BUILDING AND STRUCTURAL SURVEYING

N6

Building and Structural Surveying

Lecturer Guide

Alfred Ramahlape

Additional resource material for this title includes:

- Electronic Lecturer Guide
- Exemplar examination paper and memorandum
- Past exam papers
- PowerPoint presentation

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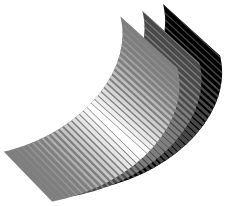

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Dedication

This book is dedicated to my children –

Itumeleng, Matshidiso, Shanah, Milani and Lulibo

CONTENTS

Lecturer guidance

1. General aims

To provide and enhance students with knowledge and skills that are applied in the building industry and to develop students' ability to solve complex problems and adhere to safety standards and procedures.

2. Specific aims

2.1 The student should acquire a systematic understanding of practice, theory and methodology in the building and structural surveying field.

2.1 The teaching of this subject is aimed to develop knowledge, professional and general competencies in:

- surveying
- building construction

3. Prerequisites

Students must have completed a National N5 Certificate with Building and Structural Surveying.

4. Duration

Full-time: 7,5 hours per week. This instructional offering may also be offered part-time or in distance-learning mode.

5. Evaluation

5.1 ICASS trimester mark

Evaluation is conducted continuously by means of two formal tests at College level. Learner must obtain a minimum ICASS mark of at least 40% in order to qualify to write the final examination and a mark will be calculated together in a ratio of 40:60 to derive the promotion mark. The learner must obtain at least 40% on the final examination.

The promotion mark will be calculated as follows:
Promotion mark = 40% of (ICASS mark) + 60% of (examination mark)

5.2 Examination

The examination in N6 Building and Structural Surveying (Engineering Studies - Report 191) will be conducted as follows:

Modules 1 to 6: Marks: 100
Duration: 3 hours

Closed book exam
- The formula sheet is attached to the question paper.
- Scientific calculators are allowed.
- No programmable calculators are allowed.
- No references are allowed.
- No external examination papers or memoranda are allowed.

5.3 Weighting

The following weights are consequently awarded to each category:

Knowledge and understanding	Application	Analysis, synthesis and evaluation
10–20%	40–60%	30–40%

6. Learning content

Theoretical background

It is essential that this subject should be illustrated and evaluated within the context of practical case studies.

Technical background

it is essential that this subject should be illustrated and evaluated within the context of technical skills and simulation of practical environment.

7. Mark allocation and weighted values of modules

Mark allocation in the examination as an indication of the weighting of the different modules:

Modules	Weighting (%)
1. Angular measurement	10
2. Traversing	20
3. Tacheometry	15
4. Contouring	20
5. Setting out	10
6. Road construction	25
Total	**100**

8. Work schedule

Week	Topic	Content	Exercises	Hours
1–2	**Module 1** Angular measurement	1.1 Theodolites 1.2 Measuring horizontal angles 1.3 Measuring vertical angles	Exercise 1.1 Exercise 1.2 Practical pair activity 1.1 Exercise 1.3 Practical pair activity 1.1 Exercise 1.4 Exercise 1.5 Summative assessment	10 hours
3–4	**Module 2** Traversing	2.1 Basic traversing concepts 2.2 Traverse computations 2.3 Plotting 2.4 Computing areas using coordinates	Exercise 2.1 Exercise 2.2 Exercise 2.3 Exercise 2.4 Exercise 2.5 Practical group activity 2.1 Exercise 2.6 Practical group activity 2.2 Exercise 2.7 Summative assessment	20 hours
5–6	**Module 3** Tacheometry	3.1 Basic concepts of tacheometric surveying 3.2 Tacheometric computation 3.3 Field procedures 3.4 Errors in tangential tacheometry	Exercise 3.1 Exercise 3.2 Exercise 3.3 Practical group activity 3.1 Summative assessment	15 hours
7	**Module 4** Contouring	4.1 Contouring definitions 4.2 Purposes of contouring 4.3 Plotting ground sections from contour drawings 4.4 Volume and area calculations 4.5 Use of contour maps	Exercise 4.1 Practical group activity 4.1 Exercise 4.2 Exercise 4.3 Exercise 4.4 Summative assessment	20 hours

Week	Topic	Content	Exercises	Hours
8–9	**Module 5** Setting out	5.1 Setting-out definitions 5.2 Setting-out procedures 5.3 Checking verticality	Practical pair activity 5.1 Practical group activity 5.2 Exercise 5.1 Summative assessment	10 hours
9–10	**Module 6** Road construction	6.1 Road construction setting out 6.2 Circular curves 6.3 Setting out horizontal circular curves 6.4 Cuttings and embankments 6.5 Plotting cutting and embankment lines from contours 6.6 Longitudinal and cross-sections	Exercise 6.1 Practical group activity 6.1 Practical group activity 6.2 Exercise 6.2 Exercise 6.3 Exercise 6.4 Exercise 6.5 Exercise 6.6 Summative assessment	25 hours
TOTAL				**100 hours**

9. Lesson plan template

LESSON	Content/Outcomes to be covered this week	List of examples to be done in class by the lecturer to explain the outcme/ concept	Facilitation method (Please tick)		Teaching resources/ aids (Please tick)		Student activity (exercise in textbook/additional supporting task) to be done this week
WEEK 1			Lecture		White board/ OHP		
			Group work		Models		
			Demonstration		Handouts		
			Simulation		Multimedia		
			Introduction to lessons				
			Recapping/Reinforcement				

LESSON	Content/Outcomes to be covered this week	List of examples to be done in class by the lecturer to explain the outcome/ concept	Facilitation method (Please tick)		Teaching resources/ aids (Please tick)		Student activity (exercise in textbook/additional supporting task) to be done this week
WEEK 2			Lecture		White board/ OHP		
			Group work		Models		
			Demonstration		Handouts		
			Simulation		Multimedia		
			Introduction to lessons				
			Recapping/Reinforcement				

LESSON	Content/Outcomes to be covered this week	List of examples to be done in class by the lecturer to explain the outcome/ concept	Facilitation method (Please tick)		Teaching resources/ aids (Please tick)		Student activity (exercise in textbook/additional supporting task) to be done this week
WEEK 3			Lecture		White board/ OHP		
			Group work		Models		
			Demonstration		Handouts		
			Simulation		Multimedia		
			Introduction to lessons				
			Recapping/Reinforcement				

LESSON	Content/Outcomes to be covered this week	List of examples to be done in class by the lecturer to explain the outcome/ concept	Facilitation method (Please tick)		Teaching resources/ aids (Please tick)		Student activity (exercise in textbook/additional supporting task) to be done this week
WEEK 4			Lecture		White board/ OHP		
			Group work		Models		
			Demonstration		Handouts		
			Simulation		Multimedia		
			Introduction to lessons				
			Recapping/Reinforcement				

<table>
<tr><th>LESSON</th><th>Content/Outcomes to be covered this week</th><th>List of examples to be done in class by the lecturer to explain the outcome/ concept</th><th colspan="2">Facilitation method (Please tick)</th><th colspan="2">Teaching resources/ aids (Please tick)</th><th>Student activity (exercise in textbook/additional supporting task) to be done this week</th></tr>
<tr><td rowspan="8">WEEK 5</td><td rowspan="8"></td><td rowspan="8"></td><td>Lecture</td><td></td><td>White board/ OHP</td><td></td><td rowspan="8"></td></tr>
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LESSON	Content/Outcomes to be covered this week	List of examples to be done in class by the lecturer to explain the outcome/ concept	Facilitation method (Please tick)		Teaching resources/ aids (Please tick)		Student activity (exercise in textbook/additional supporting task) to be done this week
WEEK 6			Lecture		White board/ OHP		
			Group work		Models		
			Demonstration		Handouts		
			Simulation		Multimedia		
			Introduction to lessons				
			Recapping/Reinforcement				

LESSON	Content/Outcomes to be covered this week	List of examples to be done in class by the lecturer to explain the outcome/ concept	Facilitation method (Please tick)		Teaching resources/ aids (Please tick)		Student activity (exercise in textbook/additional supporting task) to be done this week
WEEK 7			Lecture		White board/ OHP		
			Group work		Models		
			Demonstration		Handouts		
			Simulation		Multimedia		
			Introduction to lessons				
			Recapping/Reinforcement				

LESSON	Content/Outcomes to be covered this week	List of examples to be done in class by the lecturer to explain the outcome/ concept	Facilitation method (Please tick)		Teaching resources/ aids (Please tick)		Student activity (exercise in textbook/additional supporting task) to be done this week
WEEK 8			Lecture		White board/ OHP		
			Group work		Models		
			Demonstration		Handouts		
			Simulation		Multimedia		
			Introduction to lessons				
			Recapping/Reinforcement				

LESSON	Content/Outcomes to be covered this week	List of examples to be done in class by the lecturer to explain the outcome/ concept	Facilitation method (Please tick)		Teaching resources/ aids (Please tick)		Student activity (exercise in textbook/additional supporting task) to be done this week
WEEK 9			Lecture		White board/ OHP		
			Group work		Models		
			Demonstration		Handouts		
			Simulation		Multimedia		
			Introduction to lessons				
			Recapping/Reinforcement				

<table>
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<tr><td rowspan="8">WEEK 10</td><td rowspan="8"></td><td rowspan="8"></td><td>Lecture</td><td></td><td>White board/ OHP</td><td></td><td rowspan="8"></td></tr>
<tr><td>Group work</td><td></td><td>Models</td><td></td></tr>
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MODULE

1 *Angular measurement*

After they have completed this module, students should be able to:

- explain the following terms:
  - transit
  - swing
  - face
  - bisection of a target angle
  - angle of direction
  - temporary adjustment to theodolites
  - permanent adjustment to theodolites;
- list the fundamental lines of a theodolite and describe the desired relationship between them;
- describe operational errors and errors due to natural causes when measuring angles;
- record and reduce horizontal angular observations by calculating mean angles (angular-based method);
- record and reduce horizontal angular observation by calculating the mean direction (angular-based method);
- calculate the join (distance and direction) between two or more known points;
- calculate unknown points using distance and direction references;
- describe the measurement of vertical angle
- record and reduce vertical angles; and
- calculate the true horizontal length from the slope distance and the angle of inclination.

Introduction

Angular measurement comprises the measurement of angles in both horizontal and vertical planes. Theodolites are the precision instrument used for these measurements. The horizontal angles measured are used when calculating the length of lines in horizontal planes and when determining the position of points upon the earth's surface. Vertical angles are used for determining the differences in height between various points on the earth's surface.

Exercise 1.1

SB page 5

1. 1.1 *Face* refers to the position of the vertical circle of the instrument to the observer when readings are taken, which is either left or right of the observer.

   1.2 *Swing(ing)* is the process of rotating a turning telescope about the vertical axis in a horizontal plane. It is called 'right swing' when the telescope is turned clockwise and 'left swing' when the telescope is turned anti-clockwise.

2.
- Improper or inaccurate centring of theodolites
- Improper levelling of theodolites
- Use of incorrect tangent screws may cause errors with theodolites
- Theodolites that aren't tightly screwed to tripods may slip
- Inaccurate bisection of sighted point and non-verticality of the ranging rod
- Misreading the Vernier
- Reading the wrong scale
- Recording readings incorrectly

3.
- The axis of the plate level must be perpendicular to the vertical axis.
- The collimation lines should coincide with the optical axis of the telescope and must also be perpendicular to the vertical axis.
- The telescope axis must be parallel to the collimation line.
- The collimation line must be perpendicular to the horizontal axis, and the vertical axis should be zero when the collimation line is horizontal.

4.
- **Setting up:** The operation includes fixing the theodolite to a tripod along with approximate levelling and centring over the station mark.
- **Centring:** It is a process of bringing the vertical axis of the theodolite exactly over the station mark.
- **Levelling:** This is an operation performed to make the vertical axis of the instrument truly vertical.
- **Focusing**: An operation performed to eliminate parallax and to obtain a clear reading.

Exercise 1.2

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1.

Point	CL	CR	Mean angle	Correction	Corrected angle
K	40:14:48	197:18:26			
L	47:41:06	204:44:38			
	7:26:18	**7:26:12**	7:26:15	+00:00:01	7:26:16
L	47:41:06	204:44:38			
M	82:31:22	239:34:54			
	34:50:16	**34:50:16**	34:50:16	+00:00:01	34:50:17
M	82:31:22	239:34:54			
N	301:29:10	98:32:50			
	218:57:48	**218:57:56**	218:57:52	+00:00:01	218:57:53
N	301:29:10	98:32:50			
K	40:14:48	197:18:18			
	98:45:38	**98:45:28**	98:45:33	+00:00:01	98:45:34
			359:59:56	+00:00:04	360:00:00

Q	+ 6 725,81	+ 8 370,59
N	+ 6 916,59	+ 8 721,08
	+ 190,78	+ 350,49

Distance QN = $\sqrt{(\Delta y)^2 + (\Delta x)^2}$

Distance QN = $\sqrt{(190{,}78)^2 + (350{,}49)^2}$

Distance QN = 399,05 m

Direction QN = $\tan^{-1}\left(\frac{\Delta y}{\Delta x}\right)$

Direction QN = $\tan^{-1}\left(\frac{190{,}78}{350{,}49}\right)$

= 28: 33: 38

QN	28: 33: 38
∠NQK	98: 45: 34
QK	127: 19: 12
∠KQL	7: 26: 16
QL	134: 45: 28
∠LQM	34: 50: 17
QM	169: 35: 45
∠MQN	218: 57: 53
QN	28: 33: 38

2.

Point	CL	CR	Mean angle	Correction	Corrected angle
A	315:24:44	135:26:00			
B	120:54:26	300:56:42			
	165:29:42	**165:30:42**	**165:30:12**		
B	120:54:26	300:56:42			
C	192:42: 4	12:43:30			
	71:48:08	**71:46:48**	**71:47:28**		
C	192:42:34	12:43:30			
A	315:24:34	135:26:10			
	122:42:00	**122:42:40**	122:42:20		
			360:00:00		

S – 4 072,78 + 5 229,64 + 4 230,34
B – 4 798,46 + 4 230,34 + 5 229,64
– 725,68 + 999,30

Distance SB = $\sqrt{(\Delta y)^2 + (\Delta x)^2}$

Distance SB = $\sqrt{(725{,}68)^2 + (999{,}30)^2}$

Distance SB = 1 235 m

Direction SB = $\tan^{-1}\left(\frac{\Delta y}{\Delta x}\right)$

Direction SB = $\tan^{-1}\left(\frac{999{,}30}{725{,}68}\right)$

Direction SB = 324: 00: 49

SB 324: 00: 49
∠BSC 71: 47: 28
SC 35: 48: 17
∠CSA 122: 42: 20
SA 158: 30: 37
∠ASB 165: 30: 12
SB 324: 00: 49

3.

Point	CL	CR	Mean angle	Correction	Corrected angle
P	256:46:28	76:45:48			
Q	310:56:14	130:56:24			
	54:09:46	54:10:36	54:10:11	–00:00:06	54:10:05
Q	310:56:14	130:56:24			
R	88:28:10	268:27:34			
	137:31:56	137:31:10	137:31:33	–00:00:06	137:31:27
R	88:28:10	268:27:34			
P	256:28:10	77:04:42			
	168:00:00	168:37:08	168:18:34	–00:00:06	168:18:28
			360:00:18	–00:00:18	360:00:00

M – 1 467,36 + 2 931,21
Q – 1 923,26 + 2 012,48
– 455,90 – 918,78

Distance MQ = $\sqrt{(\Delta y)^2 + (\Delta x)^2}$

Distance MQ = $\sqrt{(445{,}90)^2 + (918{,}78)^2}$

Distance MQ = 1 025,67 m

Direction MQ = $\tan^{-1}\left(\frac{\Delta y}{\Delta x}\right)$

Direction MQ = $\tan^{-1}\left(\frac{455{,}90}{918{,}78}\right)$

Direction MQ = 206: 23: 25

MQ	206: 23 25
∠QMR	137: 31: 27
MR	343: 54: 52
∠RMP	168: 18: 28
MP	152: 13: 20
∠PMQ	54: 10: 05
MQ	206: 23: 25

4.

Point	CL	CR	Mean angle	Correction	Corrected angle
K	236:30:48	56:30:22			
L	98:20:36	278:20:12			
	221:49:48	221:49:50	221:49:49	+00:00:03	221:49:52
L	98:20:36	278:20:12			
M	186:34:40	6:34:10			
	88:14:14	88:13:58	88:14:06	+00:00:03	88:14:09
M	186:34:40	6:34:10			
K	236:30:26	56:30:16			
	49:55:46	49:56:06	49:55:56	+00:00:03	49:55:59
			359:59:51	+00:00:03	360:00:00

B + 1 737,40 – 2 012,16
K + 2 617,14 – 2 597,62
+ 879,74 –585,46

Distance BK = $\sqrt{(\Delta y)^2 + (\Delta x)^2}$

Distance BK = $\sqrt{(879{,}74)^2 + (585{,}46)^2}$

Distance BK = 1 056, m

Direction BK = $\tan^{-1}\left(\frac{\Delta y}{\Delta x}\right) + 90°$

Direction BK = $\tan^{-1}\left(\frac{879{,}74}{585{,}46}\right) + 90°$

Distance BK = 1 056,74 m

BK 123: 38: 36
∠KBL 221: 49: 52
BL 345: 28: 28
∠LBM 88: 14: 09
BM 73: 42: 37
∠MBK 49: 55: 59
BK 123: 38: 36

Practical pair activity 1.1

Encourage students to conduct the following practical activity.

Instructions

Form a survey team consisting of TWO members. One will be the ranging rod holder and the other will operate the theodolite.

Task

- Set up, centre the theodolite over a selected station.
- Peg FOUR stations around the instrument station.
- Measure the horizontal angles of the peg stations using circle left and circle right.
- Book and calculate the correct angle formed by the legs from the instrument station.

Exercise 1.3

SB page 19

1.

