:04	111:27:08

   CO-ORDINATES →
   ΔSPITSKOP + 2989,15 +298088,63

REDUCED DISTANCE →
∆SPITSKOP TO ⊙DOG 392,43 m

2. Calculate the co-ordinates of ⊙Hill and ⊙Dirt given.

	AT ⊙REK	
	⊙L	⊙R
∆WATER	281:34:23	101:34:15
∆JOHN	107:18:26	287:18:19
∆CHEST	172:06:31	352:06:10
⊙HILL	183:46:40	03:46:20
⊙DIRT	209:37:58	29:37:22
∆COLLEGE	264:02:36	84:02:16
∆WATER	281:34:10	101:34:20

CO-ORDINATES

∆REK	+4954,77	+305359,61
∆WATER	+2999,34	+305759,95
∆CHEST	+5320,64	+302720,63
∆JOHN	+6740,81	+304803,20
∆COLLEGE	+1765,39	+3,05026,66

REDUCED HORIZONTAL DISTANCES
∆REK → ⊙DIRT 3521 ,20 m
∆REK → ⊙HILL 1789,44 m

Self-Check

I am able to:	**Yes**	**No**
• Describe the temporary adjustments to optical theodolites		
• Explain the following terms:		
o Transit		
o Swing		
o Face		
o Bisection of a target angle		
o Angle of direction		
o Direction measurements of angles by theodolite		
• Describe the measurement of angles of depression and elevation by theodolite.		
• Describe computing of the true horizontal length from the slope distance and the angle of inclination.		
• Describe operational errors and errors due to natural causes in measurement of angles		

If you have answered 'no' to any of the outcomes listed above, then speak to your facilitator for guidance and further development.

Module 2

Traversing

Learning Outcomes
On the completion of this module the student must be able to:

- Explain the following terms:
  - Traversing
  - Open and closed traverses
  - The meridian
  - Magnetic meridian
  - Grid
  - Arbitrary meridian
  - Whole circle bearing
- Describe reducing angles form traverse reading
- Describe computing a theodolite traverse, including all adjustments
- Describe plotting by co-ordinates
- Describe computing the area inside a traverse
- Describe plotting of a compass traverse including graphical corrections
- Explain the Bowditch rule

2.1 Introduction

Traverse is a method in the field of surveying to establish control networks. It is also used in geodetics. Traverse networks involve placing survey stations along a line or path of travel, and then using the previously surveyed points as a base for observing the next point. Traverse networks have many advantages.

Definition: Geodetics
A branch of applied mathematics and earth sciences. It is the scientific discipline that deals with the measurement and representation of the Earth, including its gravitational field, in a three-dimensional time-varying space. Geodesists design global and national control networks, using space and terrestrial techniques while relying on datums and coordinate systems.

When a series of straight lines is shown (**Figure 2.1**), by measuring the length and direction of each line, it is known as a traverse.

A traverse can be carried out by:
a) Chain
b) Chain or tape & box sextant
c) Chain or tape and prismatic compass
d) Steel tape or steel band and theodolite

The theodolite traverse is the usual method used and is the most accurate. The points along the traverse are known as traverse stations or traverse points and the lines joining the traverse stations are known as traverse lines.

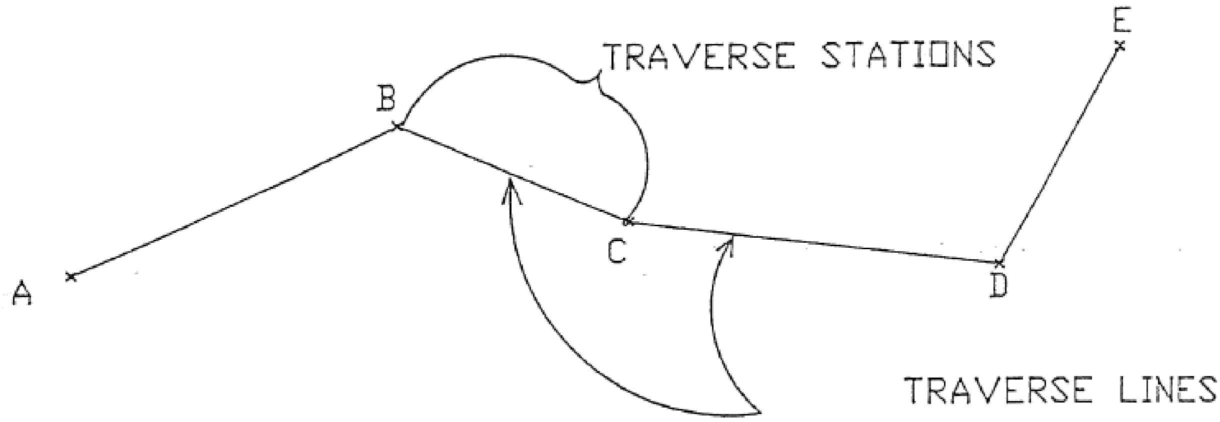


Figure 2.1 A traverse

2.2 Open traverse

In **Figure 2.2** the position of Station A is known together with the direction of line AB. The positions of all the other traverse stations can be relative to "Station" A by measuring the lines and directions of the successive lines. This is known as an open traverse and has no check on the accuracy of linear and angular measurement and should therefore be avoided.

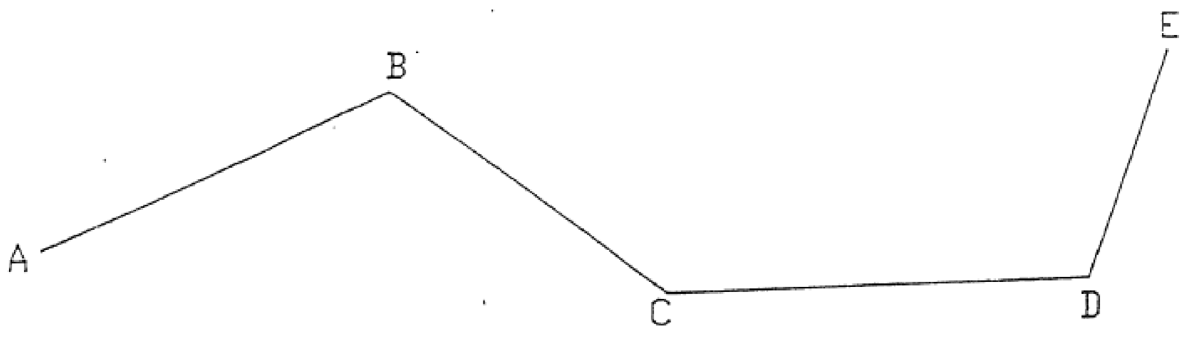


Figure 2.2

2.3 Closed traverse

In **Figure 2.3** below, the Stations and Z are known. The Traverse is done from A and the direction and distance between the successive lines are measured and closed onto the known point Z. This is known as a Closed Traverse and has a check.

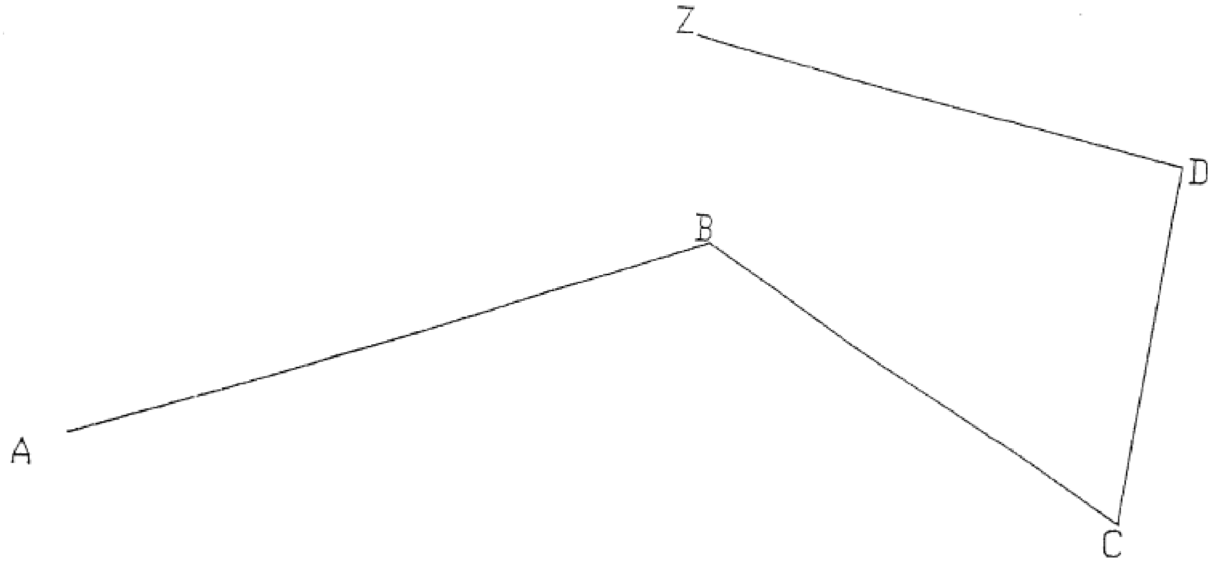


Figure 2.3

If there is a closing error, as shown in **Figure 2.4**, then it has to be adjusted by means of the Bowditch Rule.

Definition: Bowditch Rule

$$\frac{DISTANCE}{TOTAL\ DISTANCE} \times CLOSING\ ERROR$$

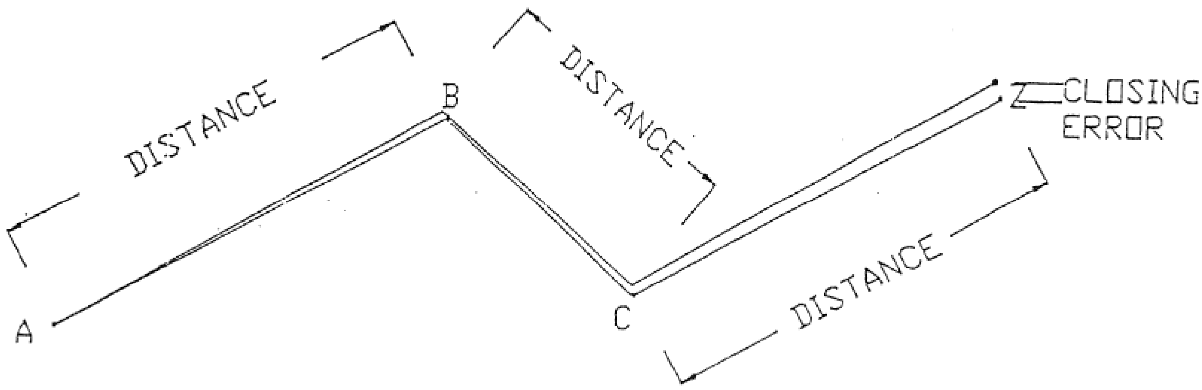


Figure 2.4

Total distance is the sum of all the Traverse lines (in the case of **Figure 2.4**). The total distance is = AB + BC + CZ.

Worked Example 2.1

Calculate the co-ordinates of $\odot T_1$, and $\odot T_2$ if the following is given:

CO-ORDINATES:

ΔA -2146,72 +3456,12
ΔB -2062,45 +3223,30

REQUIRED DISTANCES AND ORIENTATED DIRECTIONS

ΔA - $\odot T_1$	186:22:12	249,26 m
$\odot T_1$ - $\odot T_2$	284:14:30	192,44 m
$\odot T_2$ - ⊙B	96:10:11	300,24 m

NAME $\alpha; S$	**JOIN**	**ΔY**	**ΔX**	**NAME**	**Y**	**X**
ΔA				ΔA	-2146,72	+3456,16
186:22:12		-27,66	-247,72		-27,67	-247,79
249,26 m		-0,01	-0,07			
$\odot T_1$				$\odot T_1$	-2147,39	+3208,37
284:14:30		-186,53	+47,34		-186,54	+47,29
192,44 m		-0,01	-0,05			
$\odot T_2$				$\odot T_2$	-2360,93	3255,66
96:10:11		-298,50	-32,27		-298,48	+32,36
300,24 m		-0,02	-0,09			
ΔB				ΔB	-2062,45	+3223,30
741,94 m		+84,31	-232,65		+84,27	-232,86
		+84,27	-232,86			
		-0,04	-0,21			

Table 2.1

Worked Example 2.2

Calculate the traverse given:

CO-ORDINATES:

ΔA -2042,99 +5189,02
ΔB -2643,67 +4754,66

LINE	DIRECTION	DISTANCE
ΔA - C	143:40:10	121,96 m
C - D	210:16:50	240,02 m
D - E	273:51:50	372,02 m

E - ΔB 229:36:30 237,56 m

NAME $\alpha; S$	JOIN	ΔY	ΔX	NAME	Y	X
ΔA				ΔA	-2042,99	+5189,02
143:40:10		+72,25	-98,25		-72,27	-98,25
121,96 m		+0,02	-0,00			
⊙C				⊙C	-1970,72	+5090,77
210:16:50		-121,03	+207,27		-120,98	+207,26
240,02 m		+0,05	-0,01			
⊙D				⊙D	-2091,70	4883,51
273:51:50		-371,17	-25,07		-371,09	+25,08
372,02 m		+0,08	-0,01			
⊙E				⊙E	-2462,79	+4908,59
229:36:30		-180,93	-153,94		180,88	-159,93
237,56		+0,05	+0,01			
ΔB				ΔB	-2643,67	+4754,66
971,56 m		-600,88	-434,39		-600,68	-434,36
		-600,68	-434,36			
		+0,20	+0,03			

Table 2.2

Note!
Remember to use and write down the correct signs.

Activity 2.1

1. a) Calculate the traverse given:

ΔA -2539,76 + 2685,39
ΔB -3140,94 +5251,03

$\Delta A - T_1$ 143:40:15 121,96 m
$T_1 - T_2$ 210:16:45 240,20 m
$T_2 - T_3$ 273:51:50 372,03 m
$T_3 - \Delta B$ 229:36:30 237,56 m

b) Is this a closed or open traverse?

2. Calculate the traverse given:

ΔSPITSKOP -3140,47 + 5970,08
ΔROOIKRANS -3534,23 + 5917,47

ORIENTATED DIRECTIONS AND REDUCED DISTANCES

∆SPITSKOP – A	92:25:10	156,72 m
A - B	184:45:22	202, 64 m
B - C	270:36:40	122,46 m
C - D	281:42:20	249,62 m
D - ∆ROOIKRANS	301:56:18	196,34 m

3. Calculate the traverse given:

A	-2146,72	+3456116
8	-1839,45	+3340,44

AC	186:22:12	249,26
AD	284:14:30	192,44
DE	96:10:11	300,24
EF	04:32:40	156,18
FB	100:27:10	214,22

Self-Check

I am able to:	**Yes**	**No**
• Explain the following terms:		
o Traversing		
o Open and closed traverses		
o The meridian		
o Magnetic meridian		
o Grid		
o Arbitrary meridian		
o Whole circle bearing		
• Describe reducing angles form traverse reading		
• Describe computing a theodolite traverse, including all adjustments		
• Describe plotting by co-ordinates		
• Describe computing the area inside a traverse		
• Describe plotting of a compass traverse including graphical corrections		
• Explain the Bowditch rule		

If you have answered 'no' to any of the outcomes listed above, then speak to your facilitator for guidance and further development.

Module 3

Contouring

Learning Outcomes
On the completion of this module the student must be able to:

- Explain the following terms:
  - Contour line
  - Vertical interval
  - Gradient
- Describe the contouring of an area by grid and radial line method and tacheometric readings with tache and level
- Describe how to plot contours by graph and interpolation
- Explain how to plot ground sections from contoured drawings
- Describe how to compute areas and volumes from:
  - Contours
  - Spot heights
  - Ground sections
- Explain how to measure areas with a planimeter

3.1 Introduction

Contouring is the science of representing the vertical dimension of the terrain on a two dimensional map. A contour line of a function of two variables is a curve along which the function has a constant value. In cartography, a contour line joins points of equal elevation above a given level, such as mean sea level.
A contour map is a map illustrated with contour lines, for example a topographic map, which thus shows valleys and hills, and the steepness of slopes. The contour interval of a contour map is the difference in elevation between successive contour lines

3.2 Tacheometry

This branch of survey is where distances are measured from the instrument station to a point or points where a staff is held enabling both the horizontal and vertical positions of the points to be fixed by optical means.

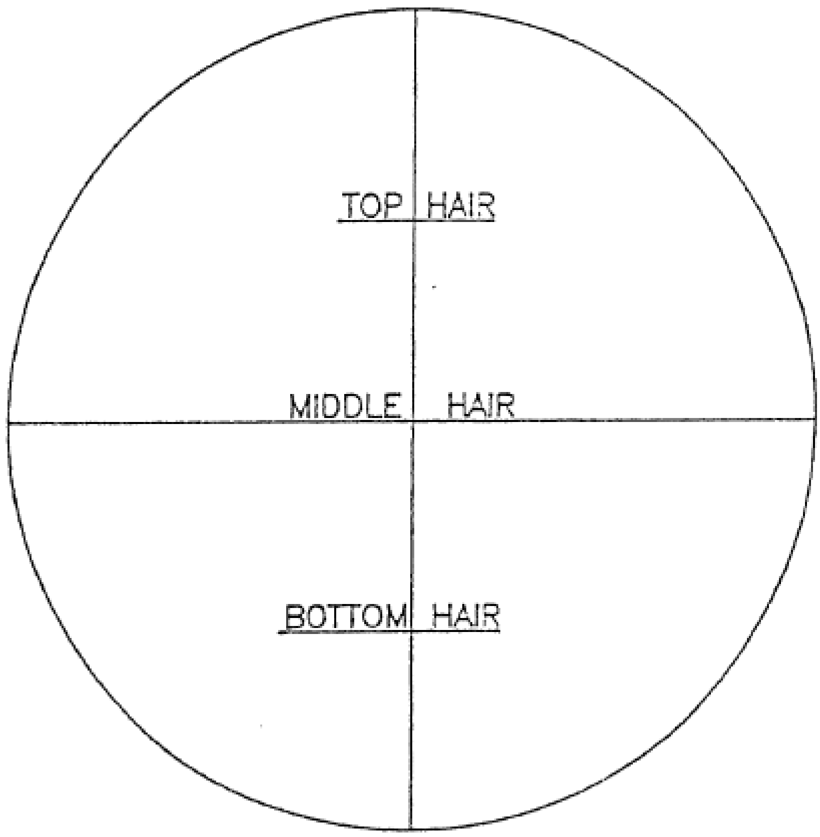


Figure 3.1

Figure 3.1 shows the view through the telescope of a theodolite that is fitted with Stadia Hairs. The Stadia Hairs are used in tacheometry. The middle hair is situated exactly half way between the top and bottom hairs. When the telescope is sighted onto the staff, the readings of the top hair, middle hair and bottom hair are taken.

Station Stasie		Distance Afstand		Hi or/of Middelhair Middelhaar MH	Angles Hoeke		Hi – MH	Height Component Hoogtekom	Height Diff Hoogte Verskil	Elevation of Point Hoogte van Punt	Remarks Opmerkings
From Van	To Na	Stadia	Hor		Hor	Ver	+ -	±	+		

Figure 3.2

Figure 3.3 shows how the formula for tacheometry calculations are derived.

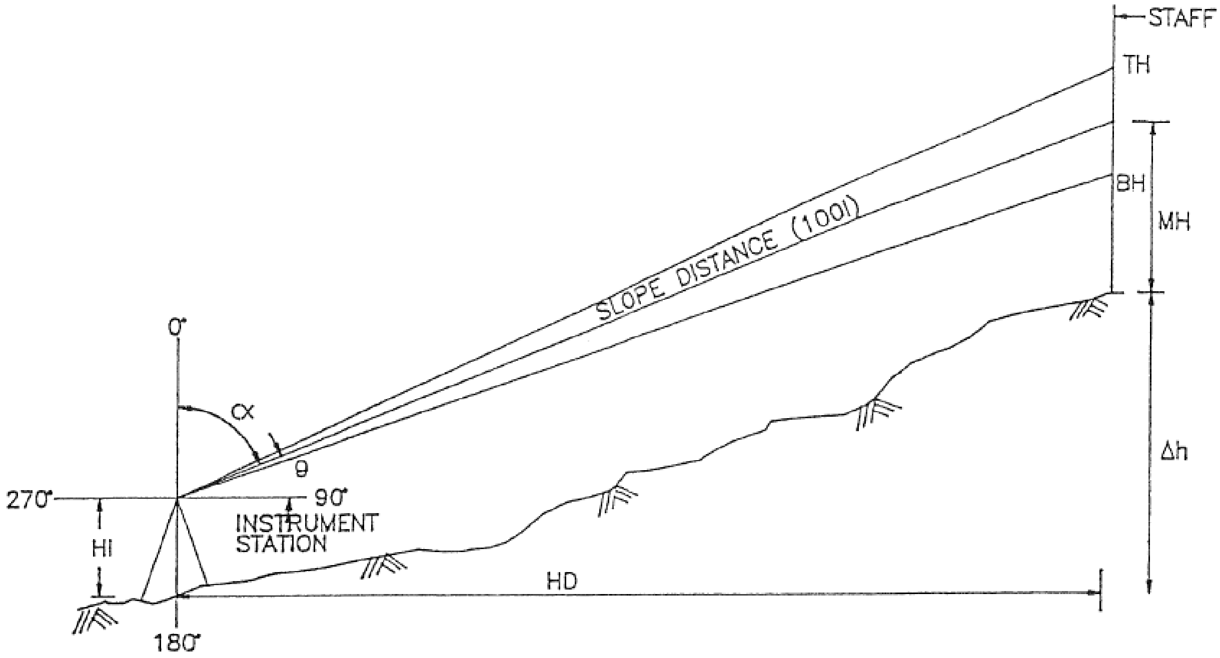


Figure 3.3

Legend
HD = Horizontal Distance
Δh = Difference in Height
' = Difference in Stadia Readings
TH = Top Hair
MH = Middle Hair
BH = Bottom Hair
⊖ = Vertical Angle (Converted)
α = Observed Vertical Angle
HI = Height on Instrument

Formula

$$HD = 100i \cos 2\ \theta$$
$$I = TOP\ HAIR - BOTTOM\ HAIR$$

$$\Delta h = 100I\ ½ \sin 2\ \theta + (HI - MH)$$
$$\theta = 90° - \alpha$$

Figure 3.2 shows the field book for recording of tacheometry readings and calculations.