FIELD-BOOK PAGE Observation at P					
Point	**CL**	**CR**	**Mean direction**	**Correction**	**Corrected direction**
A	256:46:28	76:45:48	256:46:08		256:46:08
B	310:56:14	130:56:24	310:56:19	+00:00:06	310:56:25
C	88:28:10	268:27:34	88:27:52	+00:00:12	88:28:04
A	256:46:12	76:45:28	256:45:50	+00:00:18	256:46:08

JOIN				
S	–1 368,36	+2 829,31		197:31:01
B	–1 624,26	+2 018,53		850,21 m
	–255,90	–810,78		
S			–1 368,36	+2 829,31
197:31:01	–0,300987835	–0,953627979		
850,21 m			–255,90	–810,78
B			–1 624,26	+2 018,53

DIRECTION SHEET				
Point	**Corrected direction**	**Oriented direction**	**Correction**	**Join direction**
A	256:46:08	143:20:44		
B	310:56:25		–113:25:24	197:31:01
C	88:28:04	335:02:40		

2.

FIELD BOOK PAGE Observation at P					
Point	**CL**	**CR**	**Mean direction**	**Correction**	**Corrected direction**
K	50:20:42	230:22:30	50:21:36		50:21:36
L	102:36:20	282:34:20	102:35:20	+00:00:15	102:35:35
M	190:28:30	10:26:42	190:27:36	+00:00:30	190:28:06
N	300:46:52	120:45:20	300:46:06	+00:00:45	300:46:51
K	50:20:34	230:20:38	50:20:36	+00:01:00	50:21:36

JOIN				
Q1	+3 674,22	+7 828,64		115:53:28
L	+4 256,44	+7 546,04		647,18 m
	+582,22	–282,6		
Q1			+3 674,22	+7 828,64
115:53:28	+0,899625533	–0,436662225		
647,18 m			+582,22	–282,6
L			+4 256,44	+7 546,04

DIRECTION SHEET				
Point	**Corrected direction**	**Oriented direction**	**Correction**	**Join direction**
K	50:21:36	63:39:29		
L	102:35:35		+13:17:53	115:53:28
M	190:28:06	203:45:59		
N	300:46:51	314:04:44		

3.

FIELD BOOK PAGE Observation at P					
Point	**CL**	**CR**	**Mean direction**	**Correction**	**Corrected direction**
P	68:30:24	248:31:36	68:31:00		68:31:00
Q	126:28:54	306:29:10	126:29:02	–00:00:18	126:28:44
R	200:42:28	20:42:48	200:42:38	–00:00:36	200:42:02
S	342:52:40	162:53:24	342:53:02	–00:00:54	342:53:02
P	68:32:24	248:32:00	68:32:12	–00:01:12	68:31:00

JOIN				
A	+2 593,48	+5 662,56		302:36:20
Q	+1 911,12	+6 099,04		810,02 m
	–682,36	+436,48		
A			+2 593,48	+5 662,56
302:36:20	–0,842400152	+0,538852469		
810,02 m			–682,36	+436,48
Q			+1 911,12	+6 099,04

DIRECTION SHEET				
Point	**Corrected direction**	**Oriented direction**	**Correction**	**Join direction**
P	68:31:00	244:38:36		
Q	126:28:44		+176:07:36	302:36:20
R	200:42:02	16:49:38		
S	342:53:02	285:29:22		

4.

P	–432,64	+3 272,38		111:48;09
Q	+ 346,82	+2 960,50		839,54
	+779,46	–311,88		
P			–432,64	+3 272,38
111:48;09	+0,928469622	–0,371408348		
839,54			+779,46	–311,88
Q			+346,82	+2 960,50

Practical pair activity 1.2

Encourage students to conduct the following practical activity.

Instructions

For a survey team consisting of TWO members. One will be the ranging rod holder and the other will operate the theodolite.

Task

- Set up, centre the theodolite over a selected station.
- Peg FOUR stations around the instrument station.
- Measure the horizontal direction to the pegged stations using circle left and circle right (the instrument need not be oriented to the zero of the SA coordinate system).
- Book and calculate the correct direction from the instrument station to each pegged station.

Exercise 1.4

SB page 24

1. 1.1 The *depression angle* is an angle formed between the horizontal and the line of sight that is below the horizontal.
   1.2 The *elevation angle* is an angle formed between the horizontal and the line of sight above the horizontal.
   1.3 A *zenith distance* is an angle measured in a vertical plane downward from the zenith to the observed object.

2.

Station	Circle left	Circle right	Angle circle left	Angle circle right	Mean angle
M1	86:26:35	273:22:49	+3:33:25	+3:22:49	+03:28:07
M2	94:31:22	265:27:28	–04:31:22	–04:32:32	–04:31:57

3.

Station	Circle left	Circle right	Angle circle left	Angle circle right	Mean angle
D1	119:36:28	240:25:12	–29:36:28	–29:34:48	–29:35:38
D2	88:54:32	271:06:26	+01:05:28	+01:06:36	+01:06:02
D3	82:06:56	277:54:28	+07:53:04	+07:54:28	+07:53:46

4.

Station	Circle left	Circle right	Angle circle left	Angle circle right	Mean angle
T1	82:46:26	277:14:24			
T2	118:42:36	241:15:32			
T3	132:18:18	227:39:52			

Exercise 1.5

SB page 26

1. True horizontal distance = H cos θ
   = 78,23 cos 15:35:26
   = 77,86 m

2. AB = H cos θ
   = 95,72 cos 25:00:12
   = 86,74 m

   BC = H cos θ
   = 78,68 cos 18:35:16
   = 74,58 m

   AC = 86,74 + 74,58
   = 161,32 m

3. LH = H cos θ
   = 97,48 cos 30:02:05
   = 84,39 m

   LM = H cos θ
   = 77,98 cos 38:15:00
   = 61,24 m

   MN = 84,39 – 61,24
   = 23,15 m

4. PQ = H cos θ
   = 102,55 cos 16:48:20
   = 98,17 m
   QR = H cos θ
   = 75,96 cos 27:34:12
   = 67,34 m

Summative assessment: Module 1 SB page 27

1.1 D
1.2 E
1.3 B
1.4 A
1.5 C (5 × 1)(5)

2. *Permanent adjustment* refers to procedures done to establish a fixed relationship between the instrument's fundamental lines or axis of a transit, which are important for the accuracy of observations taken with the instrument. (3)

3.
- Vibration of the theodolite caused by the wind and storms
- Irregular refraction caused by high temperatures
- Intense direct sunlight may cause differential expansion of the instrument's components. (3 × 2) (6)

4.

Point	CL	CR	Mean direction	Correction	Corrected direction
T1	38:24:45	218:22:47	38:23:46		38:23:46
T2	164:36:15	344:35:19	164:35:47	–00:00:06	164:35:41
T3	210:54:26	30:50:32	210:52:29	–00:00:12	210:52:17
T4	353:12:36	173:14:42	353:13:39	–00:00:18	353:13:21
T1	38:24:40	218:23:40	38:24:10	–00:00:24	38:23:46

JOIN				
T	+432,64	+3 272,38		248:11;33
T3	–346,82	+2 960,50		839,54
	–779,46	–311,88		
T			+432,64	+3 272,38
248:11;33	–0,928437207	–0,371489370		
839,54			–779,46	–311,88
T3			–346,82	+2 960,50

DIRECTION SHEET				
Point	**Corrected direction**	**Oriented direction**	**Correction**	**Join direction**
T1	38:23:46	75:43:02		
T2	164:35:41	201:54:57		
T3	210:52:17		+37:19:16	248:11:33
T4	353:13:21	30:32:37		

(13)

5. True horizontal distance = H cos θ
= 88,76 cos 10:44:31
= 87,20 m (3)

Total: 30 marks

MODULE

2 *Traversing*

After they have completed this module, students should be able to:

- explain the following terminology:
  - traversing
  - open traverses
  - closed link traverses
  - closed loop traverses;
- explain the following types of traverses:
  - theodolite traversing
  - compass traversing
  - tacheometric traversing;
- calculate open- and closed traverses;
- calculate the orientation of direction from observed angles (whole circle bearing and quadrant bearing);
- explain the calculation of the theodolite traverse;
- calculate closed loop traverses using the Bowditch rule for corrections;
- plot a traverse survey to scale using coordinates;
- plot a compass traverse to scale with corrections done graphically using the Bowditch rule;
- explain the preparation and use of the following plotting materials:
  - cartridge paper
  - linen
  - tracing film; and
- calculate the area inside a closed loop traverse using coordinates.

Introduction

Traversing involves conducting a survey in which the lengths and directions of a series of straight lines are measured. The points along the traverse are known as stations and the lines joining the points (distances between) are known as legs.

Exercise 2.1

SB page 37

1.

At Q		At R		At S	
P	238:12:45	Q	158:00:40	R	268:12:56
R	56:13:05	S	222:40:14	T	146:29:38
	178:00:20		64:39:34		238:16:22

PQ	237:50:32
QP	57:50:32
PQR	178:00:20
QR	235:50:52

RQ	55:50:52
QRS	64:39:34
RS	120:30:26

SR	300:30:26
RST	238:16:22
ST	178:46:48

2.

At K		At L		At M	
J	03:37:18	K	281:29:18	L	00:48:22
L	190:29:17	M	15:38:40	N	189:39:18
	186:51:59		94:08:46		188:50:56

KJ	164:27:30
JKL	186:51:59
KL	351:19:29

LK	171:19:29
KLM	94:08:46
LM	265:28:15

ML	85:28:15
LMN	188:50:56
MN	274:19:11

3.

At B		**At C**		**At D**		**At E**	
A	204:10:32	B	94:33:22	C	130:45:24	D	192:15:26
C	318:22:10	D	157:28:16	E	08:28:18	F	358:48:30
	114:11:38		62:54:54		257:42:54		166:33:04

BA	338:24:32
ABC	114:11:38
BC	92:36:10

CB	272:36:10
BCD	62:54:54
CD	335:31:04

DC	155:31:04
CDE	237:42:54
DE	33:13:58

ED	213:13:58
DEF	166:33:04
EF	19:47:47

4.

At P2		**At P3**		**At P4**		**At P5**	
P1	95:14:32	P2	128:37:16	P3	86:53:58	P4	122:35:26
P3	255:30:27	P4	54:49:13	P5	223:24:17	P6	208:54:02
	160:15:55		286:11:57		136:30:19		86:18:06

P1-P2	215:40:25
P2-P1	35:40:25
P1-P2-P3	160:15:55
P2-P3	195:56:20

P3-P2	15:56:20
P2-P3-P4	286:11:57
P3-P4	302:08:17

P4-P3	122:08:17
P3-P4-P5	136:30:19
P4-P5	258:38:36

P5-P4	78:38:36
P4-P5-P6	86:18:06
P5-P6	164:56:42

5.

At S2		At S3		At S4	
S1	320:24:12	S2	278:39:28		86:46:15
S3	102:54:34	S4	129:36:24		167:18:23
	142:30:22		210:56:56		80:32:08

S1-S2	43:22:35
S2-S1	223:22:35
S1-S2-S3	142:30:22
S2-S3	05:52:57

S3-S2	185:52:57
S2-S3-S4	210:56:56
S3-S4	36:49:53

S4-S3	216:49:53
S3-S4-S5	80:32:08
S4-S5	297:22:01

6.

At R		At S		At T	
Q	187:39:40	R	327:21:09	S	284:09:08
S	260:25:14	T	75:43:46	U	166:20:00
	72:45:34		108:22:37		242:10:52

RQ	231:02:46
QRS	72:45:34
RS	303:48:20

SR	123:48:20
RST	108:22:37
ST	232:10:57

TS	52:10:57
STU	242:10:52
TU	294:21:49

Exercise 2.2

SB page 40

1.	BA	56:12:50		
	ABC	106:40:44		
	BC	162:53:34	+ 00:05:08	162:58:42
	CB	342:53:34		
	BCD	280:02:30		
	CD	262:56:04	+ 00:10:16	263:06:20
	DC	82:56:04		
	CDE	108:20:30		
	DE	191:16:34	+ 00:15:24	191:31:58
	ED	11:16:34		
	DEF	230:24:34		
	EF	241:41:08	+ 00:20:32	242:01:40
	EF	61:41:08		
	EFG	114:52:32		
	FG	176:33:40	+ 00:25:40	176:59:20
2.	PQ	30:15:25		
	QP	210:15:25		
	PQR	250:45:16		
	QR	101:00:41	+ 00:00:05	101:00:46
	RQ	281:00:41		
	QRS	69:54:30		
	RS	350:55:11	+ 00:00:10	350:55:21
	SR	170:55:11		
	RST	15:30:22		
	ST	186:25:33	+ 00:00:15	186:25:48
	TS	06:25:33		
	STU	145:41:25		
	TU	152:06:58	+ 00:00:20	152:07:18
	UT	332:06:58		
	TUV	115:10:18		
	UV	87:17:16	+ 00:00:25	87:17:41

	VU	267:17:16		
	UVW	36:48:29		
	VW	304:05:45	+ 00:00:30	304:06:15
3.	AB	300:14:26		
	BA	120:14:26		
	ABC	71:05:47		
	BC	191:20:13	– 00:01:13	191:19:00
	CB	11:20:13		
	BCD	239:35:14		
	CD	250:55:27	– 00:02:26	250:53:01
	DC	70:55:27		
	CDE	229:23:52		
	DE	300:19:19	– 00:03:39	300:15:40
	ED	120:19:19		
	DEF	258:51:43		
	EF	19:11:02	– 00:04:52	19:06:10
4.	DE	123:52:42		
	ED	303:52:42		
	DEF	250:45:16		
	EF	194:37:58	– 00:03:18	194:34:40
	FE	14:37:58		
	EFG	69:54:30		
	FG	84:32:28	– 00:06:36	84:25:52
	GF	264:32:28		
	FGH	15:30:22		
	GH	280:02:50	– 00:09:54	279:52:56
	HG	100:02:50		
	GHI	145:41:25		
	HI	245:44:15	– 00:13:12	245:31:03

Exercise 2.3

SB page 55

1.

Name	Join	ΔY	ΔX	Name	Y	X
P1					–4 690,00	–4,280,00
169:20:20		+39,77	–211,29			
215,00 m		+1,14	+92,58			
P2				P2	–4 649,16	–4 398,71
249:10:40		–169,09	–64,30			
180,90 m		+0,95	+77,90			
P3				P3	–4 817,30	–4 385,11
315:40:49		–139,73	+143,09			
200,00 m		+1,06	+86,13			
P4				P4	–4 955,89	–4 155,89
595,90		–269,05	–132,50		–265,89	+124,11
		–265,89	+124,11			
		+3,16	+256,61			

$\frac{+\ 3{,}16}{595{,}90} \times \text{leg}$ $\frac{+\ 256{,}61}{595{,}90} \times \text{leg}$

2.

Name	Join	ΔY	ΔX	Name	Y	X
R					+110,50	+2 980,64
121:22:54		+287,70	–173,49			
337,00 m		–0,36	–0,41			
S				P2	+397,84	+2 804,74
170:21:29		+74,47	–438,32			
444,60 m		–0,47	–0,54			
T				P3	+471,84	+2 365,88
226:03:00		–228,71	–220,48			
317,68 m		–0,34	–0,39			

Name	Join	ΔY	ΔX	Name	Y	X
U				U	+242,79	+2 145,01
258:31:05		–363,09	–73,75			
370,50 m		–0,39	–0,45			
V				P4	–120,68	+2 070,80
1 469,78		–229,63	–908,04		–231,18	–909,84
		–231,18	–909,84			
		–1,55	–1,80			

$$\frac{+1{,}55}{1\,469{,}78} \times \text{leg} \qquad \frac{-1{,}80}{1\,469{,}78} \times \text{leg}$$

3.

Name	Join	ΔY	ΔX	Name	Y	X
J				J	–2 335,24	+5 202,93
174:30:24		+30,66	–318,77			
320,24 m		–19,54	+0,65			
K				K	–2 324,12	+4 884,81
227:10:48		–157,91	–146,38			
215,32 m		–13,14	+0,44			
L				L	–2 602,19	+4 738,87
196:28:40		–88,07	–297,73			
310,48 m		–18,95	+0,63			
M				M	–2 514,12	+4 441,77
310:12:46		–387,82	+325,76			
506,48		–30,91	+1,03			
N				N	–2 935,92	+4 768,57
1 352,52		–518,14	–437,12			
		–600,68	–434,36			
		–82,54	+2,76			

$$\frac{-82{,}54}{1\,352{,}52} \times \text{leg} \qquad \frac{+2{,}76}{1\,469{,}78} \times \text{leg}$$

4.

Name	Join	ΔY	ΔX	Name	Y	X
A					–3 690,00	+1 280,00
170:20:20		+36,92	–216,88			
220,00 m		–0,55	+0,32			
B				P2	–3 653,63	+1 063,44
250:10:40		–174,51	–62,90			
185,50 m		–0,46	+0,26			
C				U	–3 828,60	+1 000,80
320:40:50		–126,29	+154,18			
199,30 m		–0,50	+0,28			
D				P4	–3 955,39	+1 155,28
604,80		–263,88	–125,60		–265,39	–124,72
		–265,39	–124,72			
		–1,51	+0,88			

$$\frac{-1{,}51}{604{,}8} \times \text{leg} \qquad \frac{+0{,}88}{604{,}8} \times \text{leg}$$

5.