- The name of the instrument station is recorded in the "Station From" column and the name of the point where the staff is held is recorded in the "Station To" column.
- The top hair and bottom hair readings are recorded in the Stadia column.
- The height of instrument and middle hair readings are recorded in TH HI or Middle Hair column.

- The horizontal directions and converted vertical angles are recorded in their respective columns.
- Once all the fieldwork has been recorded as above the calculations can then be done and the other columns filled in.
- The horizontal distance is calculated using the formula and recorded in the "Distance Hor." column.
- The mid hair reading is subtracted from the height of instrument and recorded in the "HI – MH" column.
- The height component is obtained from the formula 100I ½ SIN 2⊖ and is recorded in the "Height Component" column.
- The HI - MH column is then added to the height column and this is recorded in the "Height Difference" column.
- This column is then added to the elevation of the point given or known to obtain the elevation of the unknown points.

Note:
When doing the calculations the correct mathematical signs must be shown.

Worked Example 3.1

At A the height of instrument is 1,53 m. The Stadia readings are 2,68 and 1,04. The direction is 46:12:40 and the vertical angle is 83:38:00. The elevation of point A is 150,00 m.

Calculate the horizontal distance from point A to 8 and the height of point B.

Solution:
1st Step
Record the given (or fieldwork) information in the field book.

2nd Step
Do the necessary calculations

a) MH $= \frac{TH+BH}{2}$

$= \frac{2{,}68+1{,}04}{2}$

$= 1{,}86$

b) I $= TH - BH$

$= 2{,}68 - 1{,}04$

$= 1{,}64$

c) Convert the vertical angle

⊖ $= 90 - \alpha$

$= 90 - 83{:}38{:}00$

= 6:22:00

d) Calculate horizontal distance

HD = 100I $\cos^2$ 6:22:00

= 161,983 m

e) Calculate difference in height of instrument & Mid Hair

HI – MH = 1,53 – 1,86

= -0,33

f) Calculate the height component

HC = 100I sin 2 θ

= 100 x 1,64 x ½ sin (2 x 6:22:00)

= +18,074

g) Calculate height difference

HI – Mi + Height Component = ΔAH

$\therefore$ ΔAH = -0,33 + 18,074

= 17,744

h) Calculate Height of B

Height B = 150,00 + 17,744

= 167,744

Worked Example 3.2

The notes refer to observations in a tacheometry survey. The elevation of the instrument Station A is 639,40 and the theodolite is 1,43 m above A. The booked vertical angles are ZENITH distances.

STAFF STATION	HORIZONTAL ANGLE	VERTICAL ANGLE	STADIA READINGS		
1	97:20	96:12	0,97	1,43	1,89
2	155:57	90:00	2,13	2,72	3,30
3	207:33	79:18	1,22	1,97	2,72

Solution:

1st Step

Record all the observations in the field book.

2nd Step

Do the necessary calculations

Note:

It is better to deal with one station at a time.

Therefore:

At Staff Station 1: ΔH = (HI – MH) + HC
I = 1,89 – 0,97 ΔH = 0 + -9,878
I = 0,92 ΔH = -9,878

⊖ = 90 – α Height of stn 1 = 639,40 + (-9,878)
⊖ = 90 – 96:12 = 629,522
⊖ = -6:12

HD = 100I cos² ⊖
HD = 100 x 0,92 x cos² -6:12
HD = 90,927 m

HI-MH = 1,43 – 1,43
= 0

HC = 100i ½sin 2 ⊖
HC = 100 x 0,92 x ½ sin (2 x -6:12)
HC = -9,878

At Staff Station 2:
I = TH - BH HC = 100I ½ sin 2 ⊖
I = 3,30 – 2,30 = 100 x 1,17 x ½ sin (2 x 0:00:00)
I = 1,17 = 0,000

⊖ = 90 – α ΔH = (HI – MH) + HC
⊖ = 90 – 90 = -1,29 + 0,0
⊖ = 0:00:00 = -1,29

HD = 100I cos² ⊖ Height Stn 2 = -1,29 + 639,40
HD = 100 x 1,17 x cos² 0:00:00 = 638,110
HD = 117,000 m

HI – MH = 1,43 2,72
= -1,29

At Staff Station 3:
I = TH - BH HC = 100I ½ sin 2 ⊖
I = 2,72 – 1,22 HC = 100 x 1,50 x ½ sin (2 x 10:42:00)
I = 1,50 HC = +27,366

⊖ = 90 – α ΔH = (HI – MH) + HC
⊖ = 90 – 79:18 ΔH = -0,54 + 27,366
⊖ = 10:42:00 ΔH = +26,826

HD = 100I cos² ⊖ ∴ Height of Stn 3 = +26,826 + 639,40
HD = 100 x 1,50 x cos² 10:42:00 = 666,226
HD = 144,829 m

HI – MI	= 1,43 - 1,97
	= -0,54

Station Stasie		Distance Afstand		Hi or/of Middelhair Middelhaar MH	Angles Hoeke		Hi– MH	Height Component Hoogtekom -+	Height Diff Hoogte Verskil +-	Elevation of Point Hoogte van Punt	Remarks Opmerkings
From Van	To Na	Stadia	Hor		Hor	Ver	+ -				
Example 1											
A				1,53						150,00	
1,64	B	2,68 1,04	161,983	1,86	46:12:40	6:22:00	-0,33	18,074	17,744	167,744	
Example 2											
A				1,43						639,40	
0,92	1	1,89 0,97	90,927	1,43	97:20:00	-6:12:00	0,00	-9,878	-9,878	629,522	
1,17	2	3,30 2,13	117,000	2,72	155:57:00	0:00:00	-1,29	0,00	-1,29	638,110	
1,50	3	2,72 1,22	144,829	1,97	207:23:00	10:42:00	-0,54	+27,366	+26,826	666,226	

Figure 3.4

Activity 3.1

1. A theodolite was set up 1,67 m above a point E of known elevation 1067,51 m ASL. A staff was held on point F in the direction of 284:10:20 and the following observations were made:
   Stadia Readings = 4,97 2,43
   Middle Hair = 3,70
   Vertical Angle = 97:10:00

   The staff was then moved in the direction of 301:10:22 and held on a point G. The following observations were made on point G.
   Stadia Readings = 5,87 3,14
   Middle Hair = Was not read
   Vertical Angle = 83:15:00

   Draw up a field book and calculate the distance from point E to F and F to G. Calculate the elevation of point F and the difference in height on point F & G.

2. A theodolite was set up at station P and readings were taken to spot shots 1, 2, 3, 4, 5, 6 etc. Rewrite the information given below in field book form and reduce. The elevation of point P is 176,09 and the height of the instrument is 1,46 m.

   Readings to spot shots

POINT	STADIA READINGS	VERT. ANGLE	HORIZ. READING
1	2,97 2,20 1,42	-2:35	22:47
2	3,19 2,20 1,20	-4:42	36:22
3	2,53 1,77 1,00	-6:22	93:42
4	1,62 1106 0,50	+4,36	182:20
5	1,44 0,92 0,40	+5:29	200:35
6	3,68 2,44 1,20	-3:48	274:19
8	3,82 2,41 1,00	-4:35	300:21
9	2,69 1,96 1,22	+5:32	352:15
10	2,54 1,77 1,00	+3:18	9:24

3. A theodolite was set up at Station A. The height of instrument above A was 1,60 m and readings were taken to the following points BMZ c, d, e, f B. The elevation of BMZ is 75 000

   Readings to spot shots

POINT	STADIA READINGS	VERT. ANGLE	HORIZ. READING
BMZ	2,000 1,000	95:00:00	210:.00:00

c	2,000 0,976	96:30:00	20:20:00
d	1,876 1,319	00:00:00	70:40:00
e	1,502 0,613	84:40:00	170:30:00
f	1,498 0,846	83:20:00	213:00:00
B	2,076 1,032	85:40:00	220:30:00

A) Reduce the information in the fieldbook form
B) What is the difference in elevation of BMZ & A; BMZ & 8; A & B

Self-Check

I am able to:	**Yes**	**No**
• Explain the following terms:		
o Contour line		
o Vertical interval		
o Gradient		
• Describe the contouring of an area by grid and radial line method and tacheometric readings with tache and level		
• Describe how to plot contours by graph and interpolation		
• Explain how to plot ground sections from contoured drawings		
• Describe how to compute areas and volumes from:		
o Contours		
o Spot heights		
o Ground sections		
• Explain how to measure areas with a planimeter		
If you have answered 'no' to any of the outcomes listed above, then speak to your facilitator for guidance and further development.		

Module 4

Plotting

Learning Outcomes
On the completion of this module the student must be able to:

- Identify survey symbols
- Describe survey maps
  - o Types
  - o Scales
- Explain the difference between grid, true and magnetic north
- Describe how to position by grid references
- Describe the following plotting instruments:
  - o Beam compasses
  - o French curves
  - o Flexible curves
  - o Railways curves
  - o Stencils
  - o Ink pens
- Describe the standard plotting materials
  - o Cartridge paper
  - o Linen
  - o Tracing film
  - o Explain how to plot chain, traverse and building surveys

4.1 Introduction

This module describes how to identify survey symbols and how to position plots by grid references. It also introduces various plotting instruments and materials.

4.2 Directions

The direction, angle of direction or direction angle of a line on any co-ordinate system is the angle, measured in a clockwise sense, between the zero directions of the co-ordinate system to the line concerned. The zero direction of the South African co-ordinate system in true geographical south.

Figure 4.1 a shows the angle of direction of line AB.

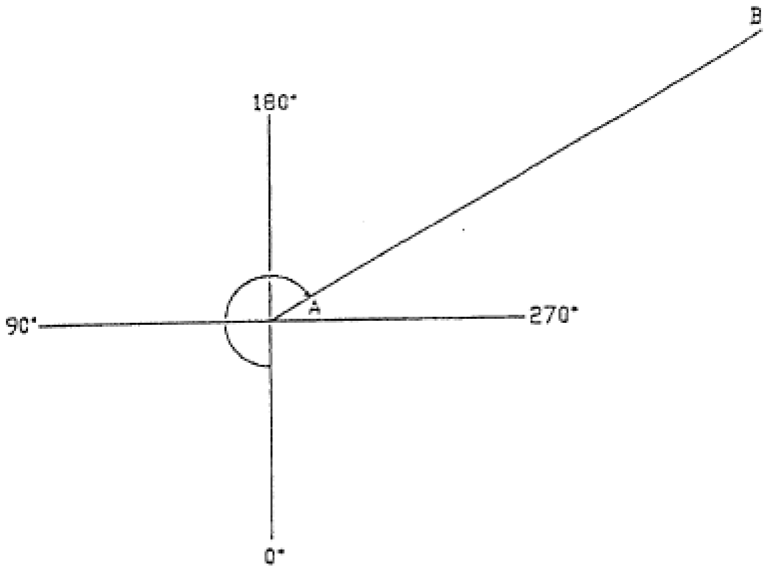


Figure 4.1

Figure 4.2 shows the directions of line AB and line BC.

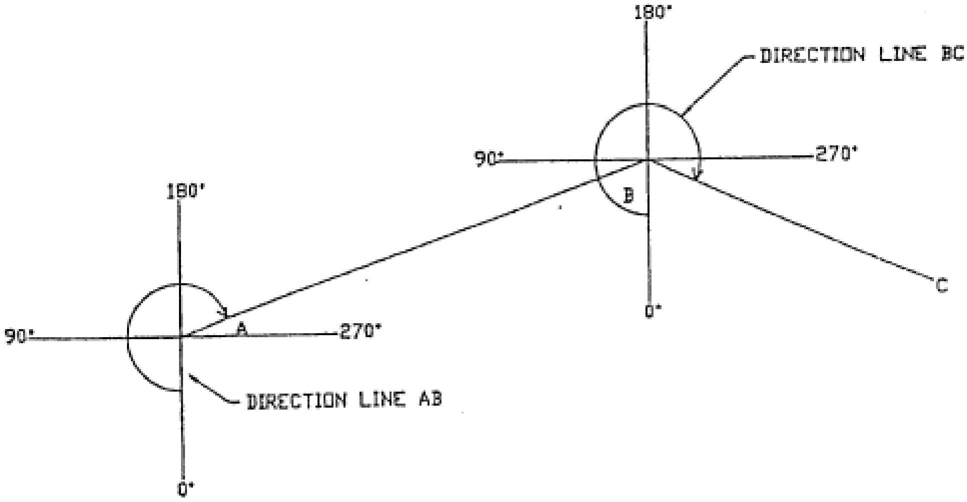


Figure 4.2

The angle between the two lines AS & BC is measured from line AB to line BC as shown in **Figure 4.3** below.

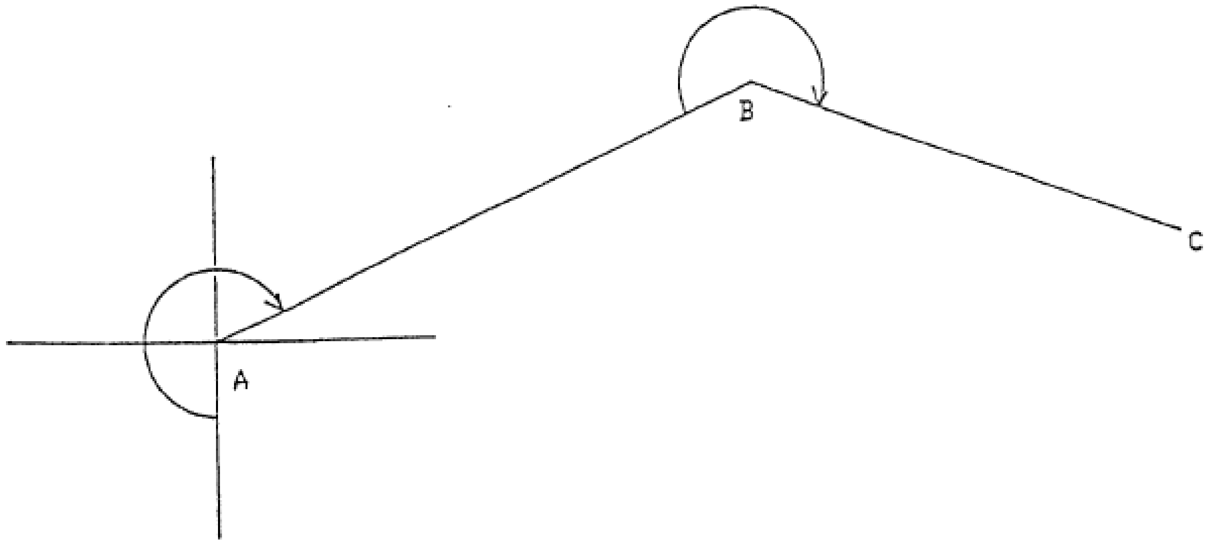


Figure 4.3

In **Figure 4.4** below the direction of line AB is 240:00:00. The surveyor is required to find the direction of line BC. He sets up on BC and measures the angle between line BA and line BC. In a clockwise direction, which was measured as 270:00:00.

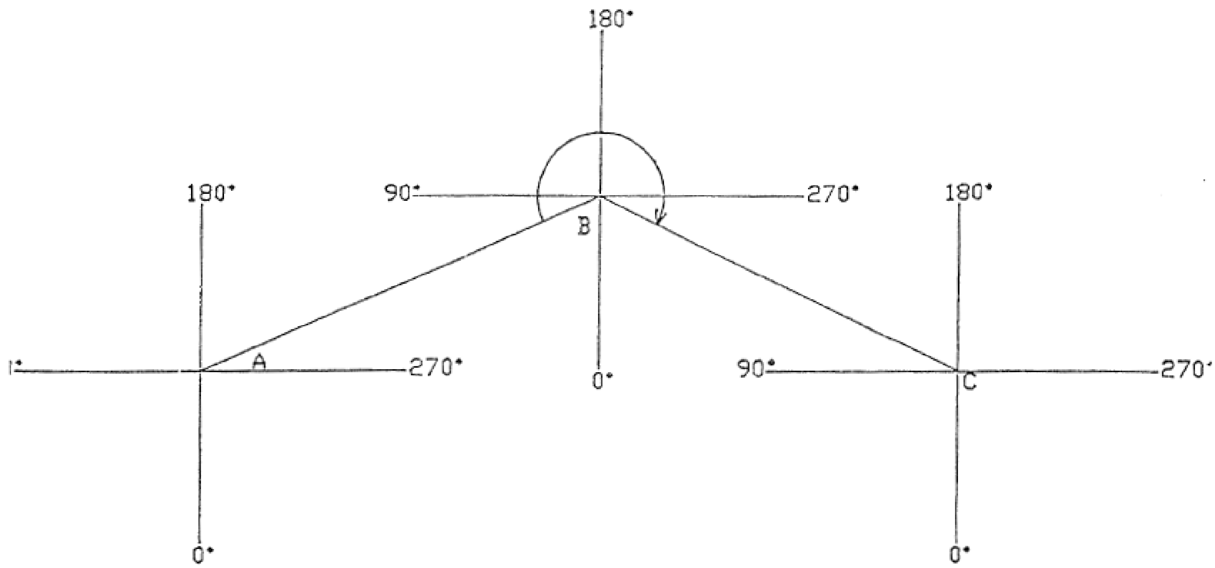


Figure 4.4

To find the direction of line BC the direction of line BA must be calculated. Direction AB is 240:00:00. Therefore 180° is subtracted to find direction BA. If direction AS was less than 180° then 180° must be added to obtain line BA

Therefore in **Figure 4.4**, Direction BA = 240:00:00 - 180:00:00
= 60:00:00

To find the direction of line BC the angle measured at B between the 2 lines (in this case 270:00:00) is added to the direction of line BA.

Direction BC = 60:00:00 + 270:00:00
= 330:00:00

Note:
1. The direction of a line is always measured in a clockwise direction from the zero direction of the co-ordinate system.
2. The angle between two lines is measured in a clockwise direction from one line to the other.

Worked Example 4.1

DIRECTION $\overline{AP}$ 50:10:20

ANGLES

AT A = 95:15:30	AT C = 200:40:20
AT B = 280:50:10	AT D = 270:15:30

CALCULATE THE DIRECTIONS $\overline{AB}$, $\overline{BC}$, $\overline{CD}$ & $\overline{DE}$

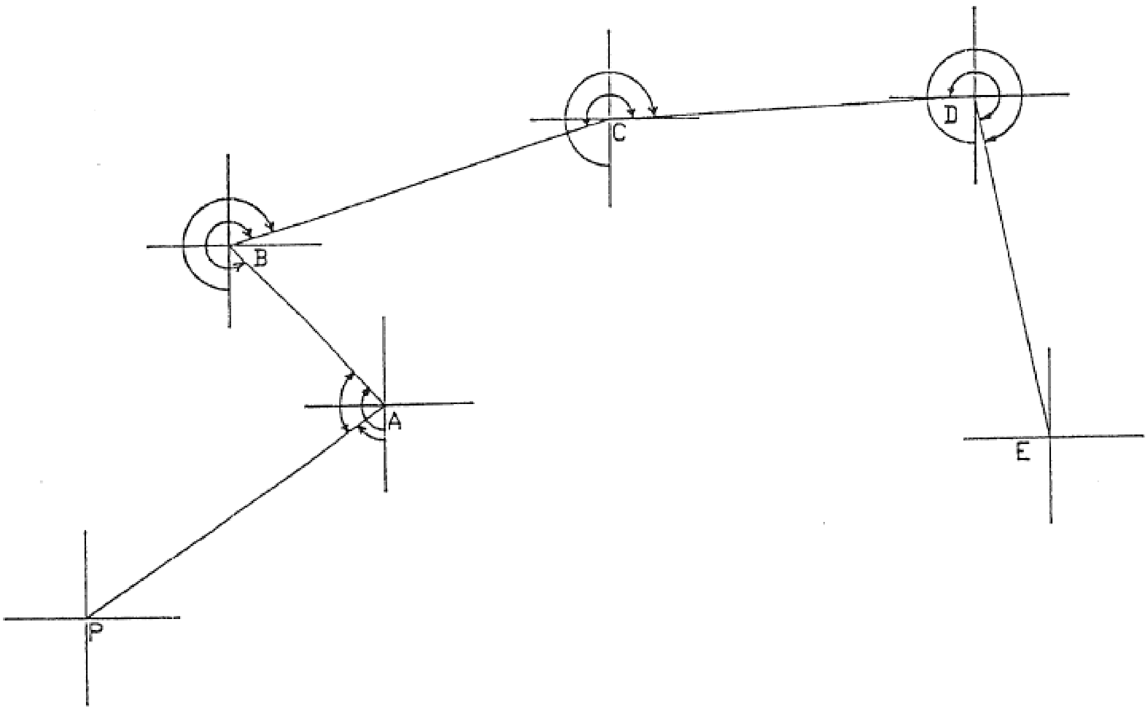


Figure 4.5

DIRECTION AP	= 50:10:20
ADD ANGLE AT A	= 95:15:30
DIRECTION AB	= 145:25:50
ADD 180:00:00	
DIRECTION BA	= 325:25:50
ADD ANGLE AT B	= 280:50:10

	606:16:00
SUBTRACT	= 360:00:00
DIRECTION BC	= 246:16:00
SUBTRACT	180:00:00
DIRECTION CB	= 66:16:00
ADD ANGLE AT C	= 200:40:20
DIRECTION CD	= 266:56:20
SUBTRACT	180:00:00
DIRECTION DC	= 86:56:20
ADD ANGLE AT D	= 270:15:30
DIRECTION DE	= 357:11:50

Worked Example 4.2

CALCULATE THE DIRECTIONS $\overline{AB}$, $\overline{BC}$, $\overline{CD}$ & $\overline{DE}$

DIRECTION $\overline{AP}$ 50:10:20

ANGLES

AT A	= 95:15:30	AT C	= 200:40:20
AT B	= 280:50:10	AT D	= 270:15:30

Note: If an angle is smaller than the one to subtract (as in ATB & ATC) add 360°

In this example first calculate the angles at A, B and C as follows:

ANGLE A	= B - P
	= 187:14:10 - 01:22:11
	= 185:51:59
ANGLE B	= C - A
	= 9:22:32 - 279:14:11
	= 369:22:32 - 279:14:11
	= 90:08:21
ANGLE C	= D - B
	= 187:34:25 - 357:20:05
	= 547:34:25 - 357:20:05
	= 190:14:20
PA	= 161:22:23
ADD	= 180:00:00
AP	= 341:22:23
ADD A	= 185:51:59
	= 527:14:22
SUBTRACT	360:00:00

AB	= 167:14:22
ADD	= 180:00:00
BA	= 347:14:22
ADD B	= 90:08:21
	= 437:22:43
SUBTRACT	360:00:00
BC	= 77:22:43
ADD	= 180:00:00
CB	= 257:22:43
ADD C	= 190:14:20
	447:37:03
CD	= 87:37:03

4.3 Area from co-ordinates

Areas can be obtained by using the co-ordinates of the corner points.

Worked Example 4.3

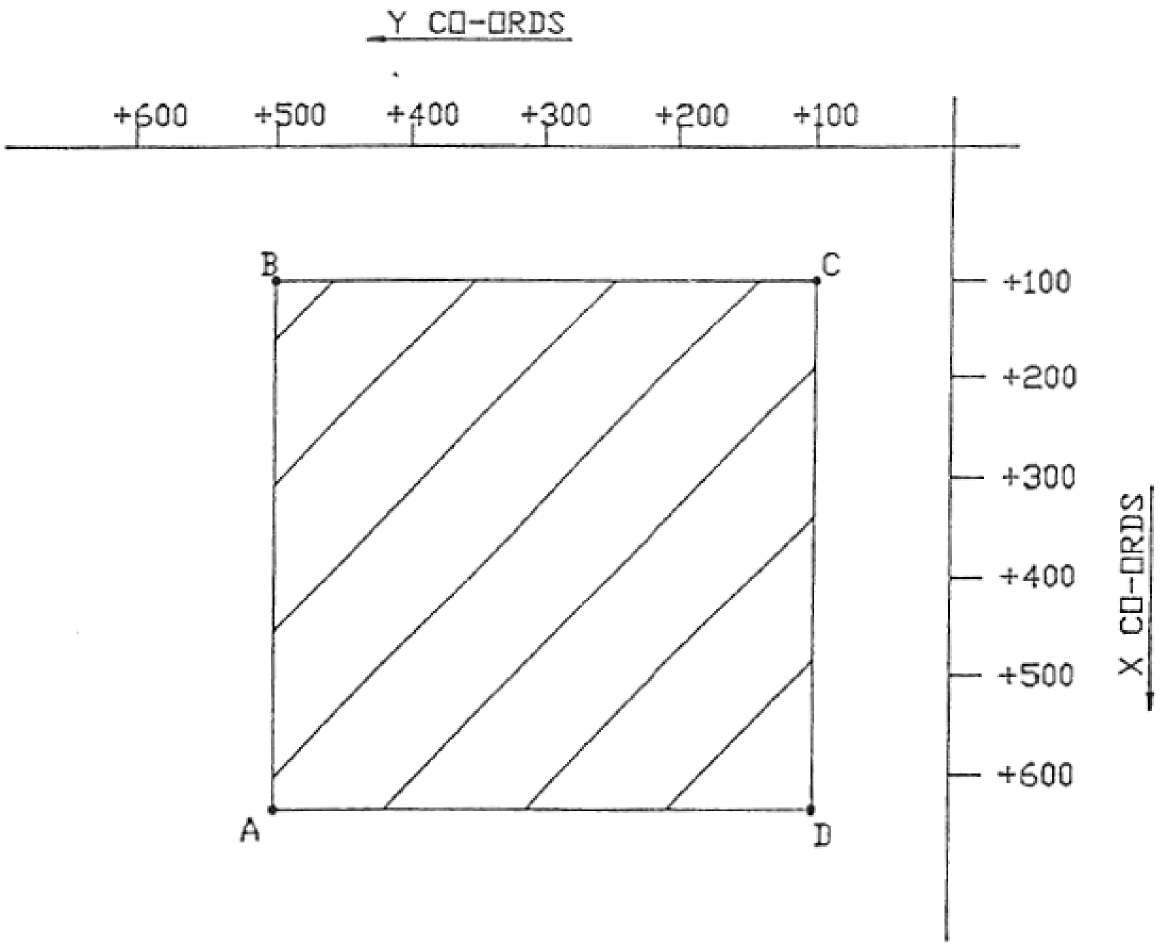


Figure 4.6

Figure 4.6 shows the area of a rectangular farm with the following co-ordinates:

A =	+500	+500
B =	+500	+100
C =	+100	+100
D =	+100	+500

The area of a rectangle is L x B, therefore the area of the farm in **Figure 4.6** is

400 x 400 = 160 000 m²
= 16 Ha

However, farms are generally not square, rectangular or simple figures and can be very irregular with several corner points. We then use the co-ordinates of the corner points to calculate the area. Using **Figure 4.6** as an example, areas from co-ordinates are shown as follows:

Y	X	Y x X	X x Y
A +500	+500		
B +500	+100	50000	250000
C +100	+100	50000	10000
D +100	+500	50000	10000
A +500	+500	50000	250000
	E	200000	520000
	-	520000	200000
	÷2	-320000	320000
		-160000	160000
		-160000	160000

160000 m² ÷ 10000
= 16 HA

Table 4.1

In the above example

$$(A_Y \times X_B) + (B_Y \times C_X) + (C_Y \times D_X) + (D_Y \times A_X)$$

$$-\ (A_X \times B_Y) + (B_X \times C_Y) + (C_X \times D_Y) + (D_X \times A_Y)$$

÷ 2 = Area in m²

Note:

1. For calculation of the area by co-ordinates all the signs of the Y co-ordinates must be the same and all the signs of the X co-ordinates must be the same. If the signs are not the same a constant must be added to make them the same.
2. However, when plotting the area the correct signs must be used (see **Worked Example 4.4**).
3. Generally, areas by co-ordinates have no check.

Worked Example 4.4

The co-ordinates given below are the corner points of a farm.

A	+374,91	+9764,32
T_1	+154,38	+9653,65
T_2	-67,40	+9893,90
T_3	+383,37	+10506,53
T_4	+565,36	+10499,00

Calculate the area of the farm and plot the co-ordinates on a graph.

Y	X	Y x X	X x Y
A +474,91	+9764,32		
T_1 +254,38	+9653,65	458614,922	248347,722
T_2 +32,60	+9893,90	2516810,282	314708,990
T_3 +483,37	+10506,53	342512,878	4782414,443
T_4 +665,36	+10499,00	5074901,630	6990624,801
A +474,91	+9764,32	6496787,955	4986080,090
		19015627,667	19557676,045
		-19557676,379	-19015627,667
	÷2	-542048,379	542048,379
	m²	-271024,189	+271024,189

Table 4.2

Divide +27104,189 m² by 10000 = 27,10 ha

The signs of the Y co-ordinates are not the same therefore a constant must be added to make the signs the same and in this case 100 was used as the constant. The constant is ·added to all the Y co-ordinates. It is not necessary to add a constant to the X co-ordinates as the signs are all the same.

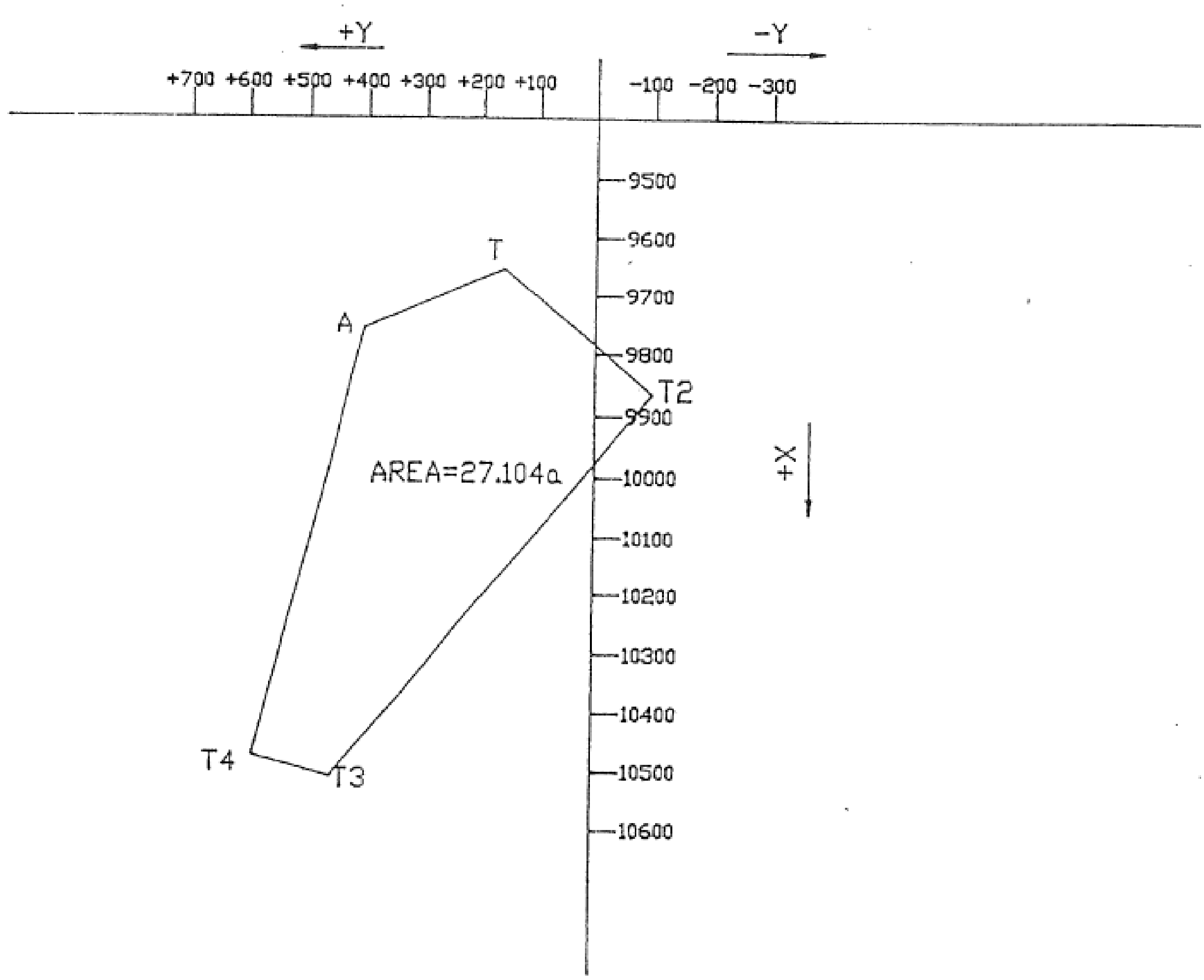


Figure 4.7

When plotting the correct co-ordinates are used as shown in **Figure 4.7**.

Activity 4.1

1. a) Calculate the directions of AB, BC, CD and DE given:
   Direction PA 214:29:52

   ANGLES

@A	@C
P 29:10:15	B 356:22:15
B104:15:30	D 295:21:51
@B	**@D**
A 119:21:35	C 284:25:55
C 20:54:50	E 106:22:56

b) If the co-ordinates of Point B are zero and the distance BC = 249,26 m calculate the co-ordinates of Point C.

2. The direction of $\overline{AP}$ is 349:25:30

ANGLES

@A	@C
P 205:10:35	B 120:54:16
B 315:22:15	D 01:17:24
@B	**@D**
A 93:22:18	C 192:25:16
C 157:28:16	E 359:59:40

3. A theodolite was set up at A, 8 and C and the following readings were observed.

At A	At 8	At C
P 03:37:18	A 281:29:18	B 00:35:12
B 190:29:17	C 12:37:39	D 190:49:32

Given the direction AP is 344:37:30. Calculate the direction DC.

Activity 4.2

1. The following co-ordinates are given

A	+8104,39	+ 915,74
B	+6142,14	+ 1187,39
C	+ 7032,31	+3749,28
D	+ 9017,54	+2107,39

Calculate:
a) The area ABCD in hectares
b) The joins AB; BC; CD & DA
c) The angles A, 8, C, 0 and check

2. Calculate the area from the following co-ordinates in hectares and plot the coordinates on a graph.

A	-26116,83	+57174,20
B	-26233,02	+57107,80
C	-26479,22	+57242,74
D	-26472,80	+57371,22
E	-26100,22	+57342,72

3. Calculate the area of the following farm in hectares with given co-ordinates:

A	+571,43	+144,77
B	+438,76	+160,58
C	+410,35	+256,13
D	+549,51	+378,46
E	+636,89	+297,21

4. a) Calculate the area of the following farm in hectares with given co-ordinates:

A	+1631,83	+1948,18
B	+1540,02	-101,12
C	-1216,00	-86,31
D	-1441,18	+1642,21

b) In which quadrants do the co-ordinates of A, 8, C & D fall?
c) Plot the co-ordinates on a graph.

Self-Check

I am able to:	**Yes**	**No**
• Identify survey symbols		
• Describe survey maps		
o Types		
o Scales		
• Explain the difference between grid, true and magnetic north		
• Describe how to position by grid references		
• Describe the following plotting instruments:		
o Beam compasses		
o French curves		
o Flexible curves		
o Railways curves		
o Stencils		
o Ink pens		
• Describe the standard plotting materials		
o Cartridge paper		
o Linen		
o Tracing film		
• Explain how to plot chain, traverse and building surveys		
If you have answered 'no' to any of the outcomes listed above, then speak to your facilitator for guidance and further development.		

Module 5

Setting out

Learning Outcomes
On the completion of this module the student must be able to:

- Explain the procedure for co-ordinated setting out
- Explain the procedure for setting out and levelling of foundations for a steel framed building
- Describe how to check verticality of tall buildings using:
  - o Theodolite
  - o Optical plumb
  - o Plumb bob

5.1 Introduction

Setting-out is to stake out reference points and markers that will guide the construction of new structures such as roads or buildings. These markers are usually staked out according to a suitable coordinate system selected for the project.

5.2 Vertical angles

When the telescope of a theodolite is level then the reading of the vertical circle will be exactly 90°. Readings under 90°indicate angles of elevation and readings over 90° indicate "angles of depression. The zero reading is obtained when the telescope points vertically upwards. The angles read on the vertical circle are known as zenith distances i.e. the angle between the zenith and the sighted point.

When vertical angles are taken with a theodolite, the circle left (ʘL) and circle right (ʘR) readings should be taken. The angles are then converted to obtain the angle of elevation or depression and the mean of the two converted angles are calculated which are the corrected angles of elevation.

Figure 5.1a and **Figure 5.1b** below show that when the circle is left the zenith distances or vertical angles read are between 0° and 180° and when the circle is right they are between 180° and 0°.

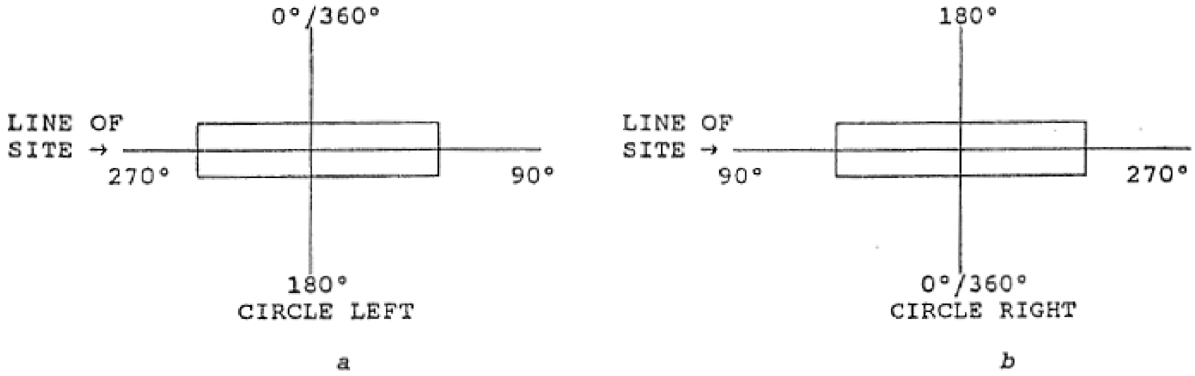


Figure 5.1

Worked Example 5.1

A theodolite was set up on Station A and angles of elevations to Stations B, C & D were taken. The readings were as follows:

AT A

STATION	CIRCLE LEFT	CIRCLE RIGHT
B	93:16:11	266:42:49
C	88:20:11	271:41:21
D	117:21:30	242:39:59

The circle left and circle right vertical angles are converted as follows:

For circle left: $\theta = 90° - \alpha$
For circle right: $\theta = \alpha - 270°$

Where θ = converted angle and α = zenith distance or angle read on the vertical circle

STATION	ZENITH DISTANCE		CONVERTED ANGLE		CORRECTED ANGLE
	⊙L	⊙R	⊙L	⊙R	
B	93:16:11	266:42:49	-3:16:11	-3:17:11	-3:16:41
C	88:20:11	271:41:21	1:39:49	1:41:21	1:40:35
D	117:21:30	242:39:59	-27:21:30	-27:20:01	-27:20:46

The corrected angle is the mean of the converted ⊙L and ⊙R angles.

Activity 5.1

1. Reduce the correct angles of elevation from B to P, Q and R from the given vertical circle readings. Clearly show whether the angles are +(rise) or -(fall).

   AT B

STATION	CIRCLE LEFT	CIRCLE RIGHT
P	87:41:10	272:21:10
Q	91:53:50	268:03:50
R	86:29:30	273:32:50

2. From the readings below, by theodolite at Station P, deduce the correct angles of elevation to Stations A, B & C.

   AT P

STATION	CIRCLE LEFT	CIRCLE RIGHT
A	82:20:30	277:40:00
C	102:40:50	257:19:00
D	96:30:20	263:29:40

Show which Stations are higher than Station P and which are lower than Station P.

Self-Check

I am able to:	Yes	No
• Explain the procedure for co-ordinated setting out		
• Explain the procedure for setting out and levelling of foundations for a steel framed building		
• Describe how to check verticality of tall buildings using:		
o Theodolite		
o Optical plumb		
• Plumb bob		

If you have answered 'no' to any of the outcomes listed above, then speak to your facilitator for guidance and further development.

Module 6

Road Construction

Learning Outcomes
On the completion of this module the student must be able to:

- Describe the methods of surveying routes for roads excluding aerial survey
- Describe the setting out of centre line or offset line
- Describe the types of control used for:
  - Embankments
  - Cuttings
  - Levels
- Calculate and set out a horizontal circular curve by tangential angle using a theodolite and steel tape
- Describe longitudinal and cross-sections
- Describe volumes of cut and fill on a straight road with traverse sloping ground

6.1 Introduction

In the case of roads or other linear infrastructure, a chainage will be established, often to correspond with the centre line of the road or pipeline. During construction, structures would then be located in terms of chainage, offset and elevation.

Offset is said to be "left" or "right" relative to someone standing on the chainage line who is looking in the direction of increasing chainage. Plans would often show plan views (viewed from above), profile views (a "transparent" section view collapsing all section views of the road parallel to the chainage) or cross-section views (a "true" section view perpendicular to the chainage).

In a plan view, chainage generally increases from left to right, or from the bottom to the top of the plan. Profiles are shown with the chainage increasing from left to right, and cross-sections are shown as if the viewer is looking in the direction of increasing chainage (so that the "left" offset is to the left and the "right" offset is to the right). "Chainage" may also be referred to as "Station".

6.2 Longitudinal sections

These are sections run along the line (usually the centre line) of a proposed engineering project, such as a road, railway, canal or pipeline and enables the

Engineer to plan the elevational details of the project in relation to the existing ground levels.

6.3 Cross-sections

These are shorter sections, run at right angles to the longitudinal section on straights and radial on curves to supply information of the slope of the ground (crossfall) on either side of the longitudinal section and also supplies data for the calculation of earthworks quantities.

The cross section length is controlled by the width of the proposed construction works, but sometimes more information is required outside the limits of construction.

Figure 6.1 below shows the cross section of a proposed canal.