TA	98:21:06		
AT	278:21:06		
TAB	119:13:04		
AB	37:34:10	+ 00:01:05	37:35:15
BA	217:34:10		
ABC	300:16:26		
BC	157:50:36	+ 00:02:10	157:52:46
CB	337:50:36		
BCD	114:15:56		
CD	92:06:32	+ 00:03:15	92:09:47
DC	272:06:32		
CDE	235:43:02		
DE	149:49:34	+ 00:04:20	149:53:54
ED	329:49:34		
DER	127:06:52		
ER	96:56:26	+ 00:05:25	97:01:51

TRAVERSE SHEET						
NAME	**JOIN**	**ΔY**	**ΔX**	**NAME**	**Y**	**X**
A				A	+340,66	+1 510,46
37:35:15		+252,83	+328,46			
414,50 m		+0,98	–4,42			
B				B	+594,47	+1 834,50
157:52:46		+72,10	–177,39			
191,48 m		+0,45	–2,04			
C				C	+667,02	+1 655,07
92:09:47		+106,74	–4,02			
106,82 m		+0,25	–1,14			
D				D	+774,01	+1 649,90
149:53:54		+94,47	–162,97			
188,37		+0,44	–2,01			
E				E	+868,92	1 484,91
901,17		+526,14	–15,93		+528,26	–25,55
		+528,26	–25,55			
		+2,12	–9,62			

$$\frac{+\ 2{,}12}{901{,}17} \times \text{leg} \qquad \frac{-\ 9{,}62}{901{,}17} \times \text{leg}$$

6.1

MP	30:12:40		
PM	210:12:40		
MPQ	212:14:46		
PQ	62:27:26	– 00:01:12	62:26:14
QP	242:27:26		
PQR	61:42:08		
QR	304:09:34	– 00:02:24	304:07:10

RQ	124:09:34		
QRS	239:40:05		
RS	03:49:39	– 00:03:36	03:46:03
SR	183:49:39		
RST	59:02:09		
ST	242:51:48	– 00:04:48	242:47:00
TS	62:51:48		
STU	74:33:22		
TU	137:25:10	– 00:06:00	137:19:10

6.2

TRAVERSE SHEET						
NAME	**JOIN**	**∆Y**	**∆X**	**NAME**	**Y**	**X**
P				P	+115,68	+1 291,56
62:26:14		+188,17	+98,22			
212,26 m		–0,55	–0,69			
Q				Q	+303,30	+1 389,09
304:07:10		–220,42	+153,11			
268,38 m		–0,70	–0,87			
R				R	+82,18	+1 541,33
03:46:03		–+12,42	+188,67			
189,08 m		–0,49	–0,61			
S				S	+94,11	+1 729,39
242:47:00		–108,21	–55,65			
121,68 m		–0,32	–0,40			
T				T	–14,42	+1 673,34
791,40 m		–128,04	+384,35		–130,10	+381,78
		–130,10	+381,78			
		–2,06	–2,57			

$$\frac{-2{,}06}{791{,}40} \times \text{leg} \quad \frac{-2{,}57}{791{,}40} \times \text{leg}$$

Exercise 2.4

SB page 63

1.1 Σ interior angle $= 180(n - 2)$
$= 180(5 - 2)$
$= 540$

NJK	90:33:39	+ 00:00:05	90:33:44
JKL	113:02:01	+ 00:00:05	113:02:06
KLM	131:15:13	+ 00:00:05	131:15:18
LMN	121:10:37	+ 00:00:05	121:10:42
MNJ	83:58:05	+ 00:00:05	83:58:10
	539:59:35	+ 00:00:25	540:00:00

JK	40:22:3
KJ	220:22:38
JKL	113:02:06
K	107:20:32

LK	287:20:32
KLM	131:15:18
LM	156:05:14

ML	336:05:14
LMN	121:10:42
MN	214:54:32

NM	34:54:32
MNJ	83:58:10
NJ	310:56:22

JN	130:56:22
NJK	90:33:44
JK	40:22:38

1.2

TRAVERSE SHEET						
NAME	**JOIN**	**∆Y**	**∆X**	**NAME**	**Y**	**X**
J				J	+298,67	+359,98
40:22:38		+194,35	+228,54			
300,00 m		+5,38	+2,51			
K				K	+498,40	+591,03
107:20:32		+300,20	–93,75			
314,50 m		+5,64	+2,63			
L			–	L	+804,24	+499,91
156:05:14		+95,16	–214,61			
234,76 m		+4,21	+1,96			
M				M	+903,61	+287,26
214:54:32		–205,96	–295,13			
359,89 m		+6,46	+3,01			
N				N	+704,11	–4,86
310:56:22		–415,31	+360,25			
549,78 m		+9,86	+4,59			
J				J	+298,67	+359,98
		–31,56	–14,70		00,00	00,00
		00,00	00,00			
		+31,56	+14 70			

$$\frac{+\ 31{,}56}{1\ 758{,}93} \times \text{leg} \quad \frac{+\ 14{,}70}{1\ 758{,}93} \times \text{leg}$$

2.1 Σ interior angle $= 180(n - 2)$

$= 180(3 - 2)$

$= 180$

$\angle STR = 180 - 26{:}25{:}31 - 29{:}53{:}47$

$= 123{:}53{:}47$

Direction of RS

$\Delta y_{RS} = 4\,328{,}66 - 4\,896{,}26 = -567{,}60$

$\Delta x_{RS} = 3\,844{,}24 - 3\,926{,}82 = -82{,}58$

$$RS = \tan^{-1}\left(\frac{\Delta y}{\Delta x}\right) + 180$$

$$RS = \tan^{-1}\left(\frac{567{,}60}{82{,}58}\right) + 180$$

RS = 261: 43: 20

SR	81:43:20	
RST	29:53:47	
ST	51:49:33	(Subtract angle from backward direction)

TS	231:49:33	
STR	123:40:42	
TR	108:08:51	(Subtract angle from backward direction)

RT	288:08:51	
TRS	26:25:31	
RS	261:43:20	(Subtract angle from backward direction)

2.2

TRAVERSE SHEET						
NAME	**JOIN**	**ΔY**	**ΔX**	**NAME**	**Y**	**X**
S				S	+4 328,66	+3 844,24
51:49:33		+241,14	+189,58			
306,74						
T				T	+4 569,80	+4 033,82
108:08:51		+326,46	–107,00			
343,55						
R				R	+4 896,26	+3 926,82
		+567,60	+82,58		+567,60	+82,58
		+567,60	+82,58			
		0,00	0,00			

3.1

DS	112:10:15
SDE	97:32:58
DE	209:43:13

3.2 Σ interior angle $= 180(n - 2)$
$= 180(5 - 2)$
$= 540$

HDE	87:53:54	– 00:00:15	87:53:39
DEF	22:41:38	– 00:00:15	22:41:23
EFG	224:35:58	– 00:00:15	224:35:43
FGH	72:30:40	– 00:00:15	72:30:25
GHD	132:19:05	– 00:00:15	132:18:50
	540:01:15	– 00:01:15	540:00:00

DE	209:43:13
ED	29:43:13
DEF	22:41:23
EF	07:01:50

FE	187:01:5
EFG	224:35:43
FG	322:26:07

GF	142:26:07
FGH	72:30:25
GH	69:55:42

HG	249:55:42
GHD	182:18:50
HD	117:36:52

DH	297:36:52
HDE	87:53:39
DE	209:43:13

3.3

TRAVERSE SHEET						
NAME	**JOIN**	**ΔY**	**ΔX**	**NAME**	**Y**	**X**
D				D	–398,99	–209,88
209:43:13		–99,15	–173,69			
200,00 m		–51,89	+62,94			
E				E	–550,03	–320,63
07:01:50		+35,19	–285,34			
287,50 m		–76,60	+90,47			
F				F	–591,44	–515,50
322:26:07		–112,76	+146,60			
184,95 m		–47,99	+58,20			
G				G	–752,19	–310,70
69:55:42		+211,21	+77,17			
224,87 m		–58,35	+70,76			
H				H	–599,33	–162,77
117:36:52		+280,46	–146,71			
316,52 m		–82,13	+99,60			
D				D	–398,99	–209,88
1 213,84		+314,95	–381,97		00,00	00,00
		00,00	00,00			
		–314,95	+381,97			

$$\frac{-\ 314{,}95}{1\ 213{,}84} \times \text{leg} \qquad \frac{+\ 381{,}97}{1\ 213{,}84} \times \text{leg}$$

4.1 Σ interior angle $= 180(n - 2)$
$= 180(6 - 2)$
$= 720$

UPQ	101:38:46	– 00:01:02	101:37:44
PQR	110:05:02	– 00:01:02	110:04:00
QRS	147:22:45	– 00:01:02	147:21:43
RST	98:05:48	– 00:01:02	98:04:46
STU	104:30:15	– 00:01:02	104:29:13
TUP	158:23:36	– 00:01:02	158:22:34
	720:06:12	– 00:06:12	720:00:00

PQ	209:43:13
QP	29:43:13
PQR	110:04:00
QR	279:39:13

RQ	99:39:13
QRS	147:21:43
RS	312:17:30

SR	132:17:30
RST	98:04:46
ST	34:12:44

TS	214:12:44
STU	104:29:13
TU	109:43:31

UT	289:43:31
TUP	158:22:34
UP	131:20:57

PU	311:20:57
UPQ	101:37:44
PQ	209:43:13

4.2

TRAVERSE SHEET						
NAME	**JOIN**	**∆Y**	**∆X**	**NAME**	**Y**	**X**
P				P	+306,88	–1 289,23
209:43:13		–99,15	–173,69			
200,00 m		–1,03	+1,72			
Q				Q	+206,70	–1 461,20
279:39:13		–283,43	+48,21			
287,50 m		–1,48	+2,48			
R				R	–78,21	–1 410,51
312:17:30		–136,81	+124,45			
184,95 m		–0,95	+1,59			
S				S	–215,97	–1 284,47
34:12:44		+126,44	+185,96			
224,87 m		–1,16	+1,94			
T				T	–90,69	–1 096,57
109:43:31		+297,95	–106,83			
316,52 m		–1,63	+2,73			
U				U	205,63	–1 200,67
131:20:57		+101,94	–89,72			
135,80 m		–0,70	+1,17			
P				P	+306,88	–1 289,23
1 349,64		+6,94	–11,62		00,00	00,00
		0,00	0,00			
		–6,94	+11,62			

$\frac{-6{,}94}{1\,349{,}64} \times \text{leg}$ $\frac{+11{,}62}{1\,349{,}64} \times \text{leg}$

5.1

TRAVERSE SHEET						
NAME	**JOIN**	**ΔY**	**ΔX**	**NAME**	**Y**	**X**
A				A	–108,73	+402,09
67:52:43		+306,12	+124,44			
330,45 m		–5,08	–2,32			
B				B	+192,31	+524,21
138:22:08		+230,09	–258,87			
346,35 m		–5,33	–2,43			
C				C	+417,07	+262,91
201:09:36		–187,20	–483,63			
518,60 m		–7,98	–3,64			
D				D	+221,89	224,36
253:04:31		–474,42	–144,36			
495,90 m		–7,63	–3,48			
E				E	–260,15	–372,20
1 691,30		–125,41	–762,42		–151,42	–774,29
		–151,42	–774,29			
		–26,01	–11,87			

$$\frac{-26{,}01}{1\,691{,}30} \times \text{leg} \qquad \frac{-11{,}87}{1\,691{,}30} \times \text{leg}$$

5.2 Direction DE = 253:04:31
Direction ED = 73:04:31

$\Delta y_{EA} = -108{,}73 - (-260{,}15) = +151{,}42$
$\Delta x_{EA} = +402{,}09 - (-372{,}20) = +774{,}29$

$$EA = \tan^{-1}\left(\frac{151{,}47}{774{,}29}\right) = 11\text{: }04\text{: }07$$

$\angle DEF = 73\text{: }04\text{: }31 - 11\text{:}04\text{:}07 = 62\text{:}00\text{:}24$

DF = DE sin DEF
DF = 495,90 sin 62:00:24
= 437,88 m

EF = DE cos DEF
EF = 495,90 cos 62:00:24
= 232,76 m

6.

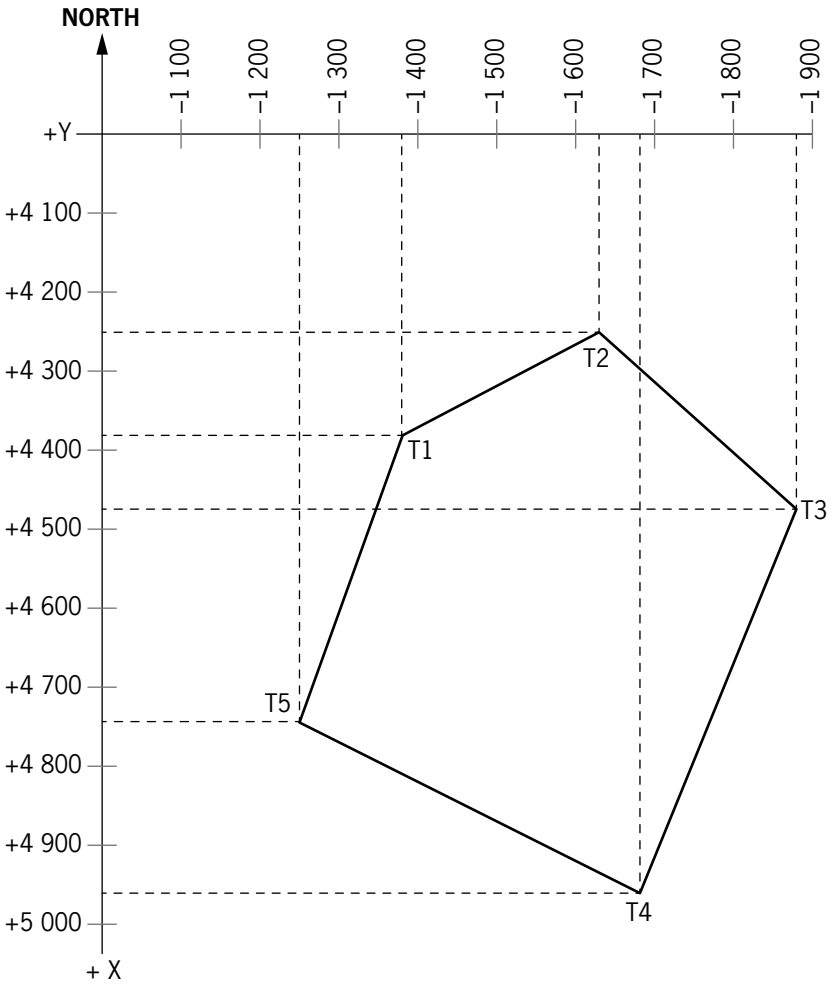
TRAVERSE SHEET						
NAME	**JOIN**	**∆Y**	**∆X**	**NAME**	**Y**	**X**
P1				P1	–152,38	–164,87
248:10:16		–320,48	–128,37			
345,23 m		+8,90	+9,95			
P2				P2	–463,96	–283,29
323:40:55		–292,44	+397,84			
493,76 m		+12,72	+14,23			
P3				P3	–743,68	+128,78
98:02:14		+292,44	–41,29			
295,34 m		+7,61	+8,51			
P4				P4	–443,63	+96,00
44:37:08		+214,76	+217,64			
305,76 m		+7,88	+8,81			
P5				P5	–220,99	+322,45
173:40:42		+55,60	–501,88			
504,95 m		+13,01	+14,55			
P1				P1	–152,38	–164,87
1 945,04		–50,12	–56,06		0,00	0,00
		0,00	0,00			
		+50,12	+56,06			

$$\frac{+\ 50{,}12}{1\ 945{,}04} \times \text{leg} \qquad \frac{+\ 56{,}06}{1\ 945{,}04} \times \text{leg}$$

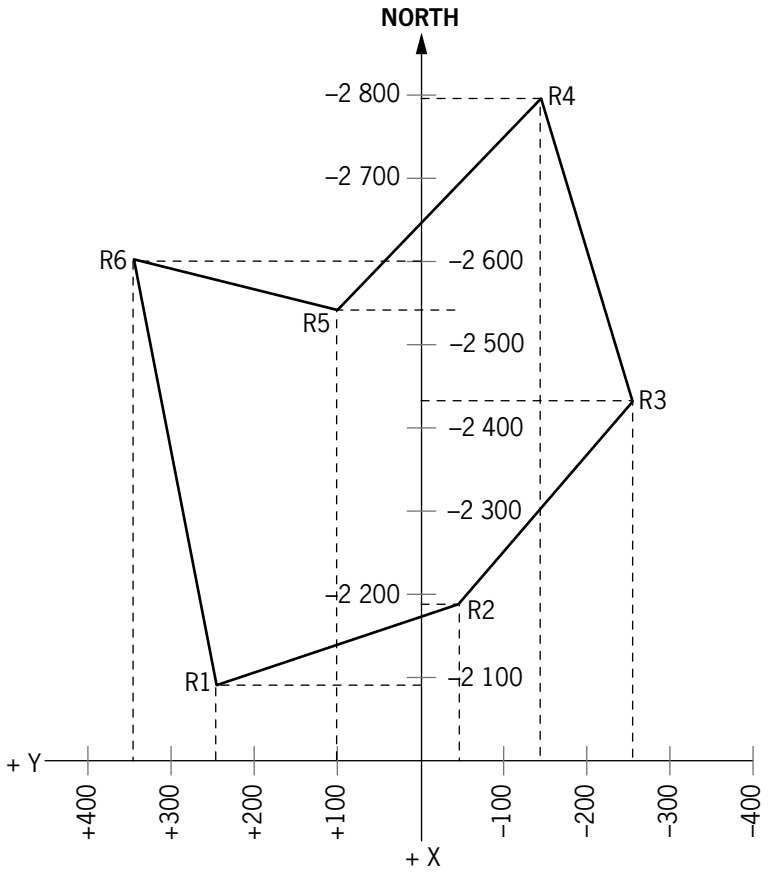
Exercise 2.5

SB page 69

1.



2.