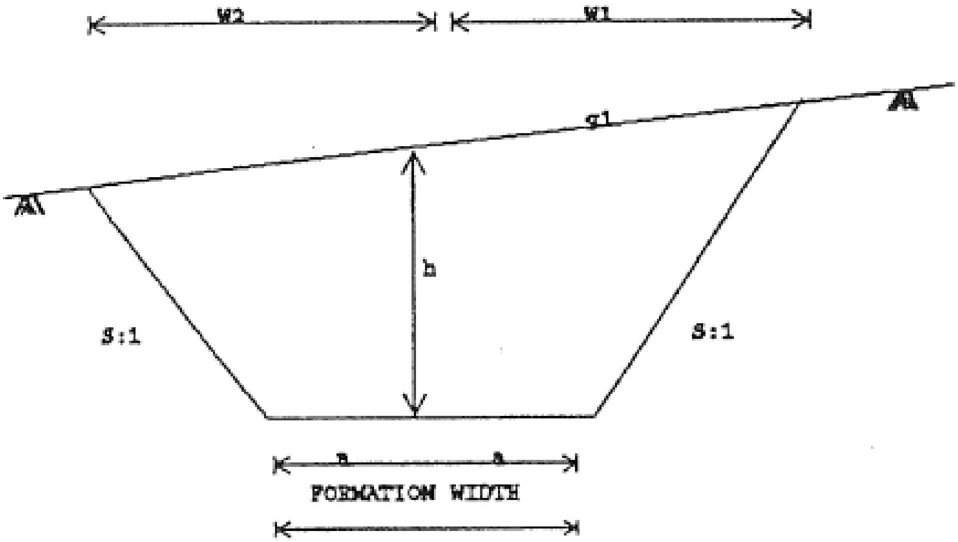


Figure 6.1

a	= ½ formation width
h	= Height at centre of cross section
S:1	= Side slope of cut or fill (in **Figure 6.1** of cut) where 1 is vertical
g:1	= Slope of ground or gradient of ground where 1 is vertical
W_1	= Width 1 (from edge of construction to centre of formation width)
W_2	= Width 2 (from edge of construction to centre of formation width)

1. Formula to obtain widths 1 and 2

$$W_1 = \frac{g(a+hs)}{(g-s)}$$

$$W_2 = \frac{g(a+hs)}{(g+s)}$$

2. Formula to obtain the area of the cross section

$$AREA = \frac{W_1 \times W_2 - a^2}{S}$$

3. Formula to obtain the volume between two cross sections

$$VOLUME = MEAN\ AREA \times DISTANCE$$

Worked Example 6.1

A cutting for a road has to be done. The formation width of the road is 10 m. The height at the centre of the formation width is 2,58 m. The side slopes of the cutting are 1:2 (1 vertical) and the ground slope is 1:7 (1 vertical).

Calculate the cross-sectional area of the cutting.

$W_1 = \frac{g(a+hs)}{(g-s)}$
$= \frac{7[5+(2,58\times 2)}{(7-2)}$
$= 14,224\ m$

$W_2 = \frac{g(a+hs)}{(g+s)}$
$= \frac{7[5+(2,58\times 2)}{(7+2)}$
$= 7,902\ m$

AREA $= \frac{W_1 \times W_2 - a^2}{2}$
$= 43,699\ m^2$

6.4 Interpolation of tacheometry

In this section contour lines are drawn from tacheometry shots taken in a grid over an area.

Contour lines are lines of equal elevation and will show the character of the ground on a plan or map of an area.

Worked Example 6.2

A Grid was done of an area 30 m x 30 m. The spot shots were taken on a Grid of 10 m. The Grid was plotted as show in Figure 6.2 below.

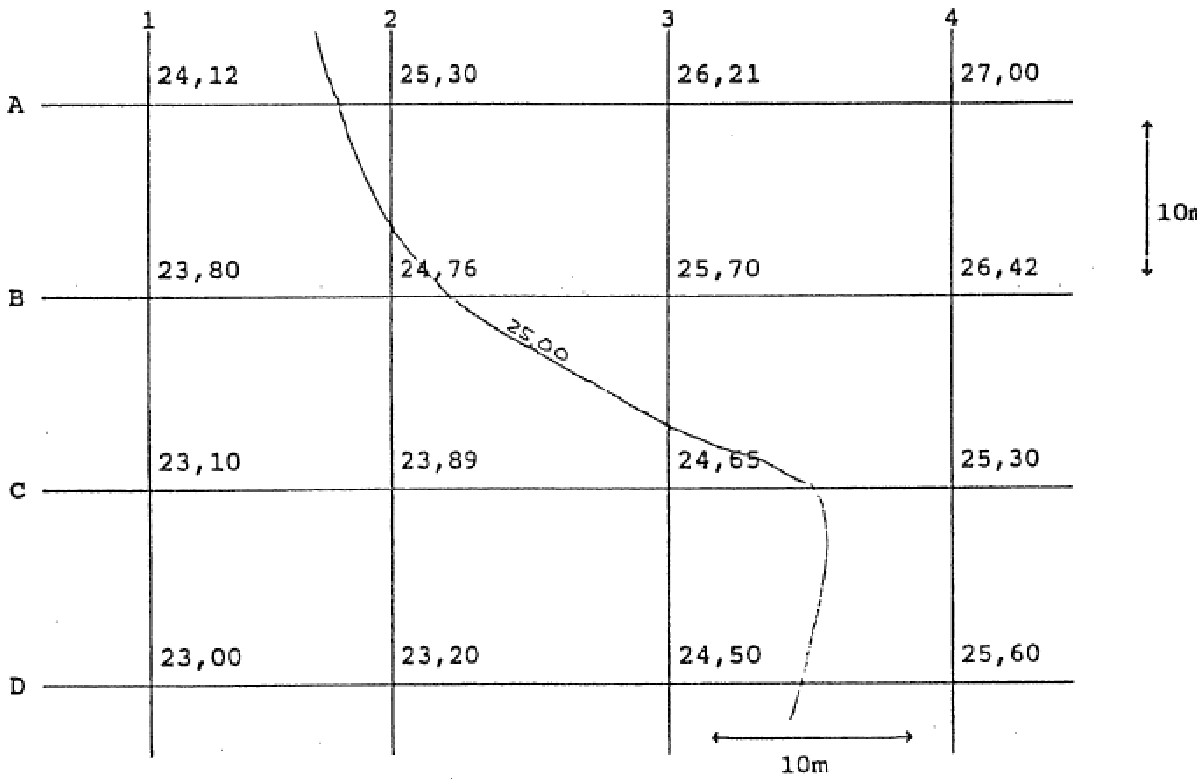


Figure 6.2

To plot the 25,00 contour line we calculate where the 25,00 point of elevation can be found on the grid lines. If we look at the grid carefully we see that the 25,00 elevation point on Grid Line A between 1 and 2; on Grid Line 2 between A and B; on Grid Line B between 2 and 3 on Grid Line 3 between B and C; on Grid Line C between 3 and 4; and on Grid Line D between 3 and 4. To plot the 25,00 contour the Grid must be drawn to a suitable scale.

The calculations are done as follows:

GRID LINE A

Step 1 → $\frac{25.30 - 24{,}12}{10} = 0{,}118\ m\ per\ m$

Step 2 → $\frac{25.00 - 24{,}12}{0{,}118} = 7{,}46\ m$

GRID LINE 2

Step 1 → $\frac{25.30 - 24{,}76}{10} = 0{,}054\ m\ per\ m$

Step 2 → $\frac{25.00 - 24{,}76}{0{,}054} = 4{,}44\ m$

GRID LINE B

Step 1 → $\frac{25.70 - 24{,}76}{10} = 0{,}094\ m\ per\ m$

Step 2 → $\frac{25.00 - 24,76}{0,094} = 2,55\ m$

GRID LINE 3

Step 1 → $\frac{25.70 - 24,64}{10} = 0,106\ m\ per\ m$

Step 2 → $\frac{25.00 - 24,64}{0,106} = 3,40\ m$

GRID LINE C

Step 1 → $\frac{25.30 - 24,64}{10} = 0,066\ m\ per\ m$

Step 2 → $\frac{25.00 - 24,64}{0,066} = 5,45\ m$

GRID LINE D

Step 1 → $\frac{25.60 - 24,50}{10} = 0,11\ m\ per\ m$

Step 2 → $\frac{25.00 - 24,50}{0,11} = 4,55\ m$

In the above calculations Step 1 gives the gradient between the two points per metre and Step 2 gives the distance from the lower elevation than the contour elevation to the point where the contour crosses the grid line.

These points are plotted on the Grid Lines and a line is drawn through the points as shown in **Figure 6.2**. This is the contour line.

Note:
Remember to convert the distances in Step 2 to suit the scale of the grid.

If the are in **Figure 6.2** has to be excavated to an elevation of 20:00 and the sides are vertical, the calculation is done as follows:

24,12 x 1	=	24,12
25,30 x 2	=	50,60
26,21 x 2	=	52,42
27,00 x 1	=	27,00
23,80 x 2	=	47,60
24,76 x 4	=	99,04
25,70 x 4	=	102,80
26,42 x 2	=	52,84
23,10 x 2	=	46,20
23,89 x 4	=	95,56
24,64 x 4	=	98,56
25,30 x 2	=	50,60

23,00 x 1	=	23,00
23,20 x 2	=	46,40
24,50 x 2	=	49,00
25,60 x 1	=	25,60
TOTALS 36		891,34

VOLUME = $\frac{891.34}{36}$ x 30 x 30
= 22283.50 m³

6.5 Circular curves

Circular curves may be divided into three classes:

1. Simple curves
2. Compound curves
3. Reverse curves

A simple curve consists simply of the arc of a circle, connecting two straights which are Tangential to the circle (refer **Figure 6.3**)

Figure 6.3

Compound curves consist of two Tangential arcs of different radii, similarly connecting two straights, and curving in the same direction. They lie on the same side of a common tangent, and their centres are on the same side of the curves (Refer **Figure 6.4**).

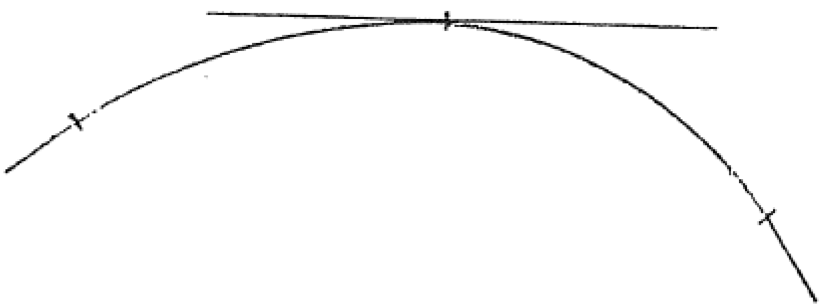


Figure 6.4

Reverse curves consist of two Tangential arcs of the same or different radii, also connecting two straights, but curving in the opposite directions. They lie on opposite sides of a common tangent, and their centres are on opposite sides of the curve (refer **Figure 6.5**).

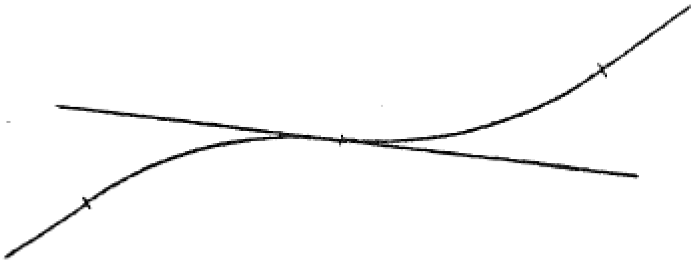


Figure 6.5

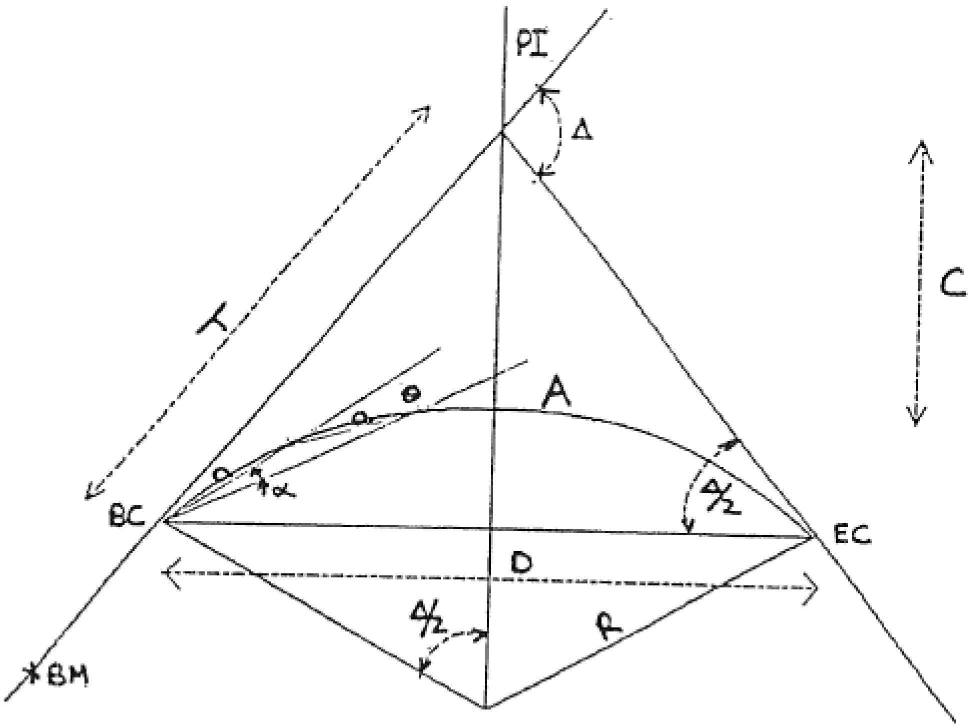


Figure 6.6

Curve to the right
Legend

A	= ARC LENGTH
Δ	= INTERSECTION ANGLE
PI	= POINT OF INTERSECTION
BC	= BEGINNING OF CURVE
EC	= END OF CURVE
T	= TANGENT LENGTH
θ	= DEFLECTION ANGLE
α	= OFFSET ANGLE
R	= RADIUS OF CURVE
D	= LONG CHORD
C	= CROWN DISTANCE

a = SHORT CHORD DISTANCE

$T = R \times \tan\frac{\Delta}{2}$ $\qquad \theta = \frac{1718{,}9 \times a}{60 \times R}$

$A = \frac{\pi \times \Delta \times R}{180}$ $\qquad D = 2 \times Rx \sin\frac{\Delta}{2}$ $\qquad C = T \times \tan\frac{\Delta}{4}$

Worked Example 6.3

Calculate the curve to the right and set out the curve from BC to EC

GIVEN

CHAINAGE OF PI = 2046,22 M

RADIUS OF CURVE = 152,25 m
INTERSECTION ANGLE = 45:00:00
CHAINAGE EVERY 20 m

$\Delta = 45:00:00$ $\qquad \frac{\Delta}{2}$ = 22:30:00

$t = R.TAN\ \frac{\Delta}{2}$ $\qquad$ A $= \frac{\pi.\Delta.R}{180}$

$= 152{,}25\ \times TAN\ 22:30$ $\qquad = \frac{\pi \times 45 \times 152{,}25}{180}$

$= 63:06\ m$ $\qquad = 119{,}58\ m$

CHAINAGE OF PI $= 2046{,}22\ m$
CHAINAGE OF BC $= PI - T = 2046{,}22 - 63{,}06 = 1983{,}16\ m$
CHAINAGE OF EC $= BC + A = 1983{,}16 + 119{,}58 = 2102{,}74\ m$

$= \frac{1718{,}9 \times a}{60.R}$

(a = 16,84) = 03:10:07
(a = 20,00) = 03:45:48
(a = 2,74) = 00:30:56

CHAINAGE		CHORD DISTANCE	DEFLECTION ANGLE	OFFSET ANGLE
BC	1983,16			00:00:00
		16,84	03:10:47	
	2000,00			03:10:07
		20,00	03:45:48	
	2020,00			06:55:55
		20,00	03:45:48	
	2040,00			10:41:43
		20,00	03:45:48	
	2060,00			14:27:31

	20,00	03:45:48	
208 0,00			18:13:19
	20,00	03:45:48	
2100 ,00			21:49:07
	2,74	00:30:56	
EC 2102 ,74			22:30:03

Table 6.1

Worked Example 6.4

Calculate the curve to the left and set out the curve from BC to EC.

GIVEN

CHAINAGE OF PI = 3768,49

Δ = 53:54:00

R = 209,57 m

CHAINAGE EVERY 20 m

$\Delta = 53:54:00$ $\qquad \frac{\Delta}{2}$ = 26:57:00

$T = R.TAN\ \frac{\Delta}{2}$ $\qquad$ A $= \frac{\pi.\Delta.R}{180}$

$= 209{,}57\ \times TAN\ \frac{\Delta}{2}$

$= 106{,}55$ $\qquad = 197{,}149$

CHAINAGE OF PI $= 3768{,}49\ m$

CHAINAGE OF BC $= 3661{,}939$

CHAINAGE OF EC $= 38{,}088$

(a = 18,061)

(a = 20,000)

(a = 19,088)

CHAINAGE	CHORD DISTANCE	DEFLECTION ANGLE	OFFSET ANGLE
BC 3661,939			360:00:00
	18,061	02:28:08	
3680			357:31:52
	20	02:44:02	
3700			354:47:50
	20	02:44:02	
3720			352:03:48

	20	02:44:02	
3740			349:19:46
	20	02:44:02	
3760			346:35:44
	20	02:44:02	
3780			343:51:42
	20	02:44:02	
3800			341:07:40
	20	02:44:02	
3820			338:23:38
	20	02:44:02	
3840			335:39:36
	19,088	02:36:34	
3859,088			333:03:02

Table 6.1

Activity 6.1

1. Calculate the cross-sectional area of the road section given the following information:

   Formation Width = 6m
   Height (h) = 2,31m
   Side slope = 1:3
   Ground slope = 1:8

2. Calculate the volume of material to be excavated for a canal from A to B. Given the following data:

   Chainage of A = 1536,28 m
   Chainage of B = 1686,91 m
   Formation Width = 5 m

   Height at A = 2,68 m
   Height at B = 1,92 m
   Side slopes = 1:2,5
   Ground slope at A = 1:5
   Ground slope at B = 1:7

3. Calculate the volume of fill for a dam wall from chainage 65 to chainage 380 m given the following information:

   <u>AT CH 65 m</u> <u>AT CH 380 m</u>

Formation Width	= 6m	Formation Width	= 6m
Ground slope	= 1:5	Ground slope	= 1:6,5
Side slopes	= 1:2,5	Side slopes	= 1:2,5
Height	= 8,15m	Height	= 6,20m

Draw a cross-section at Ch 65 and 380 m to a suitable scale.

Activity 6.2

1. Calculate the A 20 m Grid survey was done on an area 60 m x 40 m. The Grid information is given as follows:

   A1 = 24,22 B1 = 25,11 C1 = 26,00 D1 = 27,20
   A2 = 23,80 B2 = 24,80 C2 = 25,10 D2 = 26,22
   A3 = 24,90 B3 = 24,17 C3 = 24,70 D3 = 25,35

   The area has to be excavated to an elevation of 20m and the sides are vertical.

   a) Draw the Grid to a scale of 1:5 and calculate and plot the 25,00 contour line.
   b) Calculate the volume of earth to be excavated in cubic metres.

2. The following is the survey information for a 30m Grid survey:

   A1 = 445,16 B1 = 449,31 C1 = 448,34 D1 = 449,61
   A2 = 446,14 B2 = 445,38 C2 = 447,94 D2 = 448,46
   A3 = 444,15 B3 = 445,37 C3 = 445,31

   a) Calculate the volume of excavation if the sides of the excavation are vertical and the area has to be excavated to an elevation of 440,63m
   b) Draw the Grid to a scale of Icm = 1Om and calculate and plot the 447,00m contour line.

Activity 6.3

1. From the data given below, calculate the setting out data for a road curve. A peg is required at every full 15 m chainage. The curve is to the left.
   Radius is 149,28m
   Angle of intersection is 47:20:00
   Chainage of the point of intersection is 1659, 75m

2. A road curve is to be staked out from the BC to the EC. The chainage of the EC is 5821,74m. The radius of 190,58m and the angle of intersection is 75:35.
   Calculate the following:

a) Tangent length
b) Arc length
c) Chainage of the point of intersection
d) Chainage of the beginning of curve
e) Full setting out data from BC to EC. Tabulate the setting-out data. The curve is to the left. A peg is required at every full 20m chainage.

3. The data applies to a curve to the right

Direction BP = 250:10:00 and Direction PE = 290:11:20
Radius of curve = 450,00
Chainage P = 4892,11
Standard sub chord = 30,00 m

Calculate:
a) Chainage of Tangent points
b) Crown distance from P
c) Long chord distance
d) Tabulate complete setting out data

4. A railway curve is to be staked out with the point of intersection (PI) at chainage 4921,68 m. The radius is 205,68 m and the angle of intersection is 51:22:10. The curve is to the right from BC.
a) Calculate and tabulate the full setting out data from the beginning of curve to the Mid Point and then from the End of Angle to the Mid Point of the curve.
b) Calculate the crown distance from the intersection point.
c) Calculate the long chord.

Activity 6.4 Definitions and Theory exercises

A. Explain the following terms used in surveying:

1. Angle of Direction
2. Bisecting of a target angle
3. Grid North
4. Measuring areas with a planimetre
5. True north
6. Magnetic north
7. Contour line
8. Vertical interval
9. Cross section
10. Long section
11. Traversing
12. Open and closed traverse .
13. Plotting contours by interpolation

14. The direct method of contouring
15. Orientation of a theodolite
16. Gradient
17. Bowditch's rule
18. True meridian
19. Grid meridian
20. Magnetic meridian
21. Whole circle bearing
22. Resection
23. Optical square
24. Observed direction
25. The advantage of a closed traverse
26. A hectare

B.