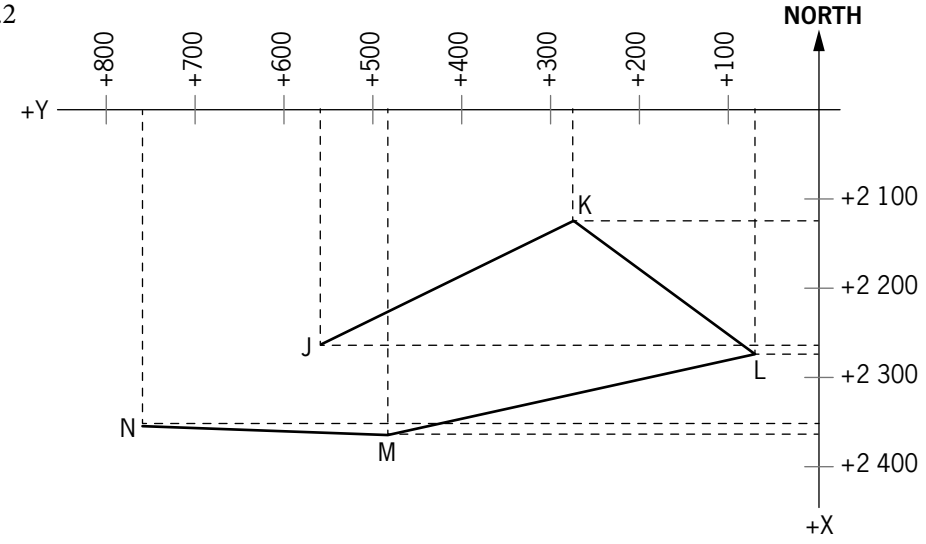
3.1

TRAVERSE SHEET						
NAME	**JOIN**	**∆Y**	**∆X**	**NAME**	**Y**	**X**
J				J	+560,60	+2 264,,48
244:10:30		–287,38	–139,08			
319,27 m		+0,30	–0,23			
K				K	+273,52	+2 125,17
306:12:40		–203,14	+148,74			
251,77 m		+0,24	–0,18			
L				L	+70,62	+2 273,73
77:16:50		+412,32	+93,07			
422,69 m		+0,40	–0,30			

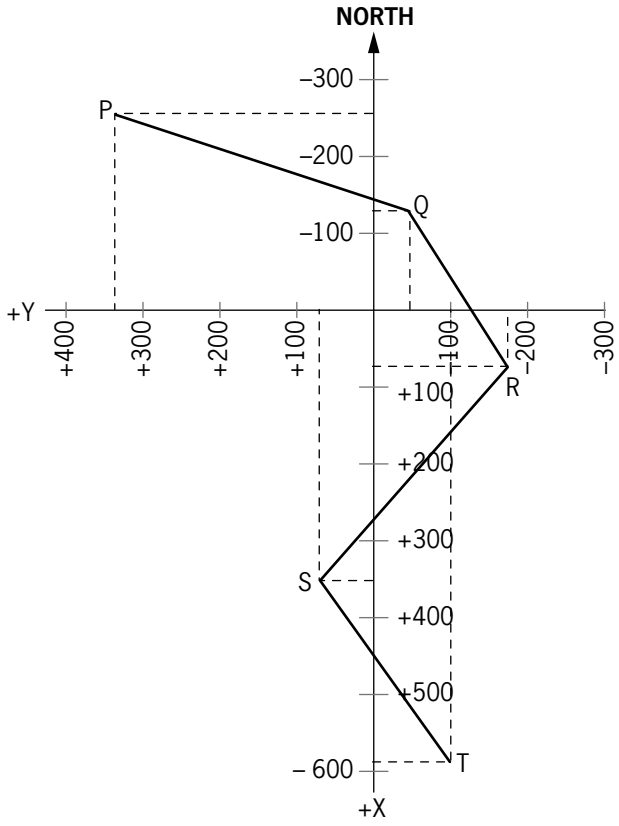
NAME	JOIN	ΔY	ΔX	NAME	Y	X
M				M	+483,34	+2 366,50
92:12:30		+277,49	–10,70			
277,70 m		+0,26	–0,20			
N				N	+761,09	+2 355,61
1 271,43		+199,29	+92,03		+200,49	+91,13
		+200,49	+91,13			
		+1,20	–0,9			

$$\frac{+1{,}20}{1\,271{,}43} \times \text{leg} \qquad \frac{-0{,}9}{1\,271{,}43} \times \text{leg}$$

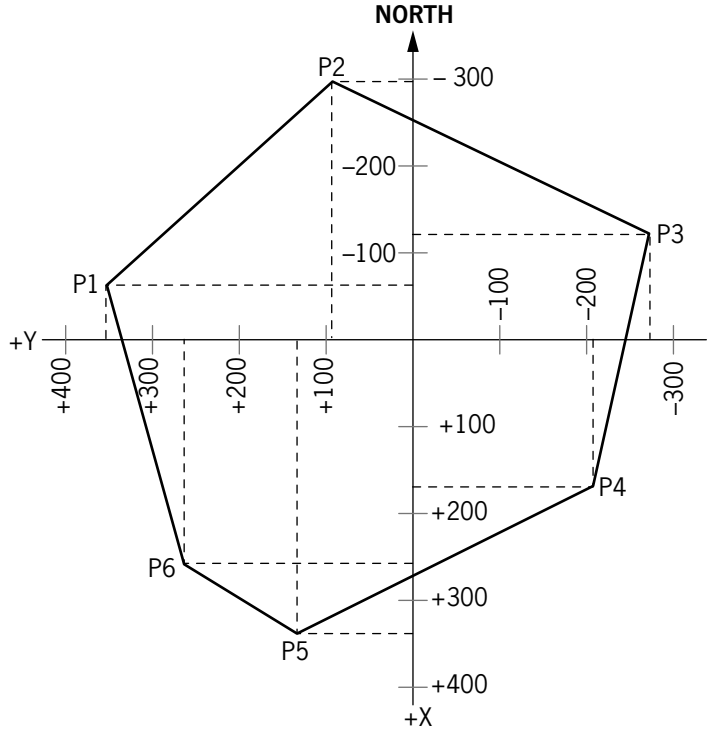
3.2



4.


NORTH
–300
P
–200
Q
–100
+Y
+400
+300
+200
+100
–100
–200
–300
+100
R
+200
+300
S
+400
+500
– 600
T
+X

5.

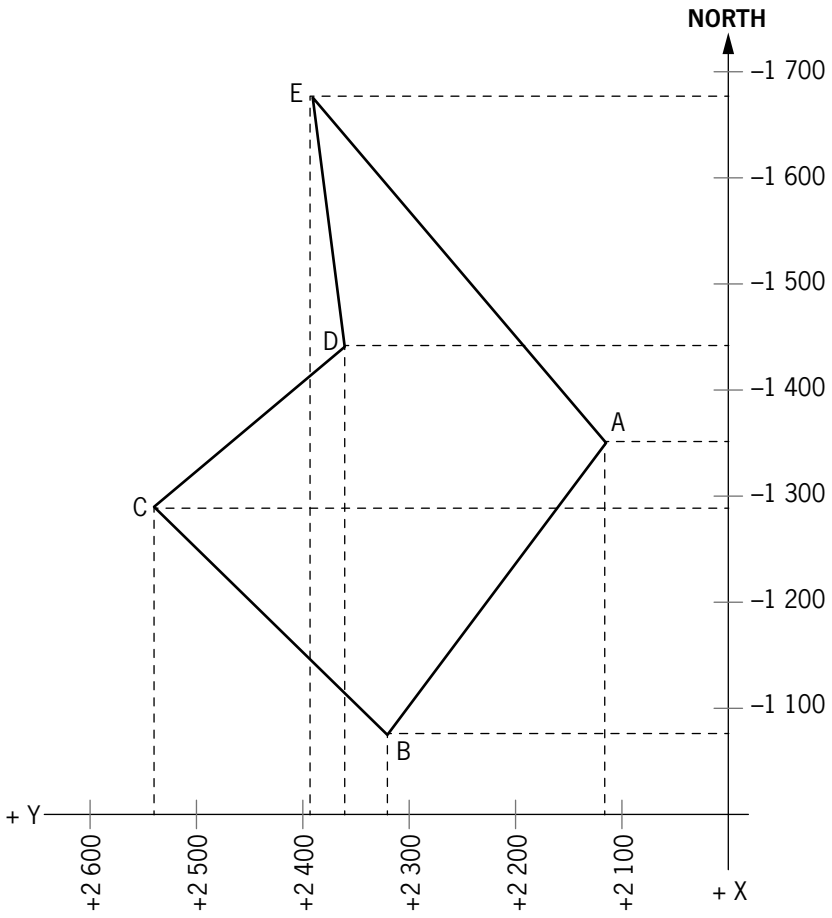

NORTH
P2
– 300
–200
P3
–100
P1
–100
–200
+Y
+400
+300
+200
+100
–300
+100
P4
+200
P6
+300
P5
+400
+X

6.1

TRAVERSE SHEET						
NAME	**JOIN**	**∆Y**	**∆X**	**NAME**	**Y**	**X**
A				A	+2 114,34	–1 349,84
37:50:45		+208,35	+268,15			
339,58 m		–1,39	+4,68			
B				B	+2 321,30	–1 077,01
135:06:20		+219,12	–219,93			
310,46 m		–1,27	+4,28			
C				C	+2 539,15	–1 292,66
229:57:18		–179,90	–151,20			
235,00 m		–0,96	+3,24			
D				D	+2 358,29	–1 440,62
172:35:09		+30,95	–237,83			
239,84 m		–0,98	+3,31			
E				E	+2 388,26	–1 675,14
319:34:17		–272,19	+319,50			
419,73 m		–1,72	+5,79			
A				A	+2 114,34	–1 349,84
1 544,72		+6,33	–21,31		0,00	0,00
		0,00	0,00			
		–6,33	+21,31			

$$\frac{-6{,}33}{1\,544{,}72} \times \text{leg} \qquad \frac{+21{,}31}{1\,544{,}72} \times \text{leg}$$

6.2



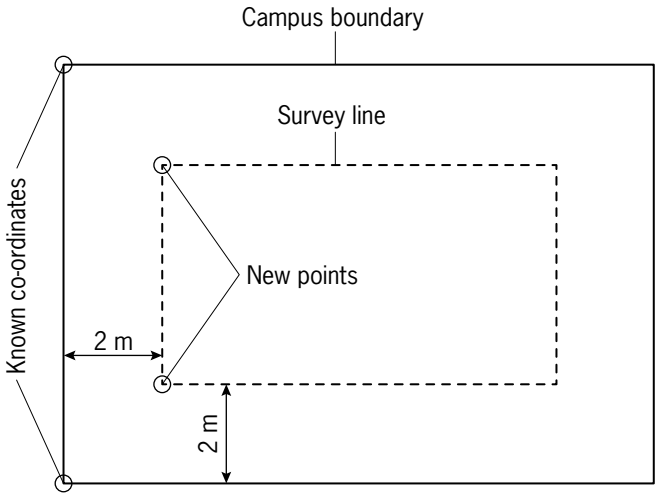
Practical group activity 2.1

Encourage students to conduct the following practical activity.

Instructions

- Form a survey team consisting of THREE members. One will hold the ranging rod, one will operate the theodolite and one will do the chaining or taping.
- Use Google Maps to find the coordinates of two boundary corners of your campus.
- Establish survey points such that the traverse legs are 2 m from the boundary line as shown in the following figure.

Note: The campus field shape may differ and the coordinates from Google Maps will be in kilometres (km).



Task

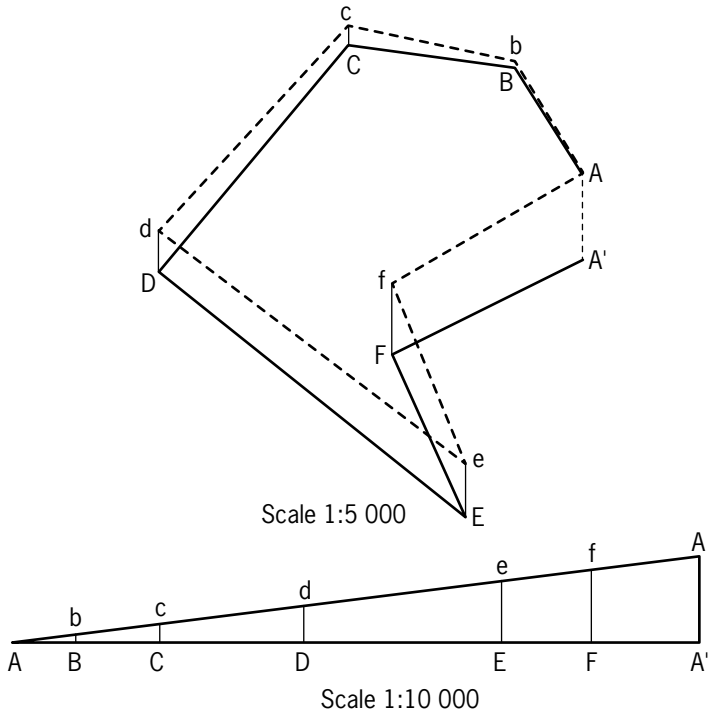
Perform a closed link traverse, between the points closer to the corners with known coordinates by measuring the angle formed by the traverse legs and the distance between the survey points.

1. Determine the coordinates of other survey points.
2. Plot the coordinates.

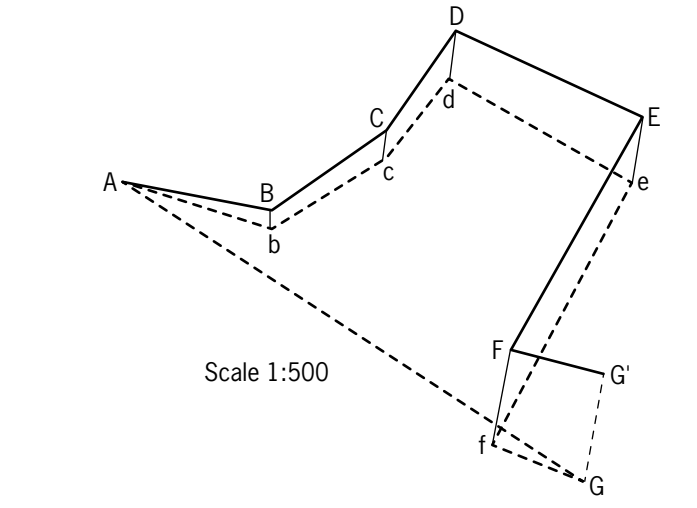
Exercise 2.6

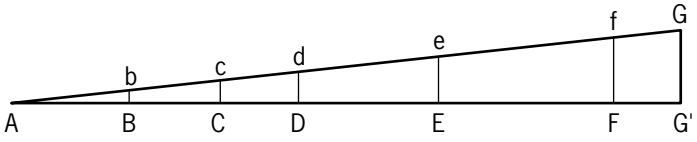
SB page 84

1.



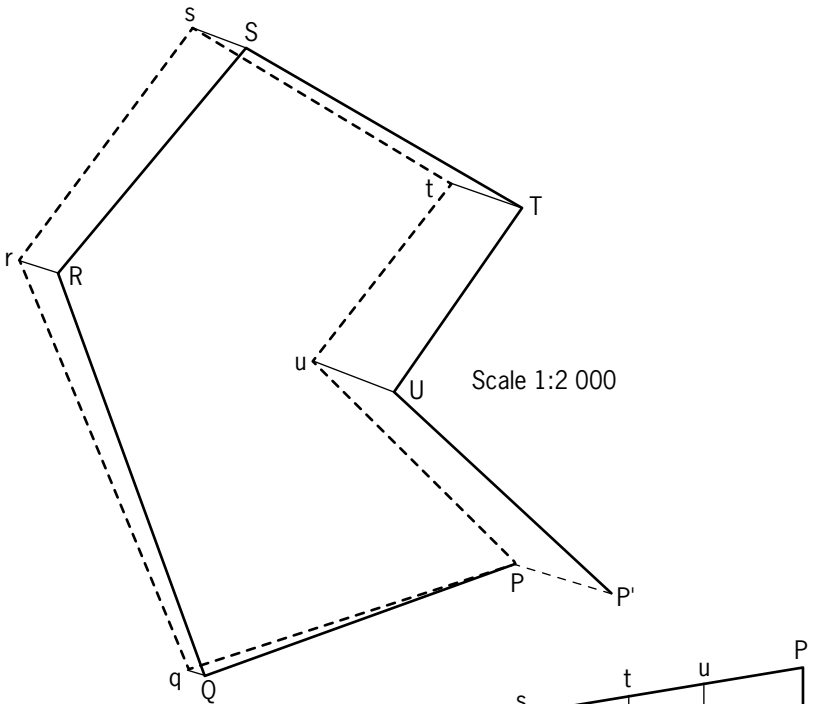
2.

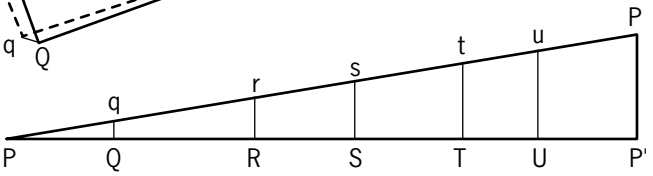




Scale 1:7 500

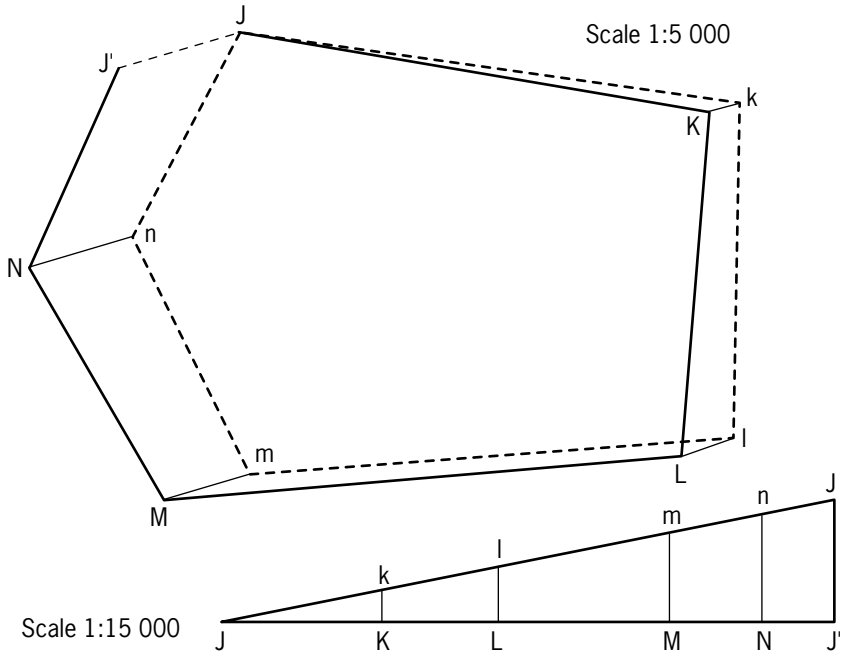
3.



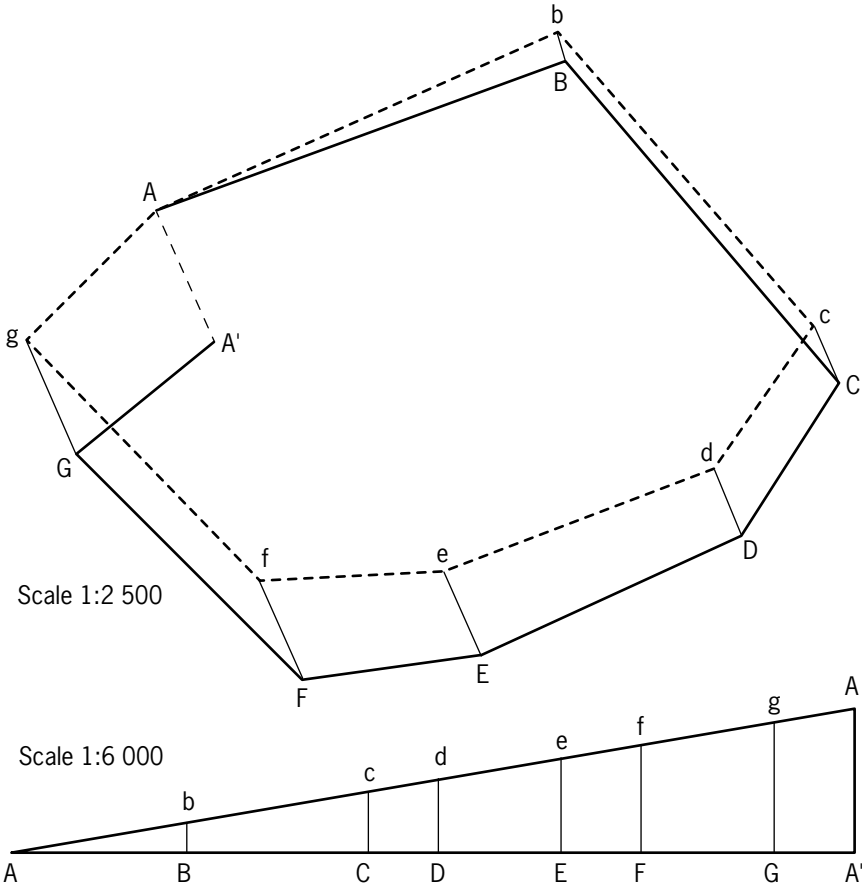


Scale 1:6 000

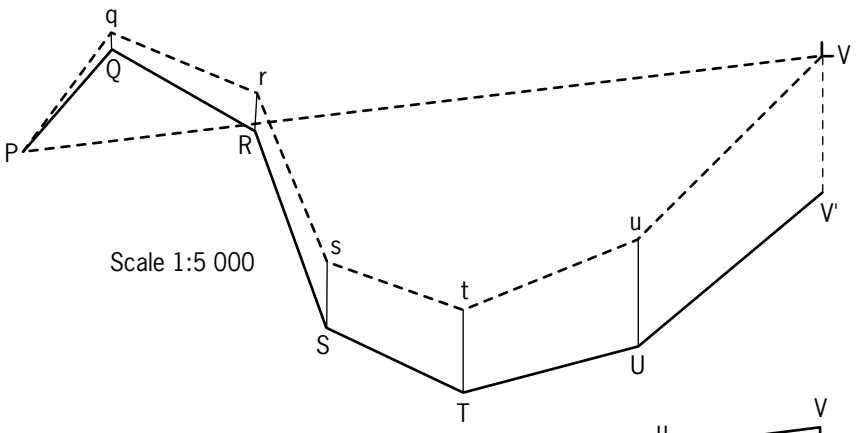
4.

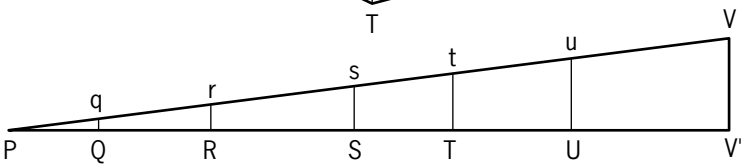

Scale 1:5 000
J
J'
K
k
n
N
m
L
l
M
Scale 1:15 000
J
K
L
M
N
J'
k
l
m
n

5.


b
B
A
A'
g
c
C
G
d
D
f
e
E
F
Scale 1:2 500
Scale 1:6 000
A
B
C
D
E
F
G
A'
b
c
d
e
f
g

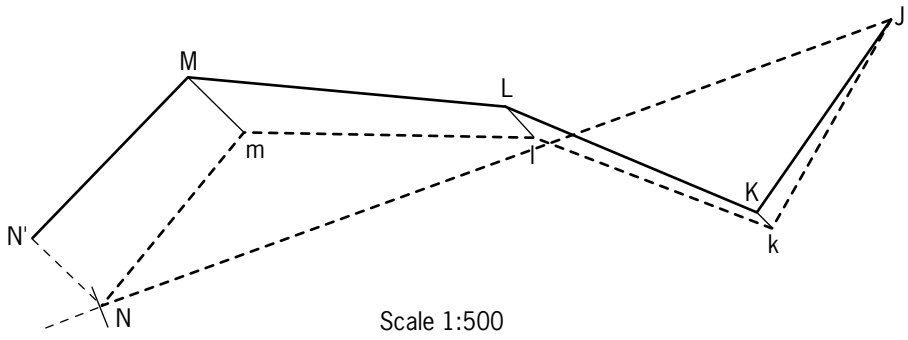
6.



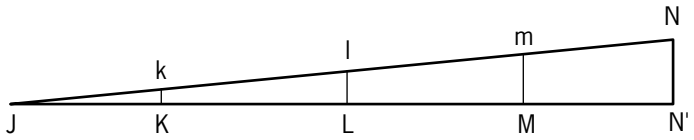


Scale 1:5 000

7.

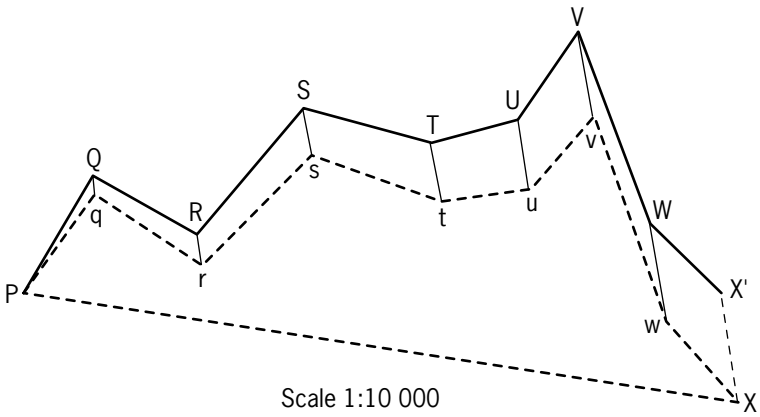


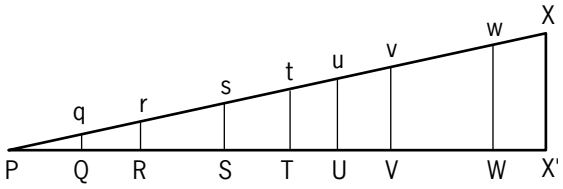
Scale 1:500



Scale 1:7 500

8.





Practical group activity 2.2

Encourage students to conduct the following practical activity.

Instructions

- Form a survey team consisting of THREE members. One will hold the ranging rod, one will operate the compass and one will do the chaining or taping.
- Establish survey points such that the traverse legs are 1,5 m from the boundary line.
- Perform a compass closed-loop traverse by measuring the bearing of the traverse legs and the distance between the survey points.

Task

Each member must record their own observation angles and distances.
Use the data to plot the traverse and if any errors occur, adjustment must be done using the Bowditch graphical method.

Exercise 2.7

SB page 91

1.

Point	Y	X	Y × X	Y × X
P	+378,46	+3 050,00		
Q	+650,50	+3 645,20	+1 379 562,39	+1 984 025,00
R	+127,80	+3 540,68	+2 303 212,34	+465 856,56
S	–210,40	+3 430,75	438 449,85	–744 959,07
T	–287,60	+3 075,56	–647 097,82	–986 683,70
P	+378,46	+3 050,00	–877 180,00	+1 163 976,44
			+2 596 946,76	+1 882 215,23
			–1 882 215,23	

$2 \times \text{area} =$ 714 731,53

Area = 357 365,77 m^2

35,74 ha

2.1

TRAVERSE SHEET						
NAME	JOIN	ΔY	ΔX	NAME	Y	X
A				A	+2 530,60	+1 140,50
149:17:46		+93,95	–158,21			
184,00 m		+0,22	–0,28			
B				B	+2 624,77	+982,01
253:29:12		–447,62	–132,71			
466,88 m		+0,56	–0,70			
C				C	+2 177,71	+848,60
18:41:52		+112,57	+332,63			
351,16 m		+0,42	–0,53			
D				A	+2 290,70	+1 180,70
1 002,04		–241,10	+41,71		–239,90	+40,20
		–239,90	+40,20			
		+1,20	–1,51			

$\frac{+1,20}{1\,002,04} \times \text{leg}$ $\frac{-1,51}{1\,002,04} \times \text{leg}$

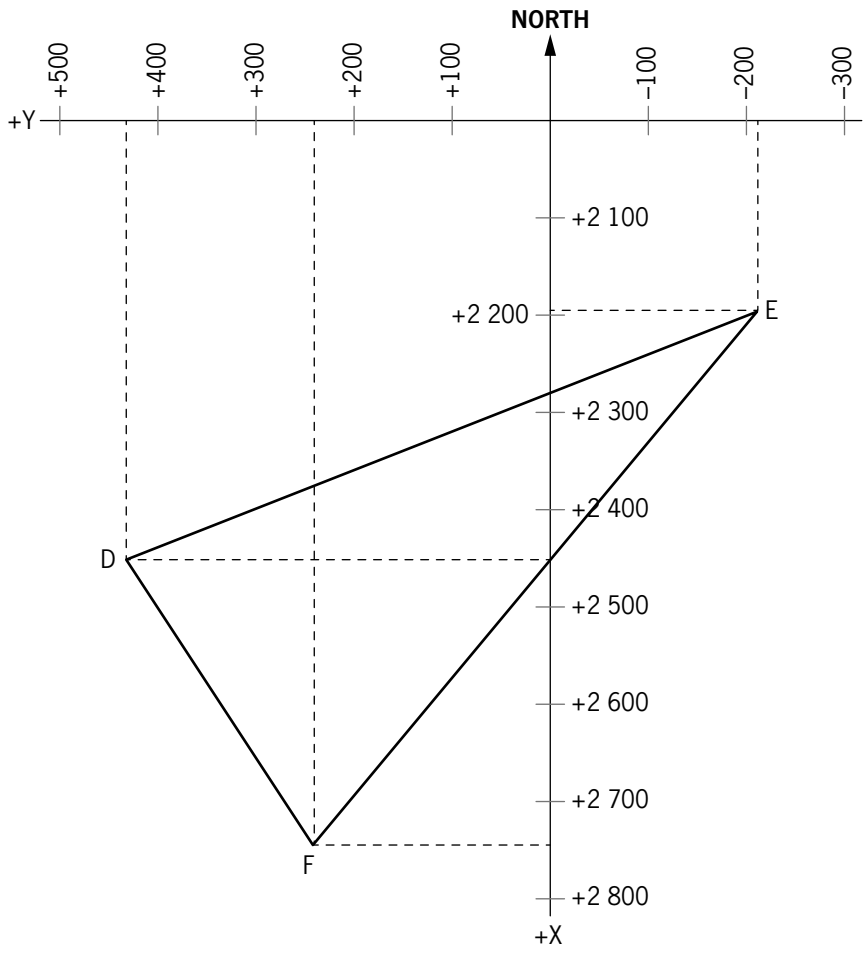
2.2

Point	Y	X	Y × X	Y × X
A	2 530,60	1 140,50		
B	2 624,77	982,01	2 485 074,51	2 993 550,19
C	2 177,71	848,60	2 227 379,82	2 138 533,00
D	2 290,70	1 180,70	2 571 222,20	1 943 888,02
A	2 530,60	1 140,50	2 612 543,35	2 987 879,42
			9 896 219,88	10 063 850,62
				9 896 219,88
			2 × area	167 630,75
			Area	83 815,37 m^2
				8,38 ha

3.1

Point	Y	X	Y × X	Y × X
D	+428,99	+2 450,25		
E	–210,40	+2 197,32	+942 628,31	–515 532,60
F	+238,40	+2 740,00	–576 496,00	+523 841,09
D	+428,99	+2 450,25	+584 139,60	+1 175 432,60
			+950 271,91	+1 183 741,09
				–950 271,91
			2 × area	+233 469,18
			Area	116 734,59
				11,67 ha

3.2



4.

Point	Y	X	Y × X	Y × X
J	–18 334,00	+12 222,46		
K	–18 252,24	+12 350,46	–226 433 333,64	–223 087 273,31
L	–18 538,34	+12 348,88	–225 394 721,49	–228 957 026,64
M	–18 357,18	+12 426,00	–230 357 412,84	–226 690 612,96
N	–18 019,36	+12 360,00	–226 894 744,80	–223 908 567,36
J	–18 334,00	+12 222,46	–220 240 906,83	–226 608 240,00
			–1 129 321 119,60	–1 129 251 720,27
				+1 129 321 119,60
			2 × area	69 399,33
			Area =	34 699,67
				3,47

5.

Point	Y	X	Y × X	Y × X
P	–300,10	+1 190,40		
Q	–164,87	+1 470,18	–441 201,02	–196 261,25
R	+135,08	+1 510,64	–249 059,22	+198 591,91
S	+240,48	+210,35	+28 414,08	+363 278,71
T	+60,00	+1 040,28	+250 166,53	+12 621,00
P	–300,10	+1 190,40	+71 424,00	–312 188,03
			–340 255,62	+66 042,35
				+340 255,62
			2 × area	406 297,97

Summative assessment: Module 2 SB page 93

1. 1.1 Orientation
   1.2 Adding
   1.3 Error
   1.4 Computed
   1.5 Known (5 × 1) (5)

2. 2.1 *Closed link traverses* start from a known point and end at another known point.
   Closed loop traverses start from a known point and end at the same point. (2)
   2.2 *Forward direction* is the direction measured from the preceding station to the succeeding station.
   Backward direction is the direction measured from the succeeding station back to the preceding station. (2)

3. 3.1 A *theodolite traverse* is a method in which the direction of survey lines is measured with a theodolite. (2)
   3.2 A *compass traverse* is a method in which the magnetic bearings of the survey lines are measured with a compass. (2)

4. Σ interior angle = 180(n − 2)
   = 180(6 − 2)
   = 720

P	130:22:45
Q	110:20:35
R	99:36:39
S	116:21:18
T	119:38:20
U	143:40:23
	720:00:00

PU	136:25:12
Angle P	130:22:45
PQ	06:02:27

QP	186:02:27
Angle Q	110:20:35
QR	75:41:52

RQ	255:41:52
Angle R	99:36:39
RS	156:05:13
SR	336:05:13
Angle S	116:21:18
ST	219:43:55
TS	39:43:55
Angle T	119:38:20
TU	280:05:35
UT	100:05:35
Angle U	143:40:23
UP	316:25:12
PU	136:25:12

(10)

5.

TRAVERSE SHEET						
NAME	**JOIN**	**∆Y**	**∆X**	**NAME**	**Y**	**X**
R				S	+4 316,08	+2 132,69
234:27:38		–683,22	–488,05			
839,63		–10,77	+3,27			
P1				P1	+3 622,09	+1 647,91
295:05:16		–962,38	+450,56			
1 062,63		–13,62	+4,14			
P2				P2	+2 646,09	+2 102,61
254:31:43		–769,42	–212,97			
798,35		–10,24	+3,12			
P3				P3	+1 866,43	+1 892,76
268:47:39		–939,14	–19,77			
939,35		–12,04	+3,66			
S				R	+915,25	+1 876,63
3 639,96		–3 354,16	–270,23		–3 400,83	–256,06
		–3 400,83	–256,06			
		–46,67	+14,17			

$$\frac{-46{,}67}{3\,639{,}96} \times \text{leg} \quad \frac{+14{,}17}{3\,639{,}96} \times \text{leg}$$

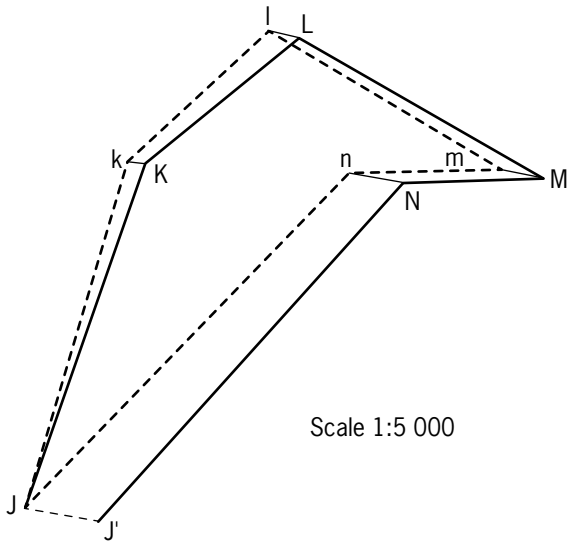
(10)

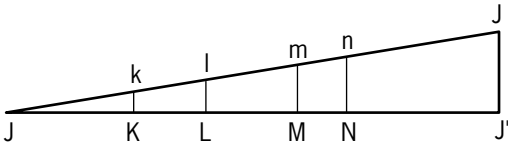
6.

Point	Y	X	Y × X	Y × X
T1	–3 160,00	+ 1 571,06		
T2	–3 218,48	+ 1 236,78	–3 908 224,80	–5 056 425,19
T3	–3 365,86	+ 1 119,06	–3 601 672,23	–4 162 828,33
T4	–3 589,28	+ 1 252,86	–4 216 951,36	–4 016 619,68
T5	–3 458,94	+ 1 264,72	–4 539 434,20	–4 333 567,57
T1	–3 160,00	+ 1 571,06	–5 434 202,28	–3 996 515,20
			–21 700 484,87	–21 565 955,96
				+21 700 484,87
			2 × area	134 528,90
			Area =	67 264,45
				6,73 ha

(10)

7.





Scale 1:5 000

(10)

Total: 53 marks

MODULE

3 *Tacheometry*

After they have completed this module, students should be able to:

- define the term tacheometry;
- explain the purpose of tacheometric surveying;
- state the advantages of tacheometric surveying
- describe the following instruments used for tacheometric surveying:
  - tacheometer
  - stadia rods
- explain the principles of tacheometry;
- explain the following systems of tacheometric measurements:
  - stadia system
  - fixed-hair method
  - moveable hair method
  - tangential method;
- explain the applications of tacheometry;
- record and reduce tachometric readings with a tacheometer and level to determine the reduced level of a survey using the tachometry field book;
- compute the horizontal distance between survey points using the cosine rule;
- explain the six steps and procedures that should be followed when carrying out tachometric surveys;
- discuss four steps that can be used as guidelines for plotting detail surveys;
- explain the following sources of gross errors:
  - wrong readings of the staff
  - wrong readings of the vertical angle
  - wrong bookings; and
- explain the systematic errors that result from the following:
  - non-perpendicularity of the staff
  - differential refraction.