1. Explain by means of notes and sketches how you would stake a new road approximately 30 km long. State how you check the survey and where you would place bench marks and reference pegs.
2. Describe the planimetre and explain how you would measure the area of any site from a plan.
3. What is the purpose of Surveying?
4. Write notes on Topographic Maps and state what they are used for.

Self-Check

I am able to:	**Yes**	**No**
• Describe the methods of surveying routes for roads excluding aerial survey		
• Describe the setting out of centre line or offset line		
• Describe the types of control used for:		
o Embankments		
o Cuttings		
o Levels		
• Calculate and set out a horizontal circular curve by tangential angle using a theodolite and steel tape		
• Describe longitudinal and cross-sections		
• Describe volumes of cut and fill on a straight road with traverse sloping ground		

If you have answered 'no' to any of the outcomes listed above, then speak to your facilitator for guidance and further development.

Past Examination Papers

higher education & training

Department: Higher Education and Training
REPUBLIC OF SOUTH AFRICA

APRIL 2013

NATIONAL CERTIFICATE

BUILDING AND STRUCTURAL SURVEYING N6

(8060056)

2 April 2013 (X-Paper)
09:00 – 12:00

This question paper consists of 5 pages, 2 addenda and a 1-page formula sheet.

TIME: 3 HOURS
MARKS: 100

INSTRUCTIONS AND INFORMATION

1. Answer ALL the questions.

2. Read ALL the questions carefully.

3. Number the answers according to the numbering system used in this question paper.

4. Write neatly and legibly

QUESTION 1

1.1 The notes refer to observations from T in a tacheometric survey.
The elevation of survey station T2 is 326,84 m and the theodolite is 1 ,40 m above T.
The booked vertical angles are zenith distances.

STAFF STATION	HORIZONTAL ANGLE	VERTICAL ANGLE	STADIA READINGS
T1	298:12:40	81:42:12	2,96 1,60
T2	20:42:36	99:46:34	1,90 0,60
T3	98:58:20	100:36:20	2,82 0,88

Use the above information to complete the tacheometric sheet ANNEXURE 1. (15)

1.2 Calculate the horizontal distance from T1-T3 in the ANSWER BOOK. (5)
[20]

QUESTION 2

2.1 FIGURE 1 shows the traverse KLMN.
Calculate the co-ordinates on ANNEXURE 2.
Adjustments must be made according to the Bowditch rule.

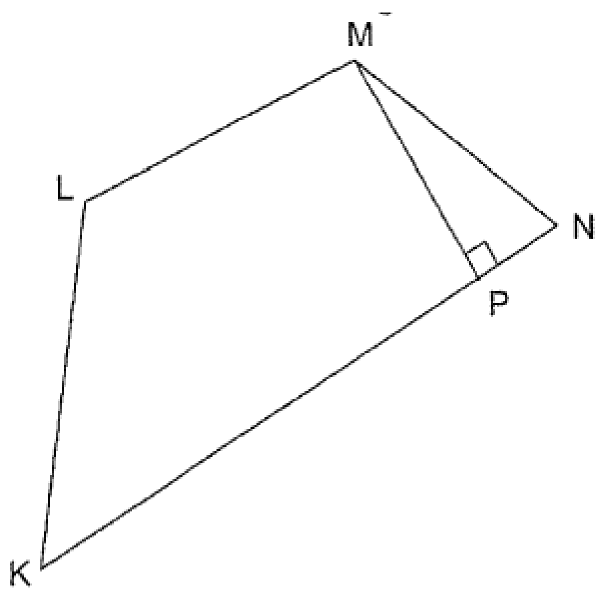


FIGURE 1

(15)

2.2 Calculate the distance MP where P lies on the line KN and angle MPN is a right angle. (5)
[20]

QUESTION 3

3.1 Explain how you would determine volumes from contour lines. (6)

3.2 Explain how a planimeter is used to find the area of an irregular figure. (8)
[14]

QUESTION 4

The co-ordinates of the boundary corner beacons of a farm are:

P	+285,50	+2 175,60
Q	-125,70	+2 045,20
R	-412,10	+2 356,20
S	-236,60	+2 736,00
T	+198,70	+2 572,50

4.1 Calculate the area of the farm in hectares. (10)

4.2 Plot the co-ordinates of P, Q, R, S and T to scale 1 : 5 000 in the ANSWER BOOK. (8)
Clearly show the direction of true north.
[18]

QUESTION 5

A right circular curve connects two straights AB and BC. (5)
Point B is the intersection point (PI).
Point A is the beginning of the road at chainage 0,0 m.
The radius of the curve is 173,00 m.
A peg is required at every FULL 20 m chainage.

The coordinates are:

A	+ 1 000,00	+ 1 000,00
B	+ 1 397,10	+ 1 469,78
C	+ 1 993,42	+ 1 443,55

Calculate the following:

5.1 The deflection angle (8)

5.2 The tangent length (3)

5.3 Length of arc (3)

5.4 Chainage at beginning of curve (2)

5.5 Chainage at end of curve (2)

5.6 The complete setting out data from beginning of curve to end of curve. Tabulate the setting out data. (10)

[28]

TOTAL: 100

EXAMINATION NUMBER: | | | | | | | | | | | | | |

ANNEXURE 1

Station		Distance		HI or middlehair MH	Angles		HI – MH + -	Height component + -	Height difference + -	Elevation of point	Remarks
From	To	Stadia	Hor		Hor	Vert					

EXAMINATION NUMBER: | | | | | | | | | | | | | |

ANNEXURE 2

NAME	JOIN	ΔY	ΔX	NAME	Y	X
K				K	- 3 690,00	+ 4 280,00
170:20:20						
220,00						
L				L		
250:10:40						
185,50						
M				M		
320:40:50						
199,30						
N				N	- 3 955,89	+ 4 155,89

BUILDING AND STRUCTURAL SURVEYING N6
FORMULA SHEET

Any applicable formula may also be used

$$\alpha = \tan^{-1}\frac{\Delta y}{\Delta x}$$

$$\alpha = \tan^{-1}\frac{\Delta x}{\Delta y} + 90^0$$

$$\alpha = \tan^{-1}\frac{\Delta y}{\Delta x} + 180^0$$

$$\alpha = \tan^{-1}\frac{\Delta x}{\Delta y} + 270^0$$

$$S = \frac{\Delta y}{\sin\alpha}$$

$$S = \frac{\Delta x}{\cos\alpha}$$

$$\Delta y = s.\sin\alpha$$

$$\Delta x = s.\cos\alpha$$

$$C = \frac{Distance}{Total\ distance} X_t$$

$$\Delta h = 50I\sin 2\theta + HI - MH = 100I\sin\theta\cos\theta + HI - MH$$

$$HD = 100I\cos^2\theta$$

$$T = R.\tan\frac{\Delta}{2}$$

$$La = \frac{\pi.\Delta.R}{180}$$

$$\vartheta = \frac{1718,9.a}{R}$$

$$Cd = T.\tan\frac{\Delta}{4}$$

$$Lc = 2.R.\sin\frac{\Delta}{2}$$

$$W_1 = \frac{g(a+hs)}{g-s}$$

$$W_2 = \frac{g(a+hs)}{g+s}$$

$$A = \frac{W_1.W_2 - a^2}{s}$$

$$a^2 = b^2 + c^2 - 2bc.CosA$$

$$b^2 = a^2 + c^2 - 2ac.CosB$$

$$c^2 = a^2 + b^2 - 2ab.CosC$$

$$\frac{SinA}{a} = \frac{SinB}{b} = \frac{SinC}{c}$$

Marking Guidelines

higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

APRIL 2013

NATIONAL CERTIFICATE

BUILDING AND STRUCTURAL SURVEYING N6

(8060056)

This marking guideline consists of 10 pages

QUESTION 1

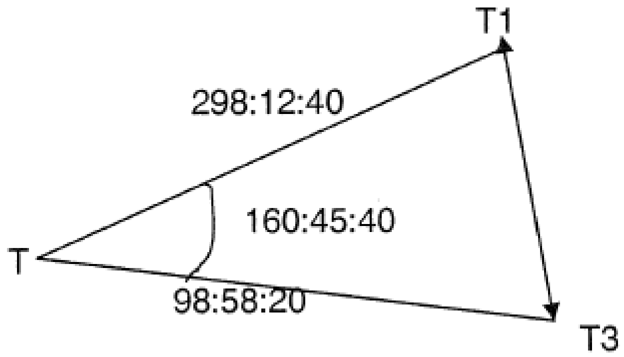
1.1

Station		Distance		HI or middlehair MH	Angles		HI – MH + -	Height component + -	Height difference + -	Elevation of point	Remarks
From	To	Stadia	Hor		Hor	Vert					
T				1,40			N			√ 348,44	
	T1	2,96 1,60	® 133,17	2,28	298:12:40	81:42:12	- 0,88	® + 19,42	√+ 18,54	√ 366,98	
							N				
	T2	1,90 0,60	® 126,25	1,25	20:42:36	99:46:34	+ 0,15	® - 21,75	√- 21,60	326,84	
							N				
	T3	2,82 0, 88	® 187,43	1,85	98:58:20	100:36:20	- 0,45	® - 35,10	√- 35,55	√ 312,89	

® = $1\frac{1}{4}$ X 6 = 7,5
N = $\frac{1}{2}$ X 3 = 1,5
√ = 1 x 6 = 6
15

(15)

1.2 T-T1 = 298:12:40
T-T3 = <u>458:58:20</u> (360 + 98:58:20)
Hor. Ang T1-T-T3 160:45:40



$a^2 = b^2+c^2 - 2bc(\cos A)$

$(T1\text{-}T3)^2 = (T\text{-}T1)^2 + (T\text{-}T3)^2 - 2(T\text{-}T1)(T\text{-}T3)\cos(T1\text{-}T\text{-}T3)$

$= (133{,}17)^2 + (187{,}43)^2\cos(160{:}45{:}40)$

$= 52\ 864{,}25 - (-\ 47\ 132{,}21)$

$= 73\ 970{,}44$

$(T1\text{-}T3) = \sqrt{99996{,}46}$

316,22 m → (5)

[20]

QUESTION 2

2.1

NAME	JOIN	ΔY	ΔX	NAME	Y	X
K				K	- 3 690,00	+ 4 280,00
170:20:20		+ 36,92	- 216,88			
220,00		-0,73	+0,55			
					√	√
L				L	- 3 653,81	+ 4 063,67
250:10:40		- 174,51	- 65,90			
185,50		-0,61	+0,46			
					√	√
M				M	- 3 828,93	+ 4 001,23
320:40:50		- 126,30	+ 154,17			
199,30		-0,66	+0,49			
N				N	- 3 955,89	+ 4 155,89
√604,80		- 263,89	- 125,61		- 265,89	- 124,11
		- 265,89	+ 124,11			
		- 2,00	+ 1,50			

$\frac{-2{,}00}{604{,}80}$ X leg $\frac{+1{,}50}{604{,}80}$ X leg (15)

2.2 Calculate MP

Direction KN $= \frac{-265,89}{-124,11}$

Tan θ $= 2,1423737$ 3rd quadrant

KN $= 244:58:41$

Direction MN $= \frac{(-126130-0166)}{(+154,17+0,49)}$

$= \frac{-126,96}{+154,66}$ 4th quadrant

Tan θ $= -0,8208094$

MN $= 320:37:03$

Angle KNP $= 320:37:03 - 244:58:41$

$= 75:38:22$

Sin A $= \frac{MP}{MN}$

But Dist MN $= \sqrt{(-126,96)^2 + (154,66)^2}$

$= 200,10$ m

MP $=$ MN x Sin KNP

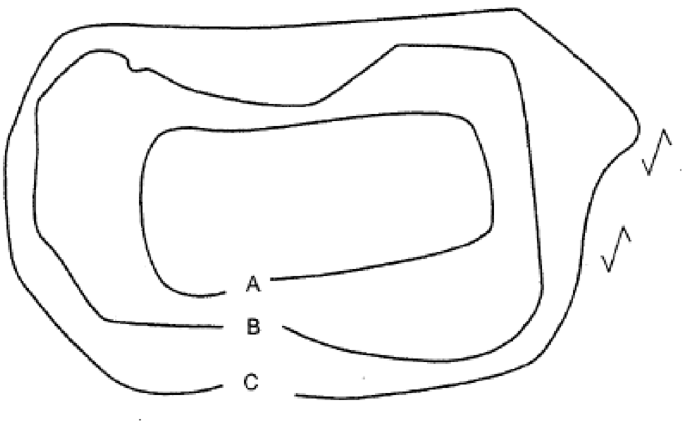
$= 200,10$ x sin $75:38:22$

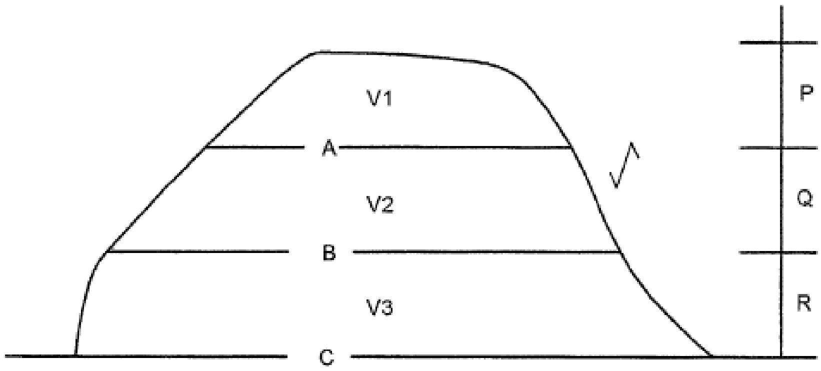
$= 193,85$ m (5)

[20]

QUESTION 3

3.1





A, B and C is the contour lines.
P, Q and R is the vertical intervals.
Measure the area of A, B and C by using a planimeter.

½ A x P = Volume V1
$\frac{A+B}{2}$ x Q = Volume V2
$\frac{B+C}{2}$ x R = Volume V3 (6)

3.2
- Place the weighted end of the planimeter on the paper outside the area. (8)
- The tracer point should be able to move freely around the perimeter of the figure.
- Mark a point on the perimeter of the figure.
- Place the tracer point on this mark.
- Set the area reading on the measuring unit to zero.
- Set the scale of the measuring unit the same as the figure (plan).
- Move the tracer point around the figure in a clockwise direction to return to the starting point.
- Note the reading.

[14]

QUESTION 4

4.1

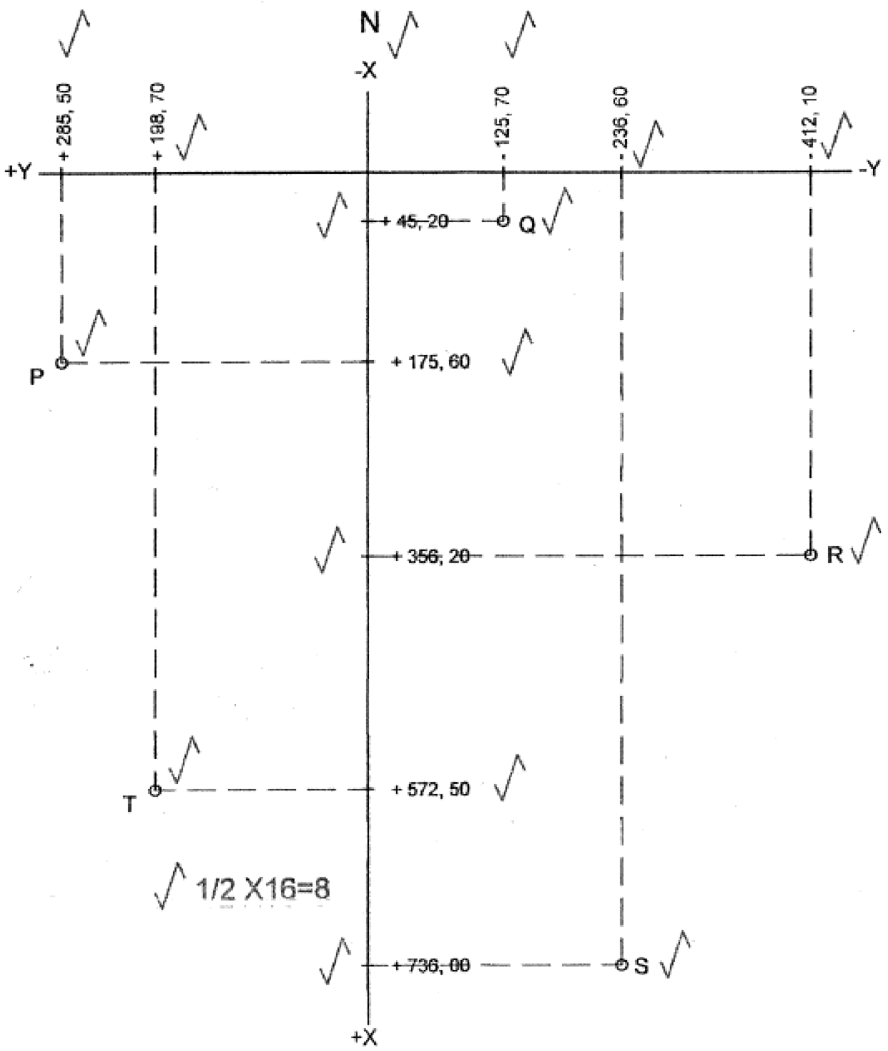
	Y	X	Y x X	X x Y
P	+ 285,50	+ 175,60		
Q	- 125,70	+ 45,20	√ 12 904,60	√ - 22 072,92
R	- 412,10	+ 356,20	√ - 44 774,34	√ - 18 626,92
S	- 236,60	+ 736,00	√ - 303 305,60	√ - 84 276,92
T	+ 198,70	+ 572,50	√ - 135 453,50	√ 146 243,20
P	√ + 285,50	√+ 175,60	√ 34 891,72	√ 163 448,75
			√ - 435 737,12	√ 184 715,19
			√ - 184 715,19	
			√ - 620 452,31	

$$Area = \frac{620\,452,31}{2} \checkmark$$

= 310 226,15 m²√
= 31,02ha√

(10)

4.2



(8)
[18]

QUESTION 5

5.1 Find distance and direction AB

Δdy_{A-B} = +1397,10-(+1000,00)
= +397,10 →

Δdy_{A-B} = +1469,78-(+1000,00)
= +469,78 →

Direction $= \frac{dy}{dx} = \frac{+397,10}{+469,78} = +0,8452893$ (1st quadrant)
= 40:12:27 →

distance $= \sqrt{(397,10)^2 + (469,78)^2}$
distance = 615,13 m→

find direction BC

Δdy_{B-C} = +1993,42-(+1397,10)
= +596,32 →

Δdy_{B-C} = +1443,55-(+1469,78)
= -26,23 →

Direction $= \frac{dy}{dx} = \frac{+596,32}{-26,23} = -22,7342737$ (2nd quadrant)
= 90:31:07 →

Δ = 92:31:07 – 40:12:27
= 52:18:40 →

(8)

5.2 T $= \text{R x tan } \frac{\Delta}{2}$ (3)
= 173,00 x tan 26:09:20
= 84,96 m

5.3 la $= \frac{\pi \Delta R}{180}$ (3)
$= \frac{\pi \times 42:18:40 \times 173,00}{180}$
= 157,95 m

5.4 BC = IP - T (3)
= 615,13 - 84,96
= 530,17 m

5.5 EC = BC + la (2)
= 530,17 + 157,95
= 688,12 m

5.6 (a=9,83) $= \frac{1718,9 \times 9,83}{173 \times 60}$ = 01:37:40 (2)

(a=20,00) $= \frac{1718,9 \times 20,00}{173 \times 60}$ = 03:18:43

(a=8,12) $= \frac{1718,9 \times 8,12}{173 \times 60}$ = 01:20:40

Chainage		Chord	Deflection Angle	Offset Angle
BC	530,17		00:00:00	√ 00:00":00
	540,00	9,83	01:37:40	√ 01:37:40
	560,00	20,00	03:18:43	√ 04:56:23
	580,00	20,00	03:18:43	√ 08:15:06
	600,00	20,00	03:18:43	√ 11:33:49
	620,00	20,00	03:18:43	√ 14:52:32
	640,00	20,00	03:18:43	√ 18:11:15
	660,00	20,00	03:18:43	√ 21:29:58
	680,00	20,00	03:18:43	√ 24:48:41
EC	688,12	8,12	01:20:40	√ 26:09:21
	157,95	157,95	26:09:21	√ 26:09:21
	√	√	√	

[28]

TOTAL: 100

Past Examination Papers

higher education & training

Department: Higher Education and Training REPUBLIC OF SOUTH AFRICA

APRIL 2012

NATIONAL CERTIFICATE

BUILDING AND STRUCTURAL SURVEYING N6

(8060056)

2 April 2012 (X-Paper)
09:00 – 12:00

This question paper consists of 4 pages, a 4-page formula sheet and 4 annexures.

TIME: 3 HOURS
MARKS: 100

INSTRUCTIONS AND INFORMATION

1. Answer ALL the questions.
2. Read ALL the questions carefully.
3. Number the answers according to the numbering system used in this question paper.
4. ALL the diagrams, sketches and drawings should be large and in good proportion, fully and clearly labelled and done in pencil.
5. Write neatly and legibly.