Introduction

Horizontal distances are generally measured by direct methods, but these methods are not always convenient if the ground is undulating, rough, difficult or inaccessible. It is under these circumstances that indirect methods are used to obtain distances, ad tacheometry is one of these indirect methods. It is a method of angular surveying in which the horizontal and vertical positions of a point are determined solely from instrument observation.

Exercise 3.1

SB page 100

1. *Tacheometry* is a system of rapid surveying by which the horizontal and vertical positions of points on the earth's surface relative to one another are determined by optical means.
2. The purpose of tacheometry is to prepare contoured maps and plans requiring the horizontal as well as vertical controls, and to provide a check on surveys of higher accuracy, where distances were measured with a tape.
3. Tacheometer and stadia rod.
4. Tacheometry is applied in the following ways:
   - Preparation of topographic maps that require both the elevation and horizontal distances.
   - Survey work on difficult terrain in which direct methods are inconvenient
   - The recording and filing of details
   - Reconnaissance surveys for highways and railways etc.
   - Hydrographic surveys
   - Checks for distances that have already been measured.
5. With fixed hairs the distance of the stadia hairs from the central hair is permanent; with moveable hairs the distance of the stadia hairs from the central hair can be varied.

Exercise 3.2

SB page 106

1.

Stations		Distances		HI or MH	Angles		HI – MH ±	Height component ±	Height difference ±	RL of point
From	To	Stadia	Hor.		Hor.	Vert.				
B				1,52						552,10
	K	4,97 2,43	250,05	3,70	27:10:15	97:10:00	–2,18	–31,44	–33,62	518,48
	L	5,86 3,14	268,24	4,50	86:28:52	83:15:00	–2,98	+43,58	+40,60	592,70
	M	3,28 2,10	113,68	2,69	190:56:42	101:02:10	–1,17	–22,17	–23,34	528,76
	N	1,92 1,00	91,67	1,46	340:44:44	88:56:30	+0,06	+1,69	+1,75	553,85

2.

Stations		Distances		HI or MH	Angles		HI – MH ±	Height component ±	Height difference ±	RL of point
From	To	Stadia	Hor.		Hor.	Vert.				
R				1,47						435,26
	R1	1,82 0,68	112,02	1,25	110:48:36	97:34:05	+0,22	–14,88	–14,66	420,60
	R2	3,12 2,42	68,78	2,77	136:22:28	82:24:14	–1,30	+9,17	+7,87	443,13
	R3	2,88 1,12	175,06	2,00	242:52:46	85:48:38	–0,53	+12,82	+12,29	447,55
	R4	2,76 1,36	136,76	2,06	292:38:34	98:45:10	–0,59	–21,06	–21,65	413,61

3.

Stations		Distances		HI or MH	Angles		HI – MH ±	Height component ±	Height difference ±	RL of point
From	To	Stadia	Hor.		Hor.	Vert.				
Q				1,50						435,26
	Q1	2,42 1,08	132,21	1,75	300:18:50	96:38:15	–0,25	–15,38	–15,63	419,63
	Q2	1,95 0,65	126,75	1,30	60:46:32	80:54:22	0,20	20,29	20,49	536,56
	Q3	2,20 0,60	155,36	1,40	120:12:18	99:48:15	0,10	–26,85	–26,75	408,51

4.

Stations		Distances		HI or MH	Angles		HI – MH ±	Height component ±	Height difference ±	RL of point
From	To	Stadia	Hor.		Hor.	Vert.				
K				1,46						506,99
	P1	2,90 1,60	127,80	2,25	58:28:36	97:34:05	–0,79	–16,77	–17,56	489,43
	P2	1,96 0,68	127,33	1,32	84:56:12	82:24:14	0,14	9,22	9,36	516,35
	P3	2,14 1,40	71,94	1,77	122:58:00	85:48:38	–0,31	12,18	11,87	495,12
	P4	1,88 0,62	122,28	1,25	198:44:22	98:45:10	0,21	–21,31	–21,10	485,89

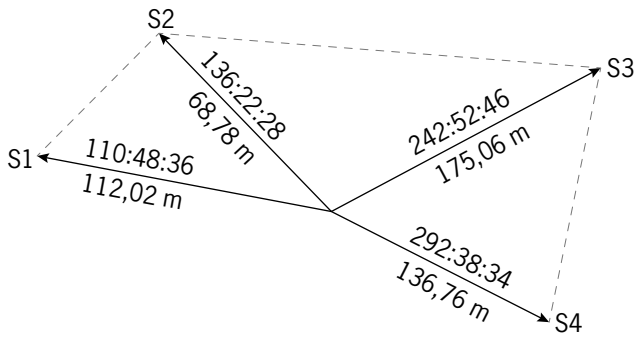
5.

Stations		Distances		HI or MH	Angles		HI – MH ±	Height component ±	Height difference ±	RL of point
From	To	Stadia	Hor.		Hor.	Vert.				
E				1,52						411,72
	E1	3,06 1,50	152,31	2,28	308:32:36	98:50:40	–0,76	–23,70	–24,46	387,26
	E2	2,20 0,96	122,34	1,58	38:24:12	96:38:46	–0,06	–14,26	–14,32	397,40
	E3	1,86 0,80	102,68	1,33	126:44:52	79:48:12	0,19	18,47	18,66	430,38

Exercise 3.3

SB page 111

1.



Angle S1-S-S2 = 136:22:28 – 110:48:36 = 25:33:52

$(S1 - S2)^2 = (112,02) = + (68,78) = -2(112,02)(68,78) \cos 25:33:52$

$S1 - S2 = \sqrt{(3\,378,28)}$

$S1 - S2 = 58,12$ m

Angle S2 – S – S3 = 242:52:46 – 136:22:28 = 106:30:18

$(S2 - S3)^2 = (68,78)^2 + (175,06)^2 - 2\ 68,78\ 175,06 \cos 106:30:18$

$S2 - S3 = 42\,218,15$

$S2 - S3 = 205,47$ m

Angle S3 – S – S4 = 292:38:34 – 242:52:46 = 49:45:48

$(S3 - S4)^2 = (175,06)^2 + (136,76)^2 - 2\ 175,06\ 136,76 \cos 49:45:48$

$S3 - S4 = 18\,419,83$

$S3 - S4 = 135,72$ m

2.1 The table is shown on the next page.

2.2

Station	Mean direction	Oriented direction	Correction	Known direction
L	177:36:42		–72:21:16	105:15:26
M	266:24:30	194:03:14		
N	310:48:22	230:27:06		

$Y_N = Y_K + d_{KL} \sin(WCB_{KL})$

$Y_N = 1\,365,22 + 86,60 \sin 230:27:06$

$Y_N = 1\,298,44$

$Y_N = X_K + d_{KL} \cos(WCB_{KL})$

$Y_N = 2\,162,70 + 86,60 \cos 230:27:06$

$Y_N = 2\,107,56$

3.1

Stations		Distances		HI or MH	Angles		HI – MH ±	Height component ±	Height difference ±	RL of point
From	To	Stadia	Hor.		Hor.	Vert.				
K				1,49						669,27
	L	2,20 0,80	136,67	1,50	177:36:42	98:52:40	–0,01	–21,35	–21,36	647,91
	M	1,80 0,80	97,45	1,30	266:24:30	80:48:36	+0,19	+15,77	+15,96	685,23
	N	2,80 1,90	86,60	2,35	310:48:22	101:12:48	–0,86	–17,77	–18,63	650,64

3.2

Stations		Distances		HI or MH	Angles		HI – MH ±	Height component ±	Height difference ±	RL of point
From	To	Stadia	Hor.		Hor.	Vert.				
P				1,50						435,26
	P1	1,63 0,59	102,20	1,11	290:48:36	97:34:05	0,36	–13,58	–13,22	422,04
	P2	3,15 2,48	65,83	2,82	316:22:28	82:24:14	–1,35	8,78	7,44	442,70
	P3	2,69 1,09	159,15	1,89	62:52:46	85:48:38	–0,42	11,66	11,24	446,50
	P4	2,86 1,47	135,78	2,17	112:38:34	98:45:10	–0,70	–20,91	–21,61	413,66

4.1 Angle P1 – P – P2 = 316:22:28 – 290:48:36 = 25:33:52

$(P1 - P2)^2 = (102{,}20)^2 + (65{,}83)^2 - 2(102{,}20)(65{,}83) \cos 25:33:52$

$P1 - P2 = \sqrt{2\,640{,}08}$

$P1 - P2 = 51{,}38$ m

Angle P2 – P – P3 = (62:52:46 +360) – 316:22:28 = 106:30:18

$(P2 - P3)^2 = 65{,}83^2 + 159{,}15^2 - 2(65{,}83)(159{,}15) \cos 106:30:18$

$P2 - P3 = \sqrt{35\,615{,}23}$

$P2 - P3 = 188{,}72$ m

Angle B – N – C = 108:12:40 – 40:50:12 = 67:22:28

$(BC)^2 = (102{,}14)^2 + (49{,}73)^2 - 2(102{,}14)(49{,}73) \cos 67:22:28$

$BC = \sqrt{8\,997{,}47}$

$BC = 94{,}85$ m

Angle C – N – D = 210:24:36 – 108:12:40 = 102:11:56

$(CD)^2 = (49{,}73)^2 + (65{,}05)^2 - 2(49{,}73)(65{,}05) \cos 102:11:56$

$CD = \sqrt{8\,071{,}70}$

$CD = 89{,}84$ m

4.2

Station	Mean direction	Oriented direction	Correction	Known direction
B	40:50:12	52:48:54		
C	108:12:40		+ 11:57:42	120:10:22
D	210:24:36	222:22:18		

$Y_B = Y_N + d_{NB} \sin(WCB_{NB})$

$Y_B = 3\,220{,}30 + 102{,}14 \sin 52:48:54$

$Y_B = +3\,301{,}67$

$X_B = X_N + d_{NB} \cos(WCB_{NB})$

$X_B = 1\,100{,}30 + 102{,}14 \cos 52:48:54$

$X_B = +1\,162{,}03$

$Y_D = Y_N + d_{NB} \sin(WCB_{NB})$

$Y_D = 3\,220{,}30 + 65{,}05 \sin 222:22:18$

$Y_D = +3\,176{,}46$

$X_D = X_N + d_{NB} \cos(WCB_{NB})$

$X_D = 1\,100{,}30 + 65{,}05 \cos 222:22:18$

$X_D = +1\,052{,}24$

5.1

Stations		Distances		HI or MH	Angles		HI – MH ±	Height component ±	Height difference ±	RL of point
From	To	Stadia	Hor.		Hor.	Vert.				
T300				1,50						150,59
	T305	2,97 1,42	154,69	2,20	23:47:25	92:35:00	–0,70	–6,98	–7,68	142,92
	T306	3,19 1,20	197,66	2,20	38:23:15	94:42:00	–0,70	–16,25	–16,95	133,65
	T307	2,53 1,00	151,12	1,77	94:39:00	96:22:00	–0,27	–16,86	–17,13	133,46
	T308	1,62 0,50	111,28	1,06	182:30:00	85:25:00	0,44	8,95	9,39	159,98
	T309	1,44 0,40	103,05	0,92	201:35:08	84:31:00	0,58	9,89	10,47	161,06

5.2.1 Angle T306 – T300 – T307 = 94:39:00 – 38:23:15 = 56:15:45

$(T306 - T307)^2 = (197{,}66)^2 + (151{,}12)^2 - 2(197{,}66)(151{,}12) \cos 56:15:45$

$T306 - T307 = \sqrt{28\,727{,}38}$

T306 – T307 = 169,49 m

5.2.2 Angle T306 – T300 – T309 = 201:35:08 – 38:23:15 = 163:11:53

$(T306 - T309)^2 = (197{,}66)^2 + (103{,}05)^2 - 2(197{,}66)(103{,}05) \cos 163:11:53$

$T306 - T309 = \sqrt{88\,687{,}40}$

T306 – T309 = 297,80 m

6.1

Station	Mean direction	Oriented direction	Correction	Known direction
S101	120:14:52		–55:52:17	64:22:35
S102	202:38:24	146:46:07		
S103	283:28:37	227:36:20		
S104	25:41:40	329:49:23		

Note

360° was added to 25:41:40 so as not to get a negative direction.

6.2 **Distance S101 – S102**

$S100 - S101 = 100(TH - BH)\cos^2 \angle S100$

$S100 - S101 = 100(1{,}50 - 0{,}9)(\cos 08:32:28)^2$

S100 – S101 = 58,68 m

$S100 - S102 = 100(TH - BH)\cos^2 \angle S100$

$S100 - S102 = 100(1{,}90 - 0{,}8)(\cos 06:42:39)^2$

S100 – S102 = 108,50 m

Angle S101 – S100 – S102 = 202:38:24 – 120:14:52 = 82:23:32

Note

Since the correction value is the same, the angle between the legs remains the same whether the mean or oriented direction is used to determine the angle.

$(S101 - S102)^2 = (58{,}63)^2 + (108{,}50)^2 - 2(58{,}68)(108{,}50) \cos 82:23:32$

$S101 - S102 = \sqrt{13\,529{,}78}$

S101 – S102 = 116,32 m

Distance S102 – S103

$S100 - S103 = 100(TH - BH)\cos^2 \angle S100$

$S100 - S103 = 100(2{,}60 - 1{,}20)(\cos 09{:}34{:}18)^2$

$S100 - S103 = 136{,}13$ m

Angle S102 – S100 – S103 = 283:28:37 – 202:38:24 = 80:50:13

$(S102 - S103)^2 = (108{,}5)^2 + (136{,}13)^2 - 2(108{,}50)(136{,}13)\cos 80{:}50{:}13$

$S102 - S103 = \sqrt{25\,599{,}51}$

$S102 - S103 = 160{,}00$ m

Distance S103 – S104

$S100 - S104 = 100(TH - BH)\cos^2 \angle S100$

$S100 - S104 = 100(2{,}68 - 0{,}88)(\cos 10{:}44{:}52)^2$

$S100 - S104 = 173{,}74$ m

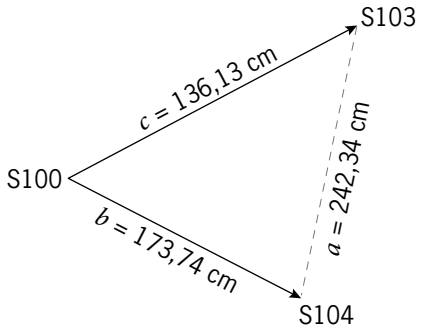
Angle S103 – S100 – S104 = (25:41:40+360) – 283:28:37 = 102:13:03

$(S103 - S104)^2 = (136{,}13)^2 + (173{,}74)^2 - 2\ 136{,}13\ 173{,}74 \cos 102{:}13{:}03$

$S103 - S104 = \sqrt{58\,727{,}27}$

$S103 - S104 = 242{,}34$ m

6.3



$$S = \frac{a+b+c}{2}$$

$$S = \frac{242{,}34 + 173{,}74 + 136{,}13}{2}$$

$S = 276{,}11$

$$\text{Area} = \sqrt{S(S-a)(S-b)(S-c)}$$

$$\text{Area} = \sqrt{276{,}11(276{,}11-242{,}34)(276{,}11-173{,}74)(276{,}11-136{,}13)}$$

Area = 11 559,15 m^2

7.1 $\Delta Y_{P400-P403} = Y_{P403} - Y_{P400}$

$\Delta Y_{P400-P403} = 1\,680{,}13 - 304{,}23 = +1\,375{,}9$

$\Delta X_{P400-P403} = X_{P403} - X_{P400}$

$\Delta X_{P400-P403} = 674{,}91 - 503{,}78 = +171{,}13$

$$\text{Direction P400} - \text{P403} = \tan^{-1}\left(\frac{\Delta y}{\Delta x}\right)$$

$$\text{Direction P400} - \text{P403} = \tan^{-1}\left(\frac{1\,375{,}9}{304{,}23}\right)$$

Direction P400 – P403 = 77:31:54

$$\text{Distance P400} - \text{P403} = \sqrt{(\Delta Y)^2 + (\Delta X)^2}$$

$$\text{Distance P400} - \text{P403} = \sqrt{(1\,375{,}9)^2 + (304{,}23)^2}$$

Distance P400 – P403 = 1 409,13 m

7.2

Station	Mean direction	Oriented direction	Correction	Join direction
P401	70:24:22	221:40:34		
P402	235:09:54	26:26:06		
P403	286:15:42		–208:43:48	77:31:54
P404	335:44:35	127:00:47		

7.3 **Distance P401 – P402**

Angle P401 – P400 – P402 = (26:26:06+360) – 221:40:34 = 164:45:32

$(P401 - P402)^2 = (135{,}27)^2 + (114{,}49)^2 - 2(135{,}27)(114{,}49)\cos 164{:}45{:}32$

$P401 - P402 = \sqrt{61\,290{,}64}$

P401 – P402 = 247,57 m

Distance P402 – P403

Angle P402 – P400 – P403 = 77:31:54 – 26:26:06 = 51:05:48

$(P402 - P403)^2 = (114{,}49)^2 + (1\,409{,}13)^2 - 2(114{,}49)(1409{,}13)\cos 51{:}05{:}48$

$P402 - P403 = \sqrt{1\,796\,120{,}52}$

P402 – P403 = 1 340,19 m

Distance P403 – P404

Angle P403 – P400 – P404 = 127:00:47 – 77:31:54 = 49:28:53

$(P402 - P403)^2 = (1\,409{,}13)^2 + (89{,}31)^2 - 2(1409{,}13)(89{,}31)\cos 49{:}28{:}53$

$P402 - P403 = \sqrt{1\,830\,096{,}18}$

P402 – P403 = 1 352,81 m

7.4 $Y_{P404} = Y_{P400} + d_{P400 - P404} \sin(WCB_{P400 - P404})$
$Y_{P404} = 304{,}23 + 89{,}31 \sin 127{:}00{:}47$
$Y_{P404} = +375{,}54$
$X_{P404} = X_{P400} + d_{P400 - P404} \cos(WCB_{P400 - P404})$
$X_{P404} = 503{,}78 + 89{,}31 \cos 127{:}00{:}47$
$X_{P404} = +450{,}02$

7.5 $\Delta Y_{P403 - P404} = Y_{P404} - Y_{P403}$
$\Delta Y_{P403 - P404} = 375{,}54 - 1\,680{,}13 = -1\,304{,}59$

$\Delta X_{P403 - P404} = X_{P404} - X_{P403}$
$\Delta X_{P403 - P404} = 450{,}02 - 503{,}78 = -53{,}76$

$$P403 - P404 = \tan^{-1}\left(\frac{\Delta y}{\Delta x}\right) + 180$$
$$P403 - P404 = \tan^{-1}\left(\frac{1\,304{,}59}{53{,}76}\right) + 180$$
$$P403 - P404 = 267{:}38{:}25$$

Practical group activity 3.1

Encourage students to conduct the following practical activity.

Instructions

Form a survey team consisting of THREE members. One will hold the ranging rod, one will operate the theodolite and one will do the chaining or taping.

- Peg three points: A, B and C
- Set up, centre and level the theodolite at station B.
- Sight one of the other points, using face left and face right, book the readings and measure the distance from the instrument station to the point.
- Without moving the instrument, sight the other point, using face left and face right, book the readings and measure the distance from the instrument station to the point.

Task

Use the data recorded to calculate the distance between points A and C.

Summative assessment: Module 3 SB page 81

1. Any FOUR of the following:
   - The method is more rapid than chaining.
   - It's not tedious as taping and chaining.
   - It is a low-cost way of surveying.
   - This method is useful where chain- and plane table surveying cannot be conducted.
   - The precision of this method is good enough for the compilation of topographic maps and hydrological surveys. (4)

2. The principles of tacheometry are based on the properties of an isosceles triangle, where the ratio of the distance of the base from the apex and the length of the base is always constant. (2)

3. Stadia system and tangential system (2)

4.1 The table is shown on the next page. (20)

4.2 Angle Q – B – R = 93:42:00 – 36:22:00 = 57:20:00

$(QR)^2 = (197{,}66)^2 + (151{,}12)^2 - 2(197{,}66)(151{,}12) \cos 57:20:00$

$QR = \sqrt{29\,661{,}62}$

QR = 172,23 m (4)

Total: 32 marks

4.1

Stations		Distances		HI or MH	Angles		HI – MH ±	Height component ±	Height difference ±	RL of point
From	To	Stadia	Hor.		Hor.	Vert.				
B				1,50						150,59
	P	2,97 1,42	154,69	2,20	22:47:00	–2:35:00	–0,70	–6,98	–7,68	167,53
	Q	3,19 1,20	197,66	2,20	36:22:00	–4:42:00	–0,70	–16,25	–16,95	150,58
	R	2,53 1,00	151,12	1,77	93:42:00	–6:22:00	–0,27	–16,86	–17,13	133,46
	S	1,62 0,50	111,28	1,06	182:20:20	+4:36:00	+0,44	+8,95	+9,39	142,32

MODULE

4 *Contouring*

After they have completed this module, students should be able to:

- explain the following terminology:
  - contouring
  - contour line
  - vertical interval (contour interval)
  - horizontal interval
  - gradient;
- explain the purpose of contouring and contour maps;
- list and explain the factors affecting the selection of contour intervals;
- explain the following methods of contouring:
  - direct method
  - indirect method;
- explain how to fix the contour position with the following operations using the direct methods of levelling:
  - levelling
  - surveying of the pegs;
- explain how to fix the contour position with the following operations using the indirect method of levelling:
  - setting out a grid
  - levelling
  - interpolating the contours mathematically and graphically;
- explain the difference between contour intervals and horizontal intervals;
- explain the characteristics of contour lines;
- calculate volumes from given spot heights and ground sections;
- calculate volumes and areas from contours; and
- explain the following uses of contour maps:
  - vertical sections
  - intersections of surfaces.

Introduction

A contour or contour line is defined as an imaginary line connecting points of equal elevation on the ground surface. It can also be defined as the line of intersection of a level surface with the surface of the earth. These lines depict relief of terrain in a two-dimensional plan.

Exercise 4.1

SB page 130

1. 1.1 Contour line – a line on a map joining points of equal height above and below sea level.
   1.2 Horizontal – a line at right angles to the direction of gravity at one point only.

2.
- Contour maps assist in studying the nature of the terrain or ground of a proposed site
- They are essential for determining the profile along the section line and working out the depth of cutting during the road alignment survey.
- They are important for determining the location of embankments, dams and identifying the flood levels.
- Contour maps are an inevitable component for the likes of route surveys of roads and canals, as well as balancing earthworks.

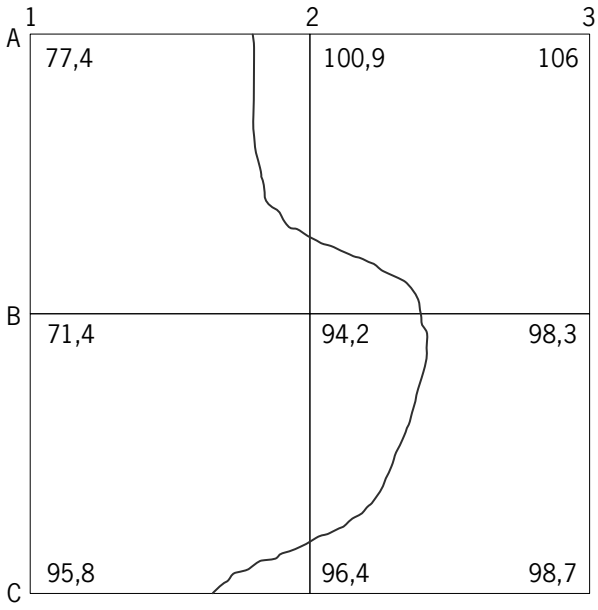
3.
- Nature of the ground
- Purpose and extent of the survey
- Scale of the map
- Time and resources available

4. In *direct* contouring, the contours to be located are directly traced out in the field by locating and marking a number of points on each contour.

   In *indirect* contouring, levels are taken at some selected points and their levels are reduced. Horizontal controls are established first and then the levels of those points.

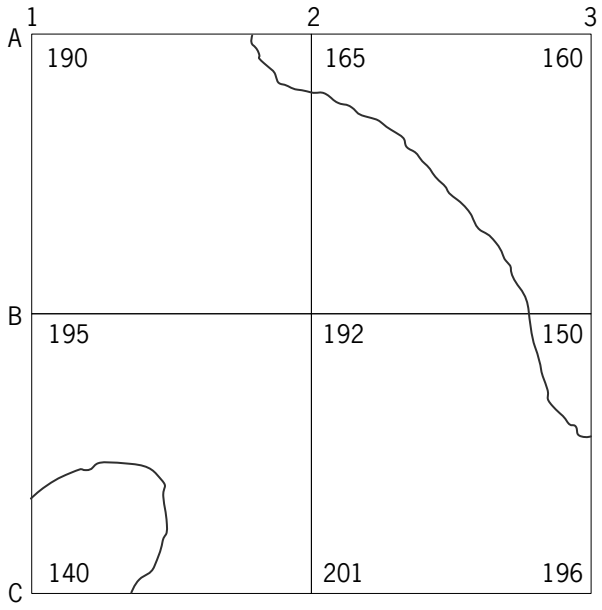
5.

Station	Fall or rise	Contour fall or rise	Distance	From	To
A2 – A1	100,9 – 77,4 = 23,5	96 – 77,4 = 18,6	$\frac{18,6}{23,5} \times 30 = 24$	A1	A2
B2 – A2	100,9 – 94,2 = 6,7	96 –94,2 = 1,8	$\frac{1,8}{6,7} \times 30 = 8$	B2	A2
B2 – B3	98,3 – 94,2 = 4,1	96 – 94,2 = 1,8	$\frac{1,8}{4,1} \times 30 = 13$	B2	B3
B2 – C2	96,4 – 94,2 = 2,2	96 – 94,2 = 1,8	$\frac{1,8}{2,2} \times 30 = 25$	B2	C2
C1 – C2	96,4 – 95,8 = 0,6	96 – 95,8 = 0,2	$\frac{0,2}{0,6} \times 30 = 10$	C1	C2



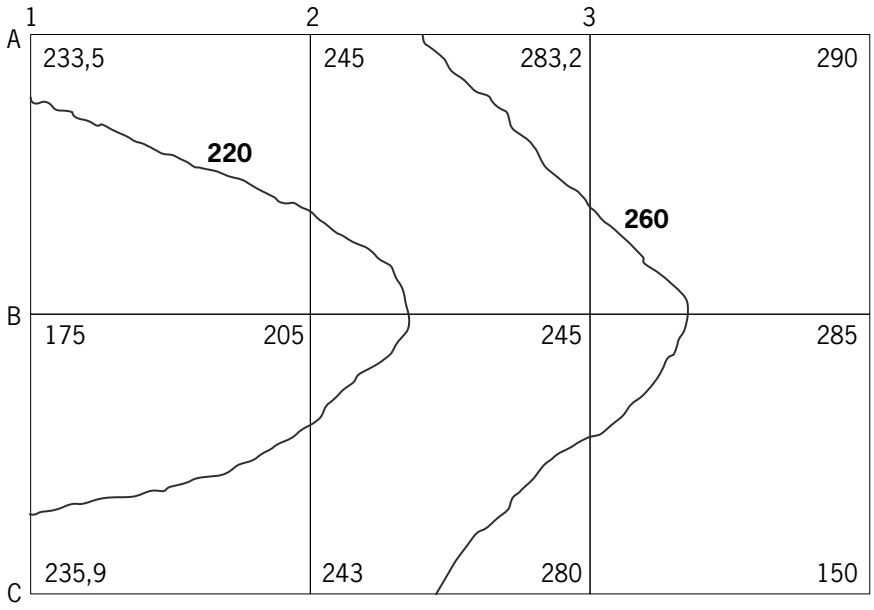
6.

Station	Fall or rise	Contour fall or rise	Distance	From	To
170-m contour					
A1 – A2	190 – 165 = 25	170 – 165 = 5	$\frac{5}{25} \times 30 = 6$	A2	A1
A2 – B2	192 – 165 = 27	170 – 165 = 5	$\frac{5}{27} \times 30 = 6$	A2	B2
B2 – B3	192 – 165 = 27	170 – 165 = 5	$\frac{5}{27} \times 30 = 16$	B3	B2
B3 – C3	196 – 150 = 46	170 – 150 = 20	$\frac{20}{46} \times 30 = 25$	13	C3
180-m contour					
B1 – C1	195 – 140 = 55	180 – 140 = 40	$\frac{40}{55} \times 30 = 10$	B3	B2
C1 – C2	201 – 140 = 61	180 – 140 = 40	$\frac{40}{61} \times 30 = 10$	B3	C3



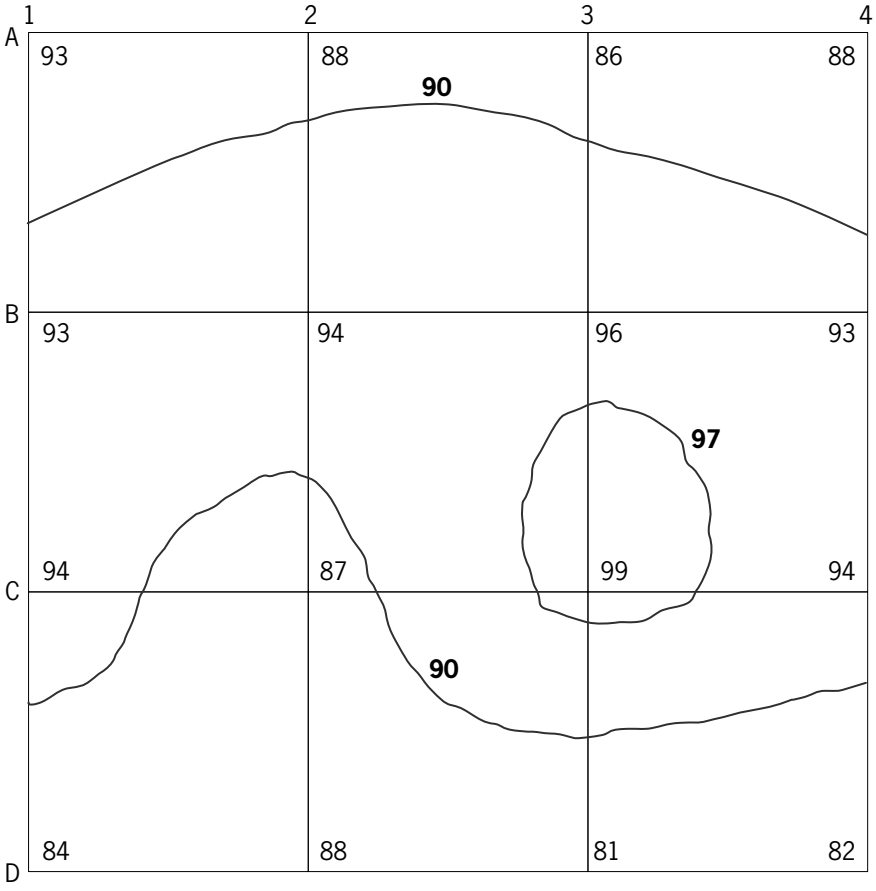
7.

Station	Fall or rise	Contour fall or rise	Distance	From	To
220-m contour					
A1 – B1	233,5 – 175 = 58,5	220 – 175 = 45	$\frac{45}{58,5} \times 30 = 23$	B1	A1
A2 – B2	245 – 205 = 40	220 – 205 = 15	$\frac{15}{40} \times 30 = 11$	A2	B2
B2 – B3	245 – 205 = 40	220 – 205 = 15	$\frac{15}{40} \times 30 = 11$	B2	B3
B2 – C2	243 – 205= 38	220 – 205 = 15	$\frac{15}{38} \times 30 = 12$	B2	C2
B1 – C1	235,9 – 175 = 46	220 – 175 = 45	$\frac{45}{46} \times 30 = 29$	B1	C1
260-m contour					
A2 – A3	283,2 – 245 = 38,2	260 – 245 = 15	$\frac{15}{38,2} \times 30 = 12$	A2	A3
B3 – A3	283,2 – 245 = 38,2	260 – 245 = 15	$\frac{15}{38,2} \times 30 = 12$	B3	A3
B3 – B4	285 – 245 = 40	260 – 245 = 15	$\frac{15}{40} \times 30 = 11$	B3	B4
B3 – C3	280 – 245= 35	260 – 245 = 15	$\frac{15}{35} \times 30 = 13$	B3	C3
C2 – C3	280 – 243 = 37	260 – 243 = 17	$\frac{17}{37} \times 30 = 14$	C2	C3



8.

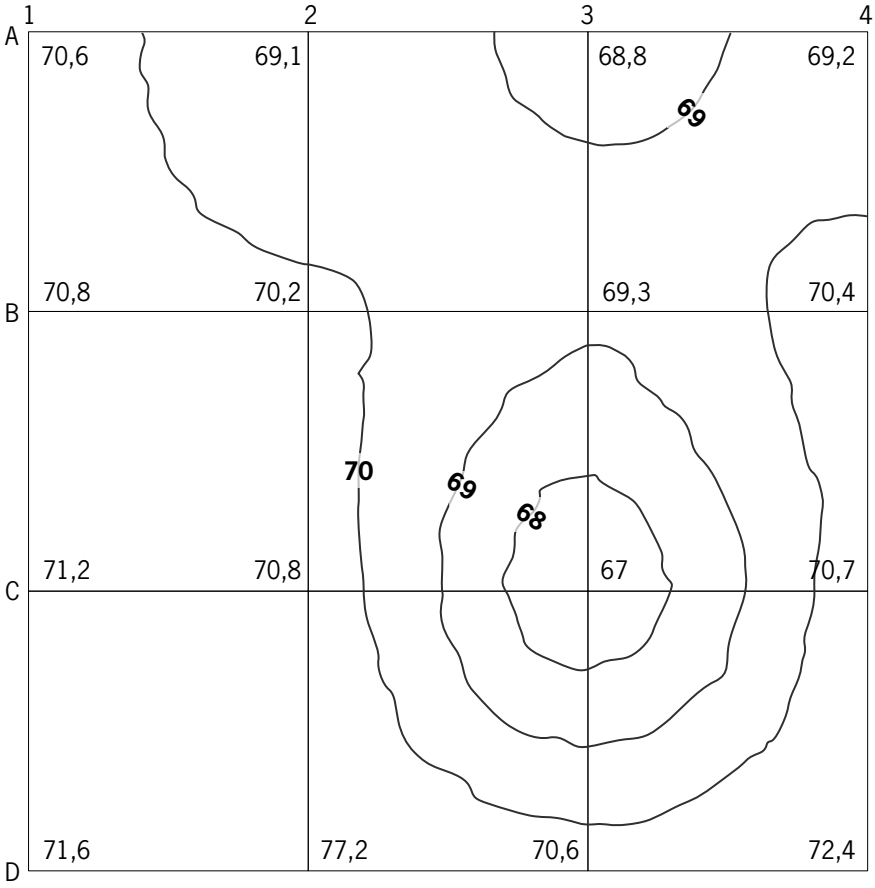
Station	Fall or rise	Contour fall or rise	Distance	From	To
90-m contour					
A1 – B1	93 – 83 = 10	90– 83 = 7	$\frac{7}{10} \times 20 = 14$	A1	B1
A2 – B2	94 – 88 = 6	90– 88 = 2	$\frac{2}{6} \times 20 = 7$	A2	B2
A3 – B3	96 – 86 = 10	90– 86 = 4	$\frac{4}{10} \times 20 = 8$	A3	B3
C1 – D1	94 – 84 = 10	90– 84 = 6	$\frac{6}{10} \times 20 = 12$	D1	C1
C1 –C2	94 – 87 = 7	90– 87 = 3	$\frac{3}{7} \times 20 = 9$	C2	C1
B2 –C2	94 – 87 = 7	90– 87 = 3	$\frac{3}{7} \times 20 = 9$	C2	B2
C2 –C3	99 – 87 = 12	90– 87 = 3	$\frac{3}{12} \times 20 = 5$	C2	B2
C3 –D3	99 – 81 = 18	90– 81 = 9	$\frac{9}{18} \times 20 = 10$	D3	C3
C4 –D4	99 – 82 = 12	90– 82 = 8	$\frac{8}{12} \times 20 = 13$	D4	C4
97-m contour					
C2 – C3	99 – 87 = 12	97– 87 = 10	$\frac{10}{12} \times 20 = 17$	C2	C3
C3 – D3	99 – 81= 18	97– 81 = 16	$\frac{16}{18} \times 20 = 18$	D3	C3
C3 – C4	99 – 94 = 5	97– 94 = 3	$\frac{3}{5} \times 20 = 12$	C4	C3
B3 – C3	94 – 84 = 10	97– 96 = 1	$\frac{1}{10} \times 20 = 2$	B3	C3



9.