QUESTION 1

Given the following information:

Observed angles	Distances
LMN 108° 57' 44"	MN 450,56 m
MNO 290° 01 I 06"	NO 227,28 m
NOP 104° 00' 36"	OP 142,62 m
OPQ 225° 27' 42"	PQ 224,17 m
PQS 116° 51' 32"	

Co-ordinates	Directions
M + 306,38 + 1 476,18	ML 86° 12' 50"
Q - 330,76 + 1 098,60	QS 211° 36' 55"

1.1 Calculate the oriented directions in the ANSWER BOOK. (10)

1.2 Use the oriented directions to calculate the traverse on ANNEXURE 1. (20)

[30]

QUESTION 2

The notes refer to observations from R in a tacheometric survey.
The elevation of survey station R is 528,76 m and the theodolite is 1 ,46 m above R.
The booked vertical angles are zenith distances.

STAFF STATION	HORIZONTAL ANGLE	VERTICAL ANGLE	STADIA READINGS
S1	110:48:36	97:34:00	1,82 0,68
S2	136:22:28	82:24:00	3,12 2,42
S3	242:52:46	85:48:00	2,88 1,12
S4	292:38:34	98:45:00	2,76 1,36

Use the above information to complete the tacheometric field book ANNEXURE 2.

[20]

QUESTION 3

From the data given below, calculate and tabulate the setting out data for a road curve.
A peg is required at every full 20 m chainage.
The curve is to the left.
The tangent length is 66,73 m.
The crown distance is 9,45 m.
The chain age at beginning of curve is 3 201,43 m.

[20]

QUESTION 4

4.1 ANNEXURE 3 (attached), FIGURE 1 represents the plan of an area to be excavated to an elevation of 96,00 m.
Surface levels at the corner of the grid are given.
The sides of the excavation are vertical.
The ·bulking factor is 12%.

Calculate the volume of ground to be carted away in cubic metres. (10)

4.2 Reproduce ANNEXURE 3 (attached), FIGURE 1 in the ANSWER BOOK to scale 1:500.

Calculate and plot the 112 m contour line. (10)

[20]

QUESTION 5

ANNEXURE 4 (attached) shows a contour plan on which a road is to be built.

A-B is the centre line of the proposed road.
The formation width of the road is 11 m.
The formation height of the road is 50 m.
The side slope is 1:2 (1 vertical).

Plot the road width and embankment line on ANNEXURE 4.

[10]

TOTAL: 100

ANNEXURE 1 **EXAMINATION NUMBER:**

NAME	JOIN	ΔY	ΔX	NAME	Y	X
M				M		
N				N		
O				O		
P				P		
Q				Q		

ANNEXURE 2

EXAMINATION NUMBER:

Station		Distance		HI or middlehair MH	Angles		HI – MH + -	Height component + -	Height difference + -	Elevation of point	Remarks
From	To	Stadia	Hor		Hor	Vert					
R				1,46							
	S1	1,82 0,68									
	S2	3,12 2,42									
	S3	2,88 1,12								528,76	BM1
	S4	2,76 1,36									

ANNEXURE 3 **EXAMINATION NUMBER:**

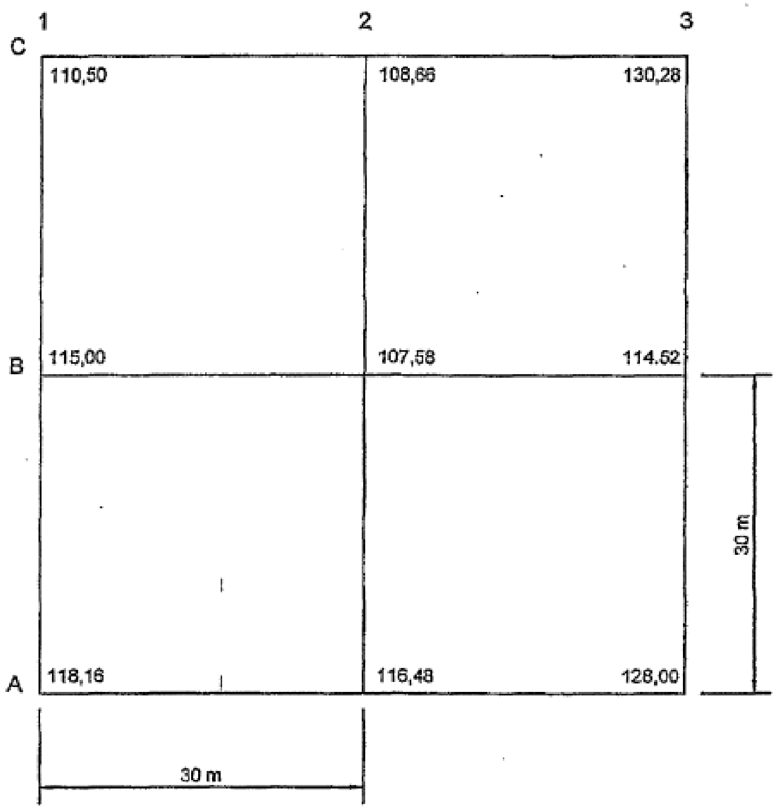
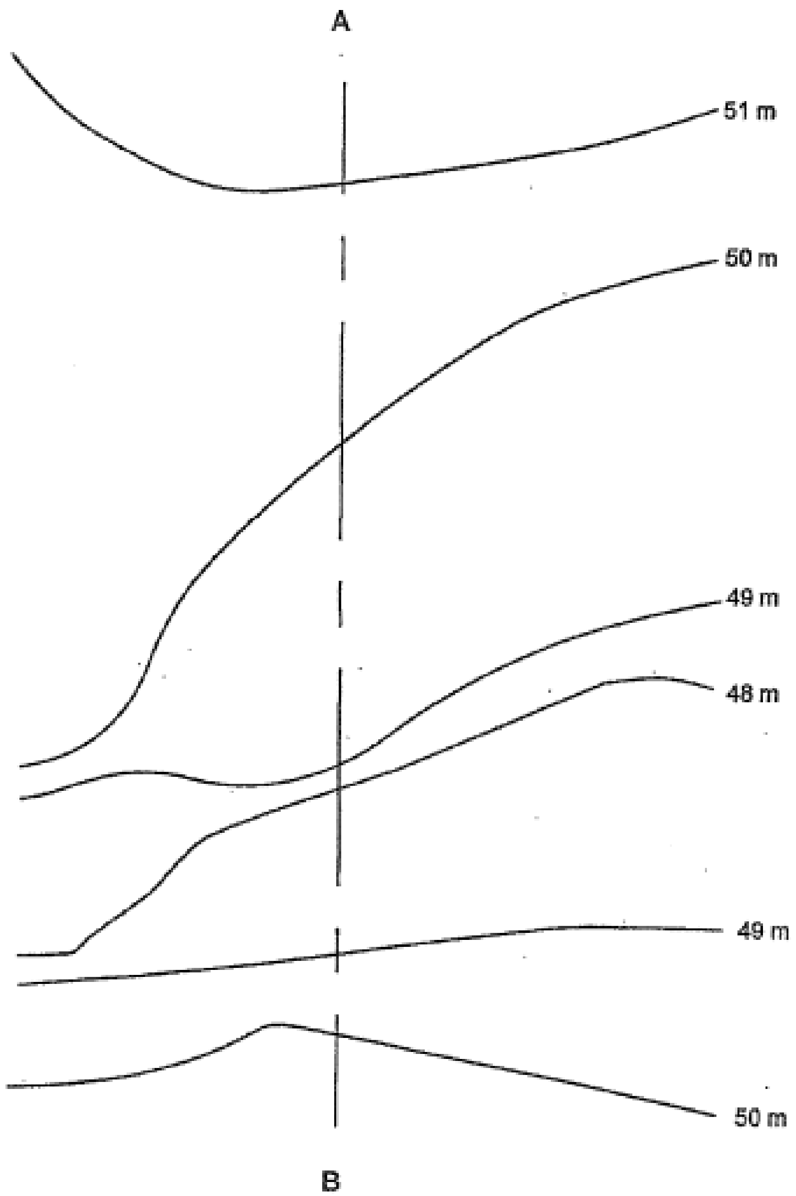


FIGURE 1

ANNEXURE 4 EXAMINATION NUMBER:



SCALE 1:250

BUILDING AND STRUCTURAL SURVEYING N6
FORMULA SHEET
Any applicable formula may also be used

$$\alpha = \tan^{-1}\frac{\Delta y}{\Delta x}$$

$$\alpha = \tan^{-1}\frac{\Delta x}{\Delta y} + 90°$$

$$\alpha = \tan^{-1}\frac{\Delta y}{\Delta x} + 180°$$

$$\alpha = \tan^{-1}\frac{\Delta x}{\Delta y} + 270°$$

$$S = \frac{\Delta y}{\sin\alpha}$$

$$S = \frac{\Delta x}{\cos\alpha}$$

$$\Delta y = s.\sin\alpha$$

$$\Delta x = s.\cos\alpha$$

$$C = \frac{\text{Distance}}{\text{Total distance}}\, X_1$$

$$\Delta h = 50I\sin 2\theta + HI - MH = 100I\sin\theta\cos\theta + HI - MH$$

$$HD = 100I\cos^2\theta$$

$$T = R.\tan\frac{\Delta}{2}$$

$$La = \frac{\pi.\Delta.R}{180}$$

$$\theta = \frac{1718{,}9.a}{R}$$

$$Cd = T.\tan\frac{\Delta}{4}$$

$$Lc = 2R.\sin\frac{\Delta}{2}$$

$$W_1 = \frac{g(a+hs)}{g-s}$$

$$W_2 = \frac{g(a+hs)}{g+s}$$

$$A = \frac{W_1 W_2 - a^2}{S}$$

$$a^2 = b^2 + c^2 - 2bc\ CosA$$

$$b^2 = a^2 + c^2 - 2ac\ CosB$$

$$c^2 = a^2 + b^2 - 2ab\ CosC$$

$$\frac{SinA}{a} = \frac{SinB}{b} = \frac{SinC}{c}$$

Marking Guidelines

higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

APRIL 2012

NATIONAL CERTIFICATE

BUILDING AND STRUCTURAL SURVEYING N6

(8060056)

This marking guideline consists of 10 pages

QUESTION 1

1.1	Direction	ML	86:12:50			
	Angle	LMN	108:57:44			
		MN	195:10:34	+ 00:01:05	=	195:11:39
		NM	15:10:34			
	Angle	MNO	290:01:06			
		NO	305:11:40	+ 00:02:10	=	305:13:50
		ON	125:11:40			
	Angle	NOP	104:00:36			
		OP	229:12:16	+ 00:03:15	=	229:15:31
		PO	49:12:16			
	Angle	OPQ	225:27:42			
		PQ	274:39:58	+ 00:04:20	=	274:44:18
		QP	94:39:58			
	Angle	PQS	116:51:32			
		QS	211:31:30	+ 00:05:25	=	211:3:55

But QS = 211:36:55

Correction $= \frac{211:36:55 - 211:31:30}{5}$ = 00:01:05 (10)

1.2

NAME	JOIN	ΔY	ΔX	NAME	Y	X
M				M	+ 306, 38	+ 1 476,18
195:11:39	√	-118, 09	-434, 81	√		
450, 56 m	√	-0, 84	+0, 29	√		
N				N	√+187, 45	√+ 1 041,66
305:13:50	√	-185, 65	+131, 11	√		
227, 28 m	√	-0, 42	+0, 15	√		
O				O	√+ 1, 38	√+1 172,92
229:15:31	√	-108, 06	-93, 08	√		
142, 62 m	√	-0, 26	+0, 09	√		
P				P	√-106, 94	√+ 1 079,93
274:44:18	√	-223, 40	+18, 52	√		
224, 17 m	√	-0, 42	+0, 15	√		
Q				Q	- 330, 76	+ 1098, 60
1 044, 63	√	-635, 20	-370, 26	√	√- 637, 14	√ - 377, 58
√	√	-637, 14	-377, 58	√		
	√	-1, 94	+0, 68	√		

√ $\frac{-1,94}{1\,044,63}$ X leg √ $\frac{+0,68}{1\,044,63}$ X leg

√ x 7 = 7

√ x 26 = $\frac{13}{20}$

(20)

[30]

QUESTION 2

Station		Distance		HI or middlehair MH	Angles		HI – MH	Height component	Height difference	Elevation of point	Remarks
From	To	Stadia	Hor		Hor	Vert	+□-	+ -	+ -		
R				1,46			N			√ 516,44	
	S1	1,82 0,68	® 112,02	1,25	110:48:36	- 07:34:00	+ 0,21	® - 14,88	√- 14,67	√ 501,77	
							N				
	S2	3,12 2,42	® 68,78	2,77	136:22:28	+ 07:36:00	- 1,31	® + 9,18	√+ 7,87	√ 524,31	
							N				
	S3	2,88 1,12	® 175,06	2,00	242:52:46	- 04:12:00	- 0,54	® + 12,86	√+ 12,32	528, 76	BM1
							N				
	S4	2,76 1,36	® 136,76	2,06	292:38:34	- 08:45:00	- 0,60	® - 21,05	√- 21,65	√ 494,79	

® $= 1\frac{1}{4} \times 8 = 10$
N $= \frac{1}{2} \times 4 = 2$
√ $= 1 \times 8 = 8$
20

[20]

QUESTION 3

cd $= T \times \tan\frac{\Delta}{4}$

9,45 $= 66{,}73 \times \tan\frac{\Delta}{4}$

$\tan\frac{\Delta}{4}$ $= \frac{9{,}45}{66{,}73}$
= 0,1416154
= 08:03:37

Δ = 4(08:03:37)
= 32:14:28

T $= R \times \tan\frac{\Delta}{2}$

66,73 = R x tan 16:07:14

R $= \frac{66{,}73}{\tan 16{:}07{:}14}$
= 230,88 m

Ia $= \frac{\pi\Delta R}{180}$
$= \frac{\pi \times 32{:}14{:}28 \times 230{,}88}{180}$
= 129,92 m

EC = 3 201,43 + 129,92
= 3 331,35 m

(a=18,57) $= \frac{1718{,}9 \times 18{,}57}{230{,}88 \times 60}$ = 02:18:15

(a=20,00) $= \frac{1718{,}9 \times 20{,}00}{230{,}88 \times 60}$ = 02:28:54

(a=11,35) $= \frac{1718{,}9 \times 11{,}35}{230{,}88 \times 60}$ = 01:24:30

Chainage		Chord	Deflection Angle	Offset Angle
BC	3 201, 43		00:00:00	√ 360:00:00
	3 220, 00	18, 57	02:18:15	√ 357:41:45
	3 240, 00	20, 00	02:28:54	√ 355:12:51
	3 260, 00	20, 00	02:28:54	√ 352:43:57
	3 280, 00	20, 00	02:28:54	√ 350:15:03
	3 300, 00	20, 00	02:28:54	√ 347:46:09
	3 320, 00	20, 00	02:28:54	√ 345:17:15
EC	3 331, 35	11, 35	01:24:30	√ 343:52:45
√	129, 92	√ 129, 92	√ 16:07:15	√ 16:07:15

√ $\frac{1}{2}$ x 12= 6
√ 1 x 14= <u>14</u>
<u>20</u>

[20]

QUESTION 4

4.1

CORNER	HEIGHT	TIMES USED	PRODUCT
A1	118,16	1	118,16 √
A2	116,48	2	232,96 √
A3	128,00	1	128,00 √
B1	115,00	2	230,0 √
B2	107,58	4	430,32 √
B3	114,52	2	229,04 √
C1	110,50	1	110,50 √
C2	108,66	2	217,32 √
C3	130,28	1	130,28 √
		16	1826,58 √

(10)

Mean height $= \frac{1826,58}{16}$

= 114,16 m

Excavation height = 114,16 – 96,00

= 18,16 m

Volume = 4(30 x 30) x 18,16

= 65 376,00 m³

12% = 65 376,00 x 0,12

= 7 845,12 m³

Total volume = 65 376,00 + 7 845,12

= 73 221,12 m³

4.2 The contour passes between:
81-82
82-83 (10)
C2-C3
81-C1
A2- 82

Difference in level

B1-B2	= 115,00 - 107,58	= 7,42
B2-B3	= 114,52 - 107,58	= 6,94
C2-C3	= 130,28 - 108,66	= 21,62
B1-C1	= 115,00 - 110,50	= 4,50
A2-B2	= 116,48 - 107,58	= 8,90

Difference in level to 112 contour (from lower level)

B1- B2	= 112,00 - 107,58	= 4,42
B2-B3	= 112,00 - 107,58	= 4,42
C2-C3	= 112,00 - 108,66	= 3,34
B1-C1	= 112,00 - 110,50	= 1,50
A2- B2	= 112,00 - 107,58	= 4,42 N

Horizontal distance to 112 contour (from lower level)

B1 - B2 $= \frac{4,42}{7,42} \times 30 = 17,87\ m$

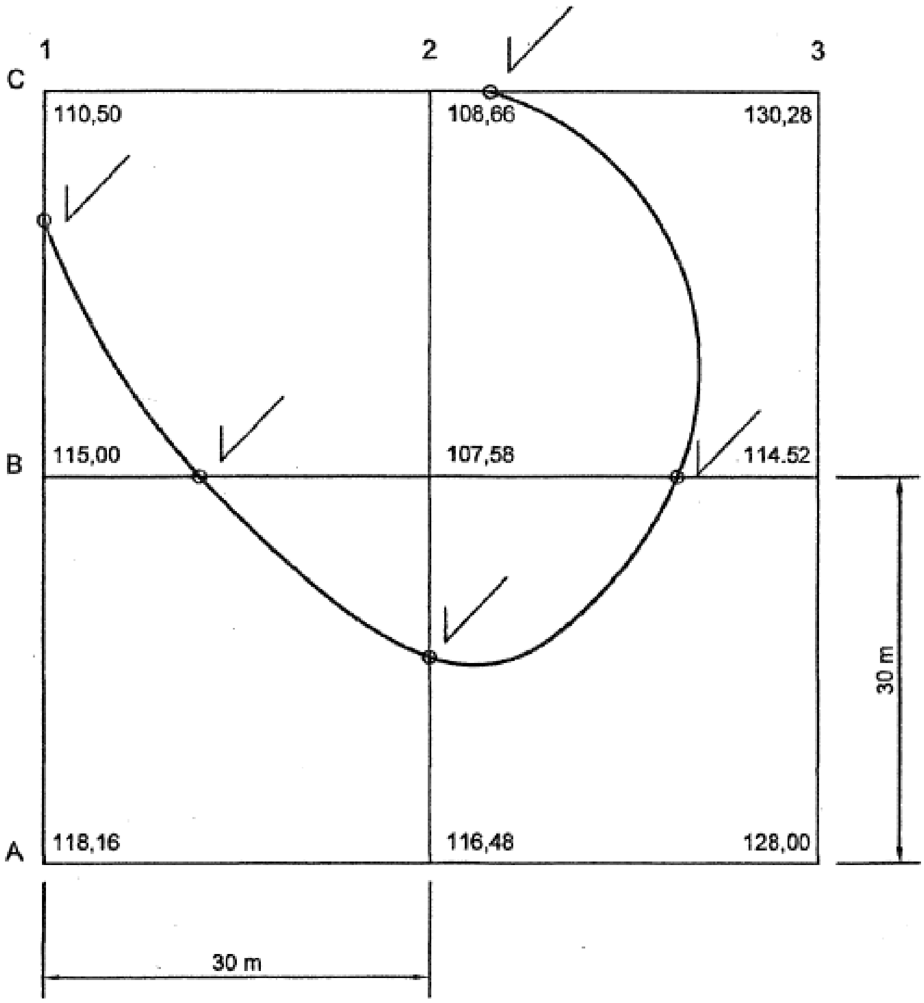
B2 - B3 $= \frac{4,42}{6,94} \times 30 = 19,10\ m$

C2 - C3 $= \frac{3,34}{21,62} \times 30 = 4,63\ m$

B1 - C1 $= \frac{1,50}{4,50} \times 30 = 10,00\ m$

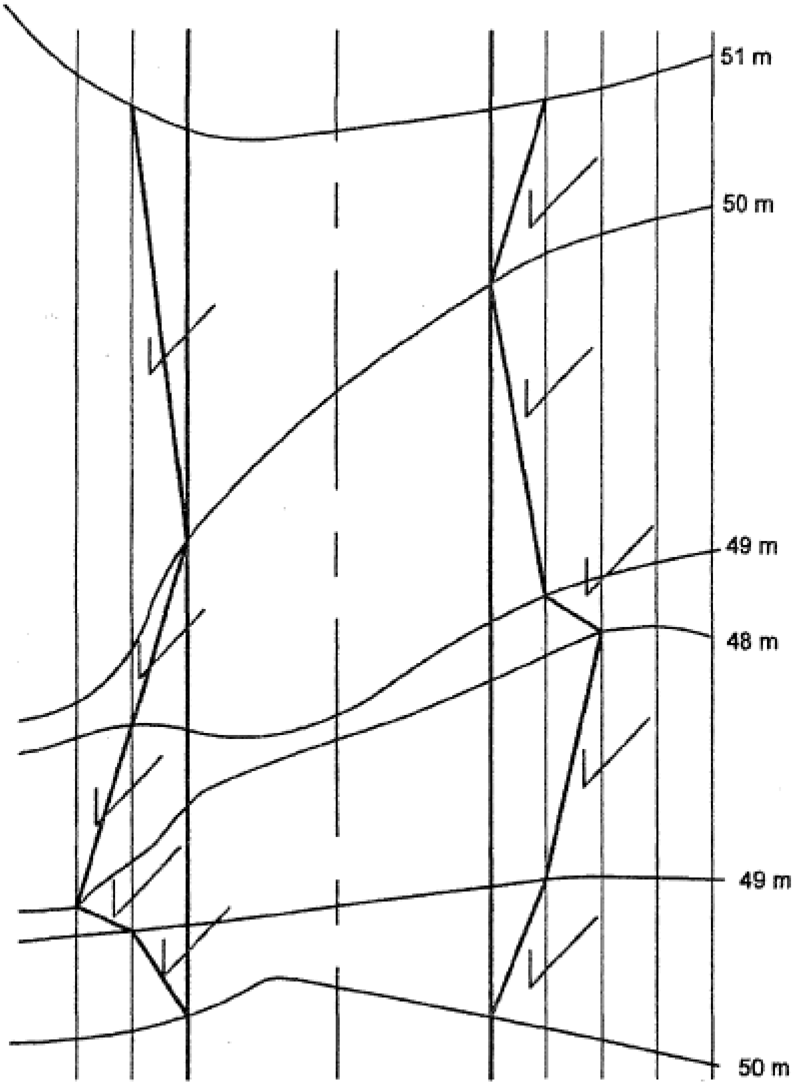
A2 - B2 $= \frac{4,42}{8,90} \times 30 = 14,89\ m$

√ X 15 = 7,5
√ Plot x 5 = 2,5
10 (10)



[20]

QUESTION 5



[10]

TOTAL: 100

Past Examination Papers

higher education
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Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

AUGUST 2011

NATIONAL CERTIFICATE

BUILDING AND STRUCTURAL SURVEYING N6

(8060056)

21 July 2011 (X-Paper)
09:00 – 12:00

This question paper consists of 5 pages, 3 annexures and a 2-page formula sheet

TIME: 3 HOURS
MARKS: 100

INSTRUCTIONS AND INFORMATION

1. Answer ALL the questions.

2. Read ALL the questions carefully.

3. Number the answers according to the numbering system used in this question paper.

4. Test ALL the calculations

5. Write your examination number on the addenda and place them in the ANSWER BOOK.

6. Write neatly and legibly.

QUESTION 1

Given the following information:

Observed angles		Distances	
SAB	87° 19' 0511	AB	167,42 m
ABC	219° 57' 38"	BC	283,20 m
BCD	237° 57' 49"	CD	226,00 m
CDE	154° 29' 28"	DE	321,54 m
DET	108° 07' 48"		

Co-ordinates			Directions	
A	+ 552,10	+ 1 494,90	AS	134° 28' 21"
E	-277,48	+ 1 632,04	ET	222° 20' 09"

1.1 Calculate the oriented directions in the ANSWER BOOK. (10)

1.2 Use the oriented directions to calculate the traverse on the attached ANNEXURE 1. (20)

[30]

QUESTION 2

The notes refer to observations from R in a tacheometric survey.
The elevation of survey station R2 is 596,00 m and the theodolite is 1,64 m above R.
The booked vertical angles are zenith distances.

STAFF STATION	HORIZONTAL ANGLE	VERTICAL ANGLE	STADIA READINGS
R1	112° 40' 28"	87° 52' 22"	1,92 1,67 1,42
R2	174° 36' 30"	97° 17' 42"	2,78 2,16 1,54
R3	220° 42' 36"	82° 24' 44"	2,20 1,60 1,00
R4	296° 34' 22"	93° 48' 50"	1,80 1,47 1,14

Use the above-mentioned information to complete the tacheometric sheet on the attached ANNEXURE 2.

[20]

QUESTION 3

From the data given below, calculate and tabulate the setting out data for a road curve.

- A peg is required at every FULL 20 m chainage
- The curve is to the left
- The coordinates at the beginning of the curve is +3 146,00 +2 876,46
- The coordinates at the point of intersection is +3 222,54 +2 848,09
- The direction from the end of the curve to the point of intersection is 253:49:45

- The chainage at the end of the curve is 3 329,70 m
- The radius of the curve is 247,5 m

[23]

QUESTION 4

ANNEXURE 3 (attached) shows a contour plan on which a road is to be built.

A-B is the centre line of the proposed road.
The formation width of the road is 1 0 m.
The formation height of the road is 56 m.
The side slope is 1:1,5 (1 vertical).

Plot the road width and embankment line to scale 1:250 on the attached ANNEXURE 3.

[10]

QUESTION 5

Explain how you would determine volumes from contour lines.

[6]

QUESTION 6

Calculate the area of a road cross section given the following information:
- Formation width10m
- Central height5,36m
- Cross slope1 :1 0 (1 vertical)
- Side slopes1:3,5 (1 vertical)

[7]

QUESTION 7

From the readings below taken by a theodolite set-up at station R, deduce the correct angles of elevation to R1 and R2.

Clearly show whether the angles+ (rise) or- (fall).

At R:

STATION	CIRCLE LEFT	CIRCLE RIGHT
R1	84:38:46	275:20:50
R2	97:32:12	262:27:34

[4]

TOTAL: 100

BUILDING AND STRUCTURAL SURVEYING N6
FORMULA SHEET

Any applicable formula may also be used

$$\alpha = \tan^{-1}\frac{\Delta y}{\Delta x}$$

$$\alpha = \tan^{-1}\frac{\Delta x}{\Delta y} + 90°$$

$$\alpha = \tan^{-1}\frac{\Delta y}{\Delta x} + 180°$$

$$\alpha = \tan^{-1}\frac{\Delta x}{\Delta y} + 270°$$

$$S = \frac{\Delta y}{\sin\alpha}$$

$$S = \frac{\Delta x}{\cos\alpha}$$

$$\Delta y = s.\sin\alpha$$

$$\Delta x = s.\cos\alpha$$

$$C = \frac{\text{Distance}}{\text{Total distance}} X_\ell$$

$$\Delta h = 50I\sin 2\Theta + HI - MH = 100I\sin\Theta\cos\Theta + HI - MH$$

$$HD = 100I\cos^2\Theta$$

$$T = R.\tan\frac{\Delta}{2}$$

$$La = \frac{\pi.\Delta.R}{180}$$

$$\theta = \frac{1718{,}9.a}{R}$$

$$Cd = T.\tan\frac{\Delta}{4}$$

$$Lc = 2R.\sin\frac{\Delta}{2}$$

$$W_1 = \frac{g(a + hs)}{g - s}$$

$$W_2 = \frac{g(a + hs)}{g + s}$$

$$A = \frac{W_1 . W_2 - a^2}{S}$$

$$a^2 = b^2 + c^2 - 2bc\ CosA$$

$$b^2 = a^2 + c^2 - 2ac\ CosB$$

$$c^2 = a^2 + b^2 - 2ab\ CosC$$

$$\frac{SinA}{a} = \frac{SinB}{b} = \frac{SinC}{c}$$

EXAMINATION NUMBER: ____________

ANNEXURE 1

NAME	JOIN	ΔY	ΔX	NAME	Y	X
A				A		
B				B		
C				C		
D				D		
E				E		

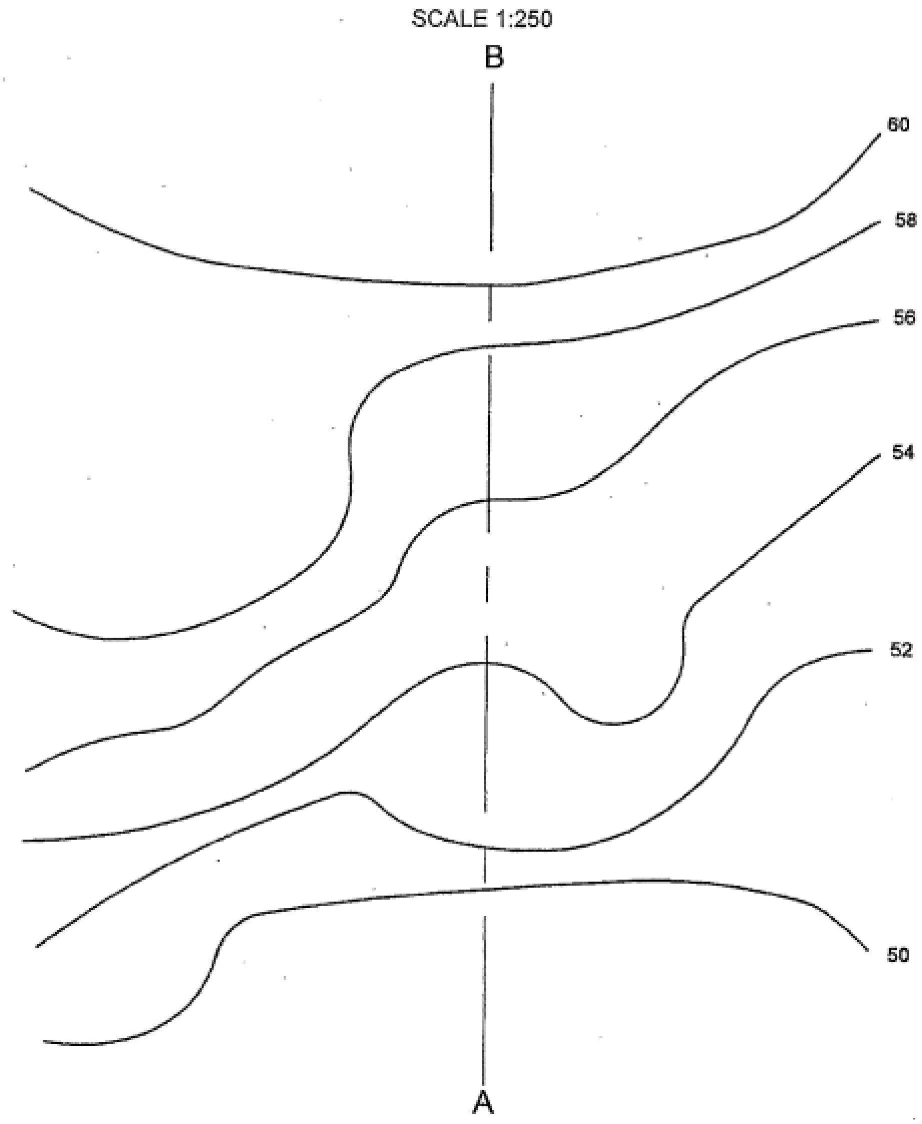
EXAMINATION NUMBER: ______________

ANNEXURE 2

Station		Distance		HI or middle hair MH	Angles		HI – MH	Height component	Height difference	Elevation of point	Remarks
From	To	Stadia	Hor		Hor	Vert	+ -	+ -	+ -		
R				1,64							
	R1										
	R2										BM1
	R3										
	R4										

EXAMINATION NUMBER:

ANNEXURE 3



Marking Guidelines

higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

AUGUST 2011

NATIONAL CERTIFICATE

BUILDING AND STRUCTURAL SURVEYING N6

(8060056)

QUESTION 1

1.1	Direction	AS	134:28;21			
	SAB		87;19:05			
	Direction	AB	221:47:26	00:00:00	=	221 :47:26
		BA	41:47:26			
	ABC		219:57:38			
	Direction	BC	261:45:04	00:00:00	=	261:45:04
		CB	81:45:04			
	BCD		237: 57:49			
	Direction	CD	319:42:53	00:00:00	=	319:42:53
		DC	139:42:53			
	CDE		154:29:28			
	Direction	DE	294:12:21	00:00:00	=	294:12:21
		ED	114:12:21			
	DET		108:07:48			
	Direction	ET	222:20:09	00:00:00	=	222:20:09

But ET is 222:20:09

Error (222:20:09 - 222:20:09) = 00:00:00 (10)

1.2 EXAMINATION NUMBER:

ANNEXURE 1

NAME	JOIN	ΔY	ΔX	NAME	Y	X
A				A	+ 552, 10	+ 1 494, 90
221:47:26	√	-111.57	-124.83	√		
167, 42	√	+ 0,28	-0,28	√		
B				B	√+ 440,81	√+ 1 369,79
261:45:04	√	-280.27	-40,63	√		
283, 20	√	+ 0,47	-0,47	√		
C				C	√+ 161,01	√+ 1 328,69
319:42:53	√	-146,13	+172,40	√		
226, 00	√	+ 0,38	-0,37	√		
D				D	√+ 15,26	√+ 1 500,72
294:12:21	√	-293,27	+131,84	√		
321, 54	√	+0,53	-0,53	√		
E				E	- 277, 48	+ 1 632, 04
998.16	√	- 831,24	+138,79	√	- 829,58	+ 137,14
√	√	- 829,58	+137,14	√	√	√
	√	+ 1,66	- 1,65	√		

$\frac{+1,66}{998,16}$ X leg √

$\frac{-1,65}{998,16}$ X leg √

√ X 7 = 7

√ x26= $\frac{13}{20}$

[30]

QUESTION 2

EXAMINATION NUMBER:

ANNEXURE 2

Station		Distance		HI or middle hair MH	Angles		HI – MH	Height component	Height difference	Elevation of point	Remarks
From	To	Stadia	Hor		Hor	Vert	+ -	+ -	+ -		
R				1, 64			N/			√612,14	
	R1	1.92 1,42	®49,93	1,67	112:40:28	87:52:22	-0,03	®+1,85	√+1,82	√613,96	
							N/				
	R2	2,78 1,54	®122,00	2,16	174:36:30	97:17:42	-0,52	®-15,62	√-16,14	596,00	BM1
							N/				
	R3	2,20 1,00	®117,91	1,60	220:42:36	82:24:44	+0,04	®+15,71	√+15,75	√627,89	
							N/				
	R4	1,80 1,14	®65,71	1,47	296:34:22	93:48:50	+0,17	®-4,38	√-4,21	√607,93	

® $= 1\frac{1}{4} \times 8 = 10$

N/ $= \frac{1}{4} \times 4 = 2$

√ $= 1 \times 8 = \underline{8}$

$\underline{20}$

[20]

QUESTION 3

To find direction from BC to PI

Δdy_{BC-PI} = +3222,54-(+3146,00)
= +76,54 →

Δdx_{BC-PI} = +2848,09-(+2876,46)
= -28,37 →

dy = positive
dx = negative
∴ 2cnd _quadrant

Direction= $\frac{dy}{dx} = \frac{+76,54}{-28,37} = -2,69792033$
tan α = -2,69792033
∴ α = arctan-2,69792033
∴ α = -69:39:45
∴ α = 110:20:15

direction from PI to EC = 253:49:45 -180:00:00
=73:49:45

Δ = 110:20:15-73:49:45
= 36:30:30

La = $\frac{\pi \Delta R}{180}$
= $\frac{\pi \times 36:30:30 \times 247,5}{180}$
= 151,70 m →

BC = EC - La
= 3 329,70 -157,70
= 3 172,00 m

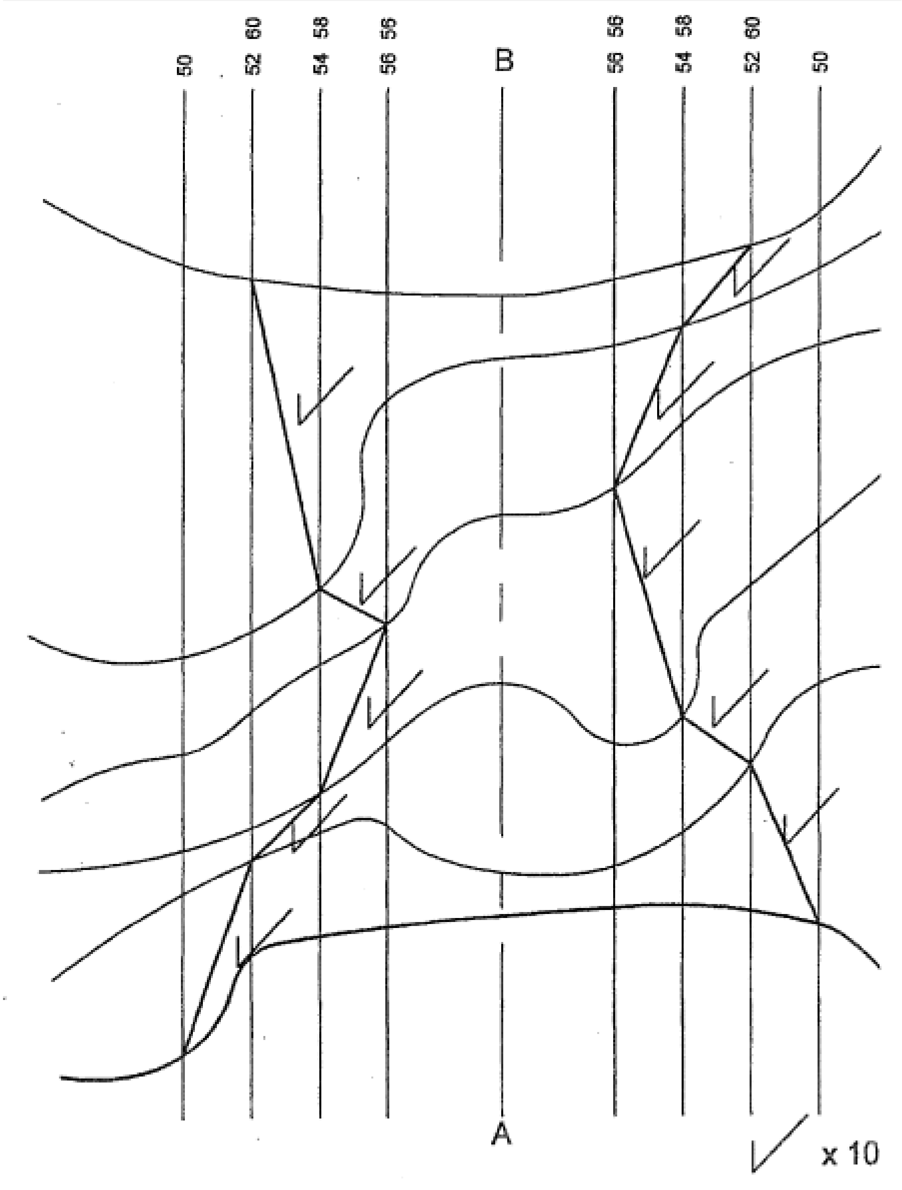
(a = 8,00) $\frac{1718,9 \times 8,00}{247,5 \times 60} = 00:55:34$
(a = 20) $\frac{1718,9 \times 20}{247,5 \times 60} = 02:18:54$
(a = 9,70) $\frac{1718,9 \times 9,70}{247,5 \times 60} = 01:07:22$

CHAINAGE	CHORD	ϑ	α
BC 3 172,00		00:00:00	√ 360:00:00
3 180,00	8,00	00:55:34	√ 359:04:26
3 200,00	20,00	02:18:54	√ 356:45:32
3 220,00	20,00	02:18:54	√ 354:26:38
3 240,00	20,00	02:18:54	√ 352:07:44
3 260,00	20,00	02:18:54	√ 349:48:50
3 280,00	20,00	02:18:54	√ 347:29:56
3 300,00	20,00	02:18:54	√ 345:11:02
3 320,00	20,00	02:18:54	√ 342:52:08
EC 3329,70	9,70	01:07:22	√ 341:44:46
√157,70	√ 157,70	√ 18:15:14	√ 18:15:14

x 14√ 7
√ x 16=16
23

[23]

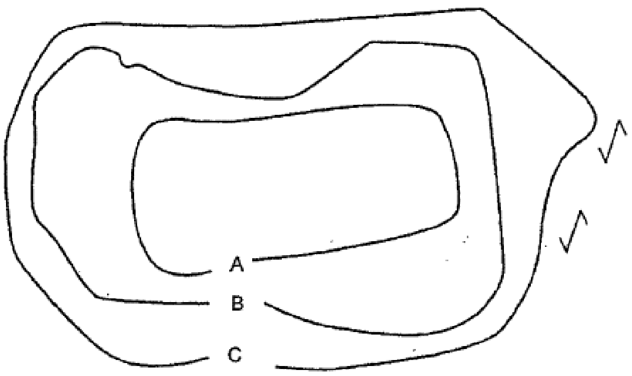
QUESTION 4

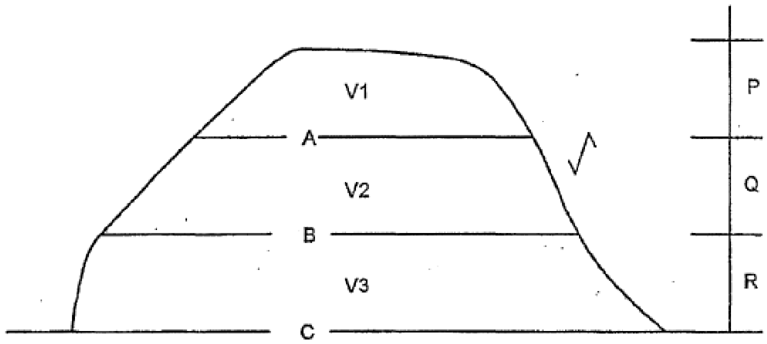


SCALE 1:250

[10]

QUESTION 5





LA,
B and C is the contour lines. N
P, Q and R is the vertical intervals. N
Measure the area of A, B and C by using a planimeter,

½ A x P = Volume V1

$\frac{A+B}{2} \times Q$ = Volume V2

$\frac{B+C}{2} \times R$ = Volume V3

[6]

QUESTION 6

a = 5
h = 5,36
g = 10
2 = 3,5

$$W_1 = \frac{g(a+\{hs\})}{g-s}$$

$$W_1 = \frac{10(5+\{5,36\times 3,5\})}{10-3,5}$$

$$W_1 = \frac{237,5}{6,5}$$

$$W_1 = 36,54 \rightarrow$$

$$W_2 = \frac{g(a+\{hs\})}{g+s}$$

$$W_2 = \frac{237{,}5}{13{,}5}$$

$$W_2 = 17{,}60 \rightarrow$$

$$\text{Area} = \frac{(W_1 \times W_2)-a^2}{s}$$

$$\text{Area} = \frac{(36{,}54 \times 17{,}60)-5^2}{3{,}5}$$

$$\text{Area} = 176{,}60$$

[7]

QUESTION 7

STATION	CL	CR	ANGLE CL	ANGLE CR	MEAN ANGLE
R1	84:38:46	275:20:50	√ 05:21:14	√ 05:20:50	√ +05:21:02 √
R2	97:32:12	262:27:34	√ 07:32:12	√ 07:32:26	√ -07:32:19 √

√ **X8 = 4**

[4]

TOTAL: 100

Past Examination Papers

higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

APRIL 2011

NATIONAL CERTIFICATE

BUILDING AND STRUCTURAL SURVEYING N6

(8060056)

1 April 2012 (X-Paper)
09:00 – 12:00

Calculators may be used.

This question paper consists of 4 pages, a 2-page formula sheet and 3 annexures.

TIME: 3 HOURS
MARKS: 100

INSTRUCTIONS AND INFORMATION

1. Answer ALL the questions.

2. Read ALL the questions carefully.

3. Number the answers according to the numbering system used in this question paper.

4. Write your EXAMINATION NUMBER on the ANNEXURES and place them in the ANSWER BOOK.

5. Test ALL the calculations

6. Write neatly and legibly.

QUESTION 1

Combine the following circle-left and circle-right horizontal angle observations which were taken from P1 and find the oriented directions P1-A and P1-C. Use the coordinates of P1 and B.

At P1

	Circle left	Circle right
A	178:42:34	358:42:18
B	260:38:12	80:37:50
C	103:04:40	283:04:06
D	178:42:12	358:42:04

Co-ordinates

P1	- 1 949,74 + 2 209,35
B	- 2 829,48 + 2 994,81

[10]

QUESTION 2

Given the following data:

Co-ordinates

A	+1 682,00	+2 000,00
E	+1 363,45	+1 080,70

Line	Direction	Distance (m)
A-B	150:36:20	380,00
B-C	192:32:18	400,00
C-D	202:12:30	280,58
D-C	281:30:10	320,00

2.1 Use ANNEXURE 1 (attached) to do the necessary calculations to find the final co-ordinates of B, C and D. Adjustments must be made according to Bowditch Rule. (20)

2.2 Plot the co-ordinates of A, B, C, D and E to scale 1 :5 000 in the ANSWER BOOK. Clearly show the direction of true north. (8)

[20]

QUESTION 3

A theodolite was set up at station A and readings were taken to spot shots A 1, A2, A3 and A4. Rewrite the information below on ANNEXURE 2 (attached) and reduce.

Elevation of point A3 is 278,46 m.

Height of instrument at A is 1 ,43 m.

Readings to spot shots:

Point	Stadia readings	Vertical angle	Horizontal reading
A1	2,86 ------ 1,68	87:12:16	14:12:38
A2	2,54 ------ 1,26	96:28:46	96:28:24
A3	2,42 ------ 1,34	98:50:48	206:54:52
A4	2,62 ------ 1,02	84:36:24	272:46:28

[20]

QUESTION 4

4.1 FIGURE 1, ANNEXURE 3 (attached), represents the plan of an area to be excavated to an elevation of 65,00 m.
Surface levels at the corner of the grid are given.
The sides of the excavation are vertical.
The bulking factor is 12o/o.

Calculate the volume of ground to be carted away in cubic metres. (10)

4.2 Reproduce FIGURE 1, ANNEXURE 3 attached, in the ANSWER BOOK to scale 1 :500.

Calculate and plot the 80 m contour line. (10)
[20]

QUESTION 5

The data on FIGURE 2, ANNEXURE 3 attached, apply to a road curve. Pegs are required at every full 20 m chainage.

Calculate and tabulate the data to set out the curve.

[20]

QUESTION 6

Explain the term bisecting of a target angle as used in surveying.

[2]

TOTAL: 100

BUILDING AND STRUCTURAL SURVEYING N6

FORMULA SHEET
Any applicable formula may also be used

$$\alpha = \tan^{-1}\frac{\Delta y}{\Delta x}$$

$$\alpha = \tan^{-1}\frac{\Delta x}{\Delta y} + 90°$$

$$\alpha = \tan^{-1}\frac{\Delta y}{\Delta x} + 180°$$

$$\alpha = \tan^{-1}\frac{\Delta x}{\Delta y} + 270°$$

$$S = \frac{\Delta y}{\sin\alpha}$$

$$S = \frac{\Delta x}{\cos\alpha}$$

$$\Delta y = s.\sin\alpha$$

$$\Delta x = s.\cos\alpha$$

$$C = \frac{\text{Distance}}{\text{Total distance}} X_\ell$$

$$h = 50I\sin 2\theta + HI - MH = 100I\sin\theta\cos\theta + HI - MH$$

$$HD = 100I\cos^2\theta$$

$$T = R.\tan\frac{\Delta}{2}$$

$$La = \frac{\pi\Delta.R}{180}$$

$$\theta = \frac{1718{,}9.a}{R}$$

$$Cd = T.\tan\frac{\Delta}{4}$$

$$Lc = 2R.\sin\frac{\Delta}{2}$$

$$W_1 = \frac{g(a + hs)}{g - s}$$

$$W_2 = \frac{g(a + hs)}{g + s}$$

$$A = \frac{W_1.W_2 - a^2}{S}$$

$$a^2 = b^2 + c^2 - 2bc.CosA$$

$$b^2 = a^2 + c^2 - 2ac.CosB$$

$$c^2 = a^2 + b^2 - 2ab.CosC$$

$$\frac{SinA}{a} = \frac{SinB}{b} = \frac{SinC}{c}$$

EXAMINATION NUMBER:

ANNEXURE 1

NAME	JOIN	ΔY	ΔX	NAME	Y	X
A				A		
B				B		
C				C		
D				D		
E				E		

EXAMINATION NUMBER:

ANNEXURE 2

Station.		Distance		HI or middle hair MH	Angles		HI – MH	Height component	Height difference	Elevation of point	Remarks
From	To	Stadia	Hor		Hor	Vert	+ -	+ -	+ -		

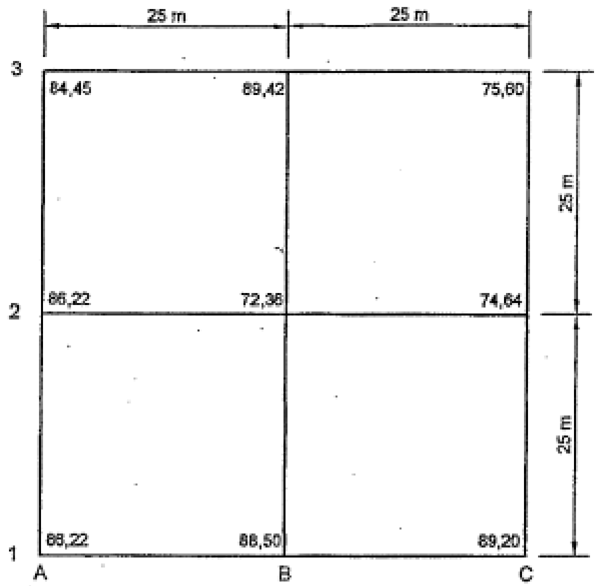


FIGURE 1

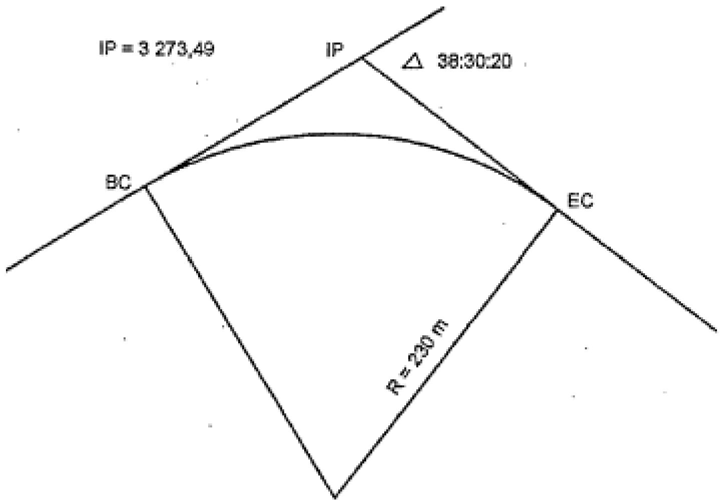


FIGURE 2

Marking Guidelines

higher education
& training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

APRIL 2011

NATIONAL CERTIFICATE

BUILDING AND STRUCTURAL SURVEYING N6

(8060056)

This marking guideline consists of 10 pages

QUESTION 1

STA.	Cir. Left	Cir. Right	Mean Ang	Cor.	Adj. Ang
A	178:42:34	358:42:18			
B	260:38:12	80:37:50			
	81:55:38	81:55:32	81:55:35	+ 00:00:06	81:55:41√
B	260:38:12	80:37:50			
C	103:04:40	283:04:06			
	202:26:28	202:26:16	202:26:22	+ 00:00:06	202:26:28√
C	103:04:40	283:04:06			
A	178:42:12	358:42:04			
	75:37:32	75:37:58	75:37:45	+ 00:00:06	75:37:51√
			359:59:42	+ 00:00:18	360:00:00√

Join P1-B

Δy_{P1-B} =- 2 829,48 – (- 1 949, 74)
= -879, 74 √

Δx_{P1-B} = + 2 994, 81 – (+ 2 209, 35)
= + 785, 46 √

Direction $= \frac{-879{,}74}{+785{,}46}$ 4th Quadrant √

Tan ß = -1, 12003157
ß = 311:45:34 √

Direction P1-B = 311:45:34
∠B-P1-C 202:26:28
P1-C = 154:12:02 → √
∠C-P1-A 75:37:51
P1-A = 229:49:53 → √
∠A-P1-B 81:55:41
P1-B = 311:45:34

√ x10 = 10

[10]

QUESTION 2

2.1 EXAMINATION NUMBER: ____________

ANNEXURE 1

(20)

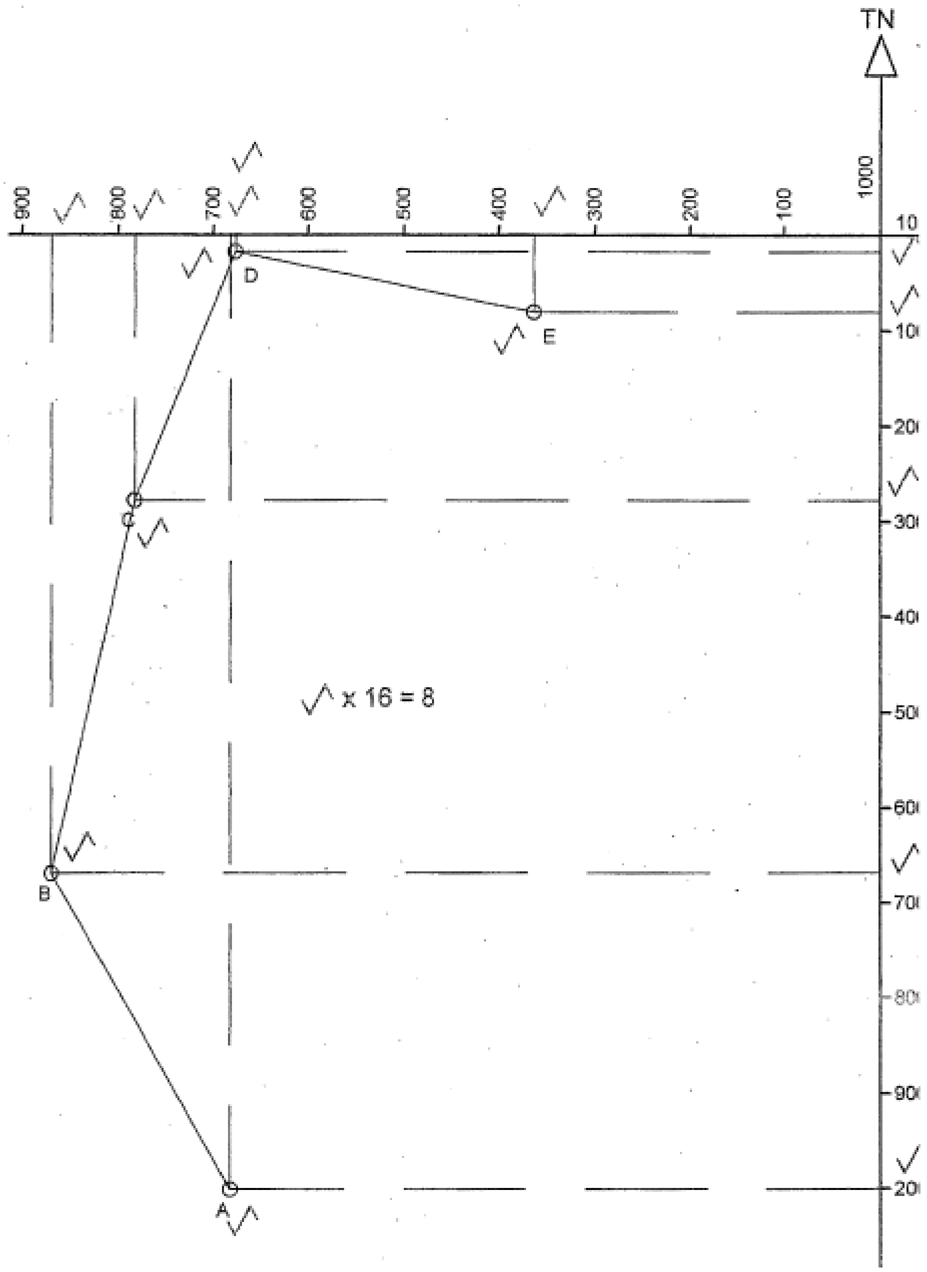
NAME	JOIN	ΔY	ΔX	NAME	Y	X
A				A	+1 682,00	+2 000,00
150:36:20	√	+186,51	-331,08	√		
380,00	√	+0,39	-0,50	√		
					√	√
B				B	+1 868,90	+1 668,42
192:32:18	√	-86,84	-390,46	√		
400,00	√	+0,41	-0,52	√		
					√	√
C				C	+1 782,47	+1 277,44
202:12:30	√	-106,05	-259,77	√		
280,58	√	+0,28	-0,37	√		
					√	√
D				D	+1 676,70	+1 017,30
281:30:10	√	-313,57	+63,81	√		
320,00	√	+0,32	-0,42	√		
E				E	+1 363,45	+1 080,70
√1380,58	√	-319,95	-917,50	√	-318,55	-919,30
	√	-318,55	-919.30	√	√	√
	√	+1,44	-1,80	√		

√ $\frac{+1,40}{1380,58}$ X leg $\frac{-1,80}{1380,58}$ X leg √

√ X 7 = 7

√ x26= $\frac{13}{20}$

2.2 (8)



[20]

QUESTION 3

EXAMINATION NUMBER:

ANNEXURE 2

Station		Distance		HI or middle hair MH	Angles		HI – MH	Height component	Height difference	Elevation of point	Remarks
From	To	Stadia	Hor		Hor	Vert	+ -	+ -	+ -		
A				1, 43			½√			√ 295,32	
	A1	2,86 1,68	®117,72	2,27	14:12:38	87:12:16	-0,84	® +5,75	√ +4,91	√ 300,23	
							½√				
	A2	2,54 1,26	®126,37	1,90	96:28:24	96:28:46	-0,47	® -14,35	√ -14,82	√ 280,50	
							½√				
	A3	2,42 1,34	®105,45	1,88	206:54:52	98:50:48	-0,45	® -16,41	√ -16,86	278,46	
							½√				
	A4	2,62 1,02	®158,59	1,82	272:46:28	84:36:24	-0,39	® +14,97	√ +14,58	√ 309,90	

® = 1¼ X 8 = 10
½√ = ¼ X 4 = 2
√ = 1 x 8 = 8
20

[20]

QUESTION 4

4.1

CORNER	HEIGHT	TIMES USED	PRODUCT	
A1	86,22	1	88,22	√
A2	86,22	2	172,44	√
A3	84,45	1	84,45	√
B1	88,50	2	177,00	√
B2	72,36	4	289,44	√
B3	89,42	2	178,84	√
C1	89,20	1	89,20	√
C2	74,64	2	149,28	√
C3	75,60	1	75,60	√
		16	1304,47	√

(10)

Mean height $= \frac{1304,47}{16}$
= 81,53 m →

Excavation height = 81,53-65,00
= 16,53 m →

Volume = 4(25x25) x 16,53
= 41 325 m³→

12°/o = 41 325 x 0,12
= 4 959 m³

Total volume = 41 325 + 4 959
= 46 284 m³

4.2 The contour passes between:
A2-B2
B3-C3
B1-B2
B2-B3
C1-C2

(10)

Difference in level
A2 - B2 = 86,22 -72,36 =13,86
B3 - C3 = 89 42-75 60 =13 82
B1 - B2 = 88,50-72,36 = 16,14
B2 - B3 = 89,42-72,36 = 17,06
C1 - C2 = 89,20-74,64 = 14,56

Difference in level to 90 contour (from lower level)

A2 - B2 = 80-72,36 = 7,64
B3 - C3 = 80-75,60 = 4,4
B1 - B2 = 80-72,36 = 7,64
B2 - B3 = 80-72,36 = 7,64
C1 - C2 = 80-74,64 = 5,36

Horizontal distance to 90 contour (from lower level)

A2-B2 = $\frac{7,64}{13,86} \times 25 = 13,78\,m$

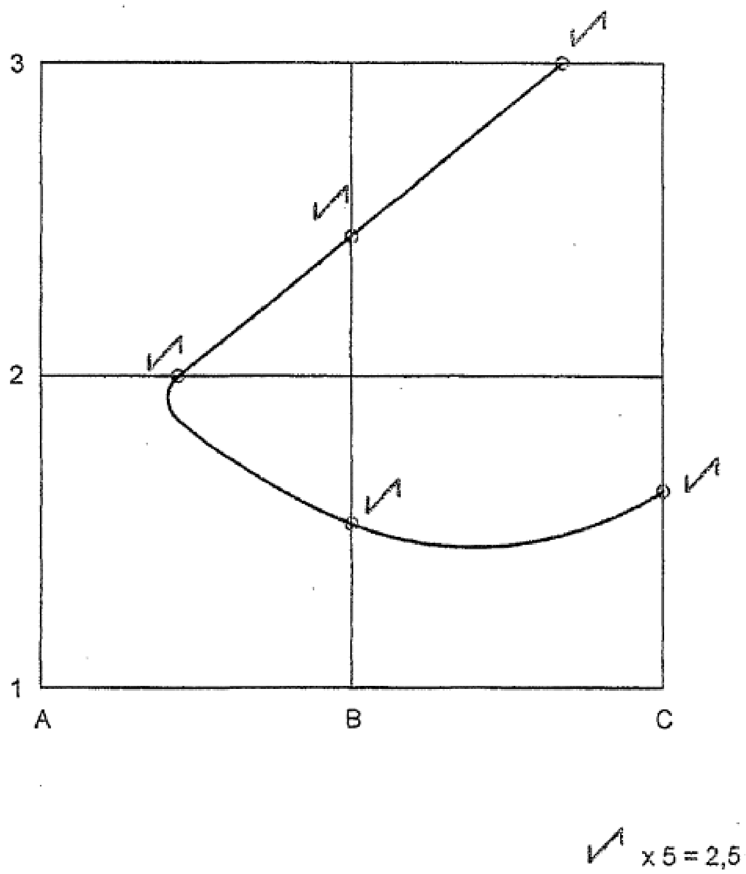
B3-C3 = $\frac{4,4}{13,82} \times 25 = 7,96\,m$

B2-B2 = $\frac{7,64}{16,14} \times 25 = 11,83\,m$

B2-B3 = $\frac{7,64}{17,06} \times 25 = 11,20\,m$

C1-C2 = $\frac{5,36}{14,56} \times 25 = 9,20\,m$

Note See drawing for plot



SCALE 1:500

[20]

QUESTION 5

T = R tan $\frac{\Delta}{2}$

T = 230 x tan 19:15:10

= 80,33 m

BC = IP – T

= 3 273,49 – 80,33

= 3 193,16 m

la = $\frac{\pi \Delta R}{180}$

la = $\frac{\pi \times 38:30:20 \times 230}{180}$

= 154,57 m

EC = BC + la

= 3 193,16 + 154,57

= 3 347, 73 m

(a = 6,84) $\frac{1718,9 \times 6,84}{230 \times 60} = 00:51:07$

(a = 20) $\frac{1718,9 \times 20}{230 \times 60} = 02:29:28$

(a = 7,73) $\frac{1718,9 \times 7,73}{230 \times 60} = 00:57:46$

CHAINAGE	CHORD	ϑ	α
BC 3 193,16		00:00:00	√ 00:00:00
3 200,00	6,84	00:51:07	√ 00:51:07
3 220,00	20,00	02:29:58	√ 03:20:35
3 240,00	20,00	02:29:58	√ 05:50:03
3 260,00	20,00	02:29:58	√ 08:19:31
3 280,00	20,00	02:29:58	√ 10:48:59
3 300,00	20,00	02:29:58	√ 13:18:27
3 320,00	20,00	02:29:58	√ 15:47:55
3 340,00	20,00	02:29:58	√ 18:17:23
EC 3 347,73	7,73	02:22:58	√ 19:15:0
√ 154,57	√ 154,57	√ 19:15:09	√ 19:15:09

√ x 14 = 7

√ x 13 = 13

20

[20]

QUESTION 6

When OL and OR observations are made and the mean of these two observations are calculated to obtain an accurate reading.

[2]

TOTAL: 100

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