Station	Fall or rise	Contour fall or rise	Distance	From	To
68-m contour					
C2 – C3	70,8 – 67 = 3,8	68– 67 = 1	$\frac{1}{3,8} \times 20 = 5$	C3	C2
C3 – D3	70,6 – 67 = 3,6	68– 67 = 1	$\frac{1}{3,6} \times 20 = 6$	C2	D3
C3 – C4	70,7 – 67 = 3,7	68– 67 = 1	$\frac{1}{3,7} \times 20 = 5$	C3	C4
B3 – C3	69,3 – 67 = 2,3	68– 67 = 1	$\frac{1}{2,3} \times 20 = 9$	C3	B3
69-m contour					
C2 – C3	70,8 – 67 = 3,8	69– 67 = 2	$\frac{2}{3,8} \times 20 = 11$	C3	C2
C3 – D3	70,6 – 67 = 3,6	69– 67 = 2	$\frac{2}{3,6} \times 20 = 11$	C2	D3
C3 – C4	70,7 – 67 = 3,7	69– 67 = 2	$\frac{2}{3,7} \times 20 = 11$	C3	C4
B3 – C3	69,3 – 67 = 2,3	69– 67 = 2	$\frac{2}{2,3} \times 20 = 17$	C3	B3

70-m contour					
A1 – A2	70,6 – 69,1 = 1,5	70 – 69,1 = 0,9	$\frac{0,9}{1,5} \times 20 = 12$	A2	A1
A2 – B2	70,2 – 69,1 = 1,1	70 – 69,1 = 0,9	$\frac{0,9}{1,1} \times 20 = 16$	A2	B2
B2 – B3	70,2 – 69,3 = 0,9	70 – 69,3 = 0,7	$\frac{0,7}{0,9} \times 20 = 16$	B3	B2
C2 – C3	70,8 – 67 = 3,8	70 – 67 = 3	$\frac{3}{3,8} \times 20 = 16$	C3	C2
C3 – D3	70,6 – 67 = 3,6	70 – 67 = 3	$\frac{3}{3,6} \times 20 = 17$	C3	D3
C3 –C4	70,7 – 67 = 3,7	70 – 67 = 3	$\frac{3}{3,7} \times 20 = 16$	C3	C4
B3 – B4	70,4 – 69,3 = 1,1	70 – 69,3 = 0,7	$\frac{0,7}{1,1} \times 20 = 15$	B3	B4
A4 – B4	70,4 – 69,2 = 1,2	70 – 69,2 = 0,8	$\frac{0,8}{1,2} \times 20 = 13$	A4	B4



Practical group activity 4.1

Encourage students to conduct the following practical activity.

Instructions

Form a survey team consisting of THREE members. One will insert the pegs, one will operate the theodolite and one will hold the staff.

- Set out a grid with 4 squares, 5 m × 5 m on slightly sloping ground.
- Take staff readings at each corner of the grid squares.
- Select a point outside the grid that is higher than the corners of the grid square.
- Assume that the point is a benchmark 186,5 m above the mean sea level.
- Take a reading on the benchmark.

Task

- Calculate the reduced level of each corner.
- Find points on the grid lines between the corners that have the same staff reading.
- Record the reading.
- Draw the grid to a suitable scale and plot the points with the same readings.

Exercise 4.2

SB page 137

1.1 C
1.2 D
1.3 C
1.4 A
1.5 B

2.

Contour interval	Horizontal equivalent
Based on vertical distances	Represents horizontal distances
No measurement or scaling is required since the contour levels are indicated on the contour lines.	The distance must be measured on the map and converted to an actual distance by multiplying with the scale of the map.
In a given map the contour interval is constant.	The horizontal equivalent varies with slope. Closer distances indicate steep slopes and wider distances indicate gentler slopes.

3. Interpolation is the process of spacing the contours proportionally between the plotted ground points.

Exercise 4.3

SB page 141

1.

Corner	Elevation	No. of appearances	Product
A1	110,50	1	110,50
A2	168,66	2	337,32
A3	130,28	1	130,28
B1	115,00	2	230,00
B2	107,58	4	430,32
B3	114,52	2	229,04
C1	118,16	1	118,16
C2	116,48	2	232,96
C3	128,00	1	128,00
		16	1 946,58

Mean height = $\frac{1\,946{,}58}{16}$ = 121,66

Excavation depth = 121,66 – 97,00 = 24,66

Volume = Area × Excavation depth

Volume = 4(30 × 30) × 24,66

Volume = 88 776 m^3

Bulking = 88 776 × 0,12

= 10 653,12

Total volume = 88 776 + 10 653,12

= 99 429,12 m^3

2.

Corner	Elevation	No. of appearances	Product
A1	159,88	1	159,88
A2	162,26	2	324,52
A3	160,68	2	321,36
A4	162,26	1	162,26
B1	163,00	2	326,00
B2	162,16	4	648,64
B3	166,08	4	664,32
B4	167,88	2	335,76
C1	163,86	1	163,86
C2	163,24	2	326,48
C3	161,74	2	323,48
C4	160,78	1	160,78
C3	128,00	1	128,00
		24	3 917,34

$$\text{Mean height} = \frac{3\,917{,}34}{24} = 163{,}22$$

Excavation depth = 163,22 – 137,76 = 25,46

Volume = Area × Excavation depth
Volume = 6(25 × 25) × 25,46
Volume = 95 475 m^3

Bulking = 95 475 × 0,12
= 11 457

Total volume = 95 475 + 11 457
= 106 932 m^3

3.

Corner	Elevation	No. of appearances	Product
A1	95,20	1	95,20
A2	95,10	2	190,20
A3	93,90	2	187,80
A4	94,10	1	94,10
B1	95,90	2	191,80
B2	96,00	4	384,00
B3	95,00	4	380,00
B4	96,30	3	288,90
B5	94,50	1	94,50
C1	95,20	1	95,20
C2	96,00	2	192,00
C3	95,10	2	190,20
C4	96,20	2	192,40
C5	96,10	1	96,10
		28	2 383,90

$$\text{Mean height} = \frac{2\,383{,}90}{28} = 85{,}14$$

Filled height = 96,50 – 85,14 = 11,36

Volume = Area × Fill height
Volume = 7(15 15) × 11,36
Volume = 17 892 m^3

Bulking = 17 892 × 0,12
= 2 147,04

Total volume = 17 892 + 2 147,04
= 20 039,04 m^3

4.1

Corner	Elevation	No. of appearances	Product
A1	335,68	1	335,68
A2	324,60	2	649,20
A3	345,34	1	345,34
B1	317,88	2	635,76
B2	315,00	4	1260,00
B3	332,34	2	664,68
C1	326,66	1	326,66
C2	338,56	2	677,12
C3	331,22	1	331,22
		16	5 225,66

$$\text{Mean height} = \frac{5\,225{,}66}{16} = 326{,}60$$

Filled height = 326,60 – 314,00 = 11,36

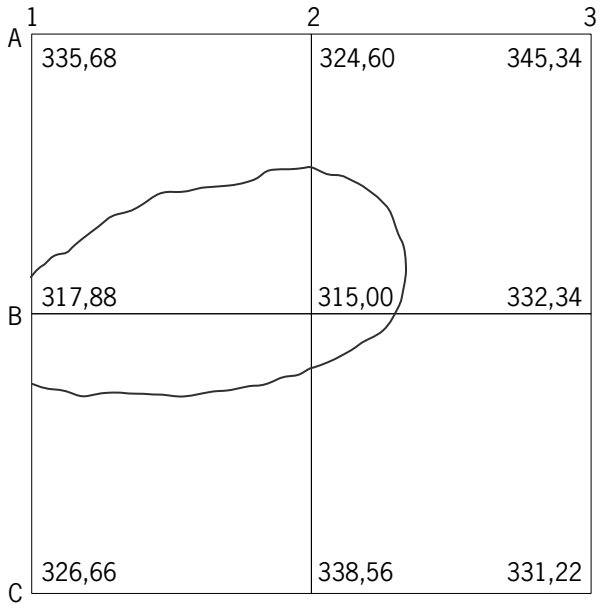
Volume = Area × Fill height
Volume = 4(30 × 25) × 11,36
Volume = 34 080 m^3

Bulking = 38 080 × 0,12
= 4 089,60

Total volume = 34 080 + 4 089,60
= 38 169,60 m^3

4.2

Station	Fall or rise	Contour fall or rise	Distance	From	To
A1 – B1	335,68 – 317,88 = 17,8	320 – 317,88 = 2,12	$\frac{2{,}12}{17{,}8} \times 25 = 3$	B1	A1
A2 – B2	324,6 – 315 = 9,6	320 – 315 = 5	$\frac{5}{9{,}6} \times 25 = 13$	B2	A2
B2 – B3	332,34 – 315 = 17,34	320 – 315 = 5	$\frac{5}{17{,}36} \times 25 = 30$	B2	B3
B2 – C2	338,56 – 315 = 23,56	320 – 315 = 5	$\frac{5}{23{,}56} \times 25 = 25$	B2	C2
B1 – C1	326,66 – 317,88 = 8,78	320 – 317,88 = 2,12	$\frac{2{,}12}{8{,}78} \times 25 = 6$	B1	C1



Exercise 4.4

SB page 146

1. $V = \frac{h}{2}[A_1 + A_n + 2(A_2 + A_3 + A_4 \ldots + A \ldots)]$

   $V = \frac{4}{2}[1\,876{,}75 + 1\,356{,}00 + 2(1\,723{,}5 + 1\,504{,}20)]$

   $V = 2[1\,876{,}75 + 1\,356{,}00 + 2(2\,227{,}70)]$

   $V = 2 \times 9\,688{,}15$

   $V = 19\,376{,}30\ m^3$

2. $V = \frac{h}{2}[A_1 + A_n + 2(A_2 + A_3 + A_4 \ldots + A \ldots)]$

   $V = \frac{4}{2}\ [2\,344 + 1\,399 + 2(2\,180{,}22 + 1\,989{,}20 + 1\,654{,}80 + 1\,432{,}54)]$

   $V = 2[2\,344 + 1\,399 + 2(7\,256{,}76)]$

   $V = 2 \times 18\,256{,}52$

   $V = 36\,513\ m^3$

3. 3.1 $V = \frac{h}{2}[A_1 + A_n + 2(A_2 + A_3 + A_4 \ldots + A \ldots)]$

   $V = \frac{2}{2}[3\,369{,}53 + 520 + 2(3\,050 + 2\,730{,}50)]$

   $V = 15\,450{,}53\ m^3$

3.2 $V = \frac{h}{2}[A_1 + A_n + 2(A_2 + A_3 + A_4 \ldots + A \ldots)]$

$V = \frac{2}{2}\ [1\ 567 + 2(276{,}40 + 2\ 1920 + 2\ 098{,}22)]$

$V = 11\ 879{,}84\ m^3$

3.3 Total volume carted away = 15 450,53 – 11 879,84
= 3 630,69 m3

4. $V = \frac{h}{2}[A_1 + A_n + 2(A_2 + A_3 + A_4 \ldots + A \ldots)]$

$V = \frac{3}{2}[2\ 576{,}75 + 3\ 904{,}30 + 2(3\ 023{,}50)]$

$V = 1{,}5 \times 12\ 528{,}05$

$V = 18\ 792{,}08\ m^3$

Summative assessment: Module 4 SB page 150

1.1 The nature of the ground determines the size of the interval. In flat and uniformly sloping terrain, contour intervals are small; but, in areas with hills and ponds, contour intervals are large. (2)

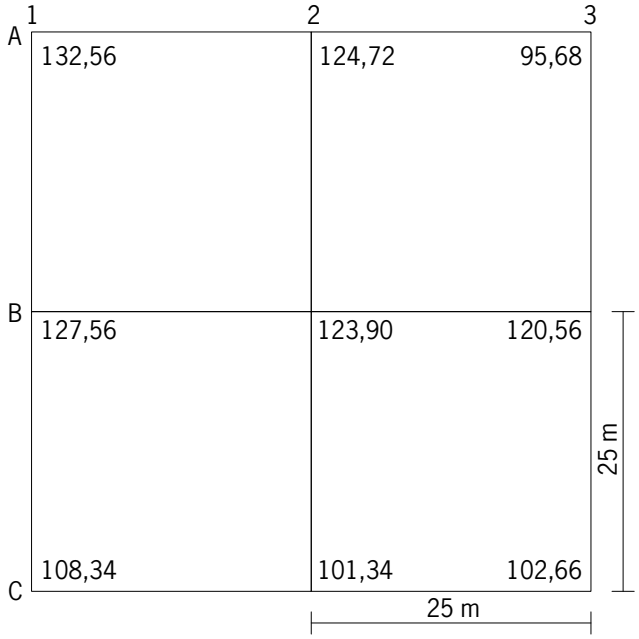
1.2 The purpose and extent of the survey determines the size of the interval. For example, when preparing maps for setting out a highway on a hill slope, large contour intervals are suitable. However, for construction of a factory building, small contour intervals are better suited for more accurate work. (2)

2. In *direct contouring*, the contours to be located are directly traced out in the field by locating and marking a number of points on each contour. These points are then surveyed and plotted on a plan, and the contours are drawn through them.

   In *indirect contouring*, the points located and surveyed are not necessarily on the contour lines, but the levels are taken at some selected points and their levels are reduced, horizontal controls are first established and then the levels of those points. After locating the points on a plan, reduced levels are marked and contour lines are interpolated between the selected points. (10)

3. Any FIVE of the following:
   - Contour lines must close themselves but not necessarily within the limits of the map.
   - Widely separated contour lines indicate flat ground.
   - Closely spaced contour lines indicate steeply sloped ground.
   - Equally spaced contour lines indicate uniform slopes.
   - Irregularly spaced contour lines indicate uneven ground.
   - Approximately concentric closed contour lines with decreasing values towards the centre.
   - Approximately concentric closed contour lines with increasing values towards the centre.
   - Contour lines with a U-shape with convexity indicated lower ground.
   - Contour lines with a V-shape with convexity indicated higher ground.
   - Contour lines generally do not meet or intersect each other. If contour lines are meeting in some portion, it indicates the existence of a vertical cliff.

- Contour lines of different elevations cannot cross each other. If contour lines cross each other, it indicates the existence of an overhang cliff or cave. (5)



4.1

Corner	Height	Times used	Product
A1	132,56	1	132,56
A2	124,72	2	249,44
A3	95,68	1	95,68
B1	127,56	2	255,12
B2	123,90	2	495,60
B3	120,56	2	241,12
C1	108,23	1	108,23
C2	101,34	2	202,68
C3	102,66	1	102,66
		16	1 883,20

$$\text{Mean height} = \frac{1\,883{,}20}{16}$$

$$= 117{,}70 \text{ m}$$

$$\text{Excavation height} = 117{,}70 - 95$$

$$= 22{,}70 \text{ m}$$

(10)

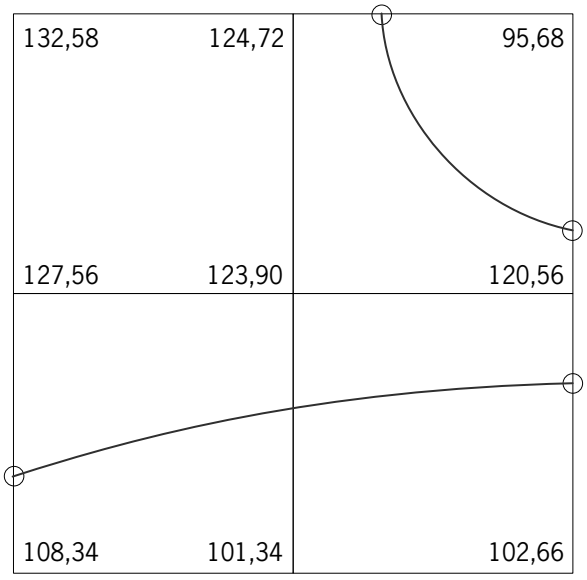
Volume = $4(25 \times 25) \times 22{,}70$
= $56\ 750\ m^3$

12% bulking = $56\ 750 \times 0{,}12$
= $6\ 810\ m^3$

Total volume = $56\ 750 + 6\ 810$
= $63\ 560\ m^3$

4.2

Station	Fall or rise	Contour fall or rise	Distance	From	To
A2– A3	124,72 – 95,68 = 29,04	115 – 95,68 = 19,32	$\frac{19{,}32}{29{,}04} \times 25 = 16{,}63$	A3	A2
B1 – C1	127,58 – 108,34 = 19,22	115 – 108,34 = 6,66	$\frac{6{,}66}{19{,}22} \times 25 = 13$	B2	A2
B2 – C2	332,34 – 315 = 17,34	320 – 315 = 5	$\frac{5}{17{,}36} \times 30 = 9$	B2	B3
B3 – C3	338,56 – 315 = 23,56	320 – 315 = 5	$\frac{5}{23{,}56} \times 25 = 5$	B2	C2
B3 – A1	326,66 – 317,88 = 8,78	320 – 317,88 = 2,12	$\frac{2{,}12}{8{,}78} \times 25 = 6$	B1	C1



(10)

Total: 39 marks

MODULE

5 *Setting out*

After they have completed this module, students should be able to:

- explain the following terminology:
  - horizontal controls
  - vertical controls
  - vertical alignment controls;
- describe the following procedures:
  - coordinated setting out
  - setting out a point by forward intersection
  - setting and levelling foundations for steel-framed buildings;
- describe how to check the verticality of tall buildings using the following surveying instruments:
  - theodolite
  - optical plumb
  - plumb bob; and
- explain the vertical and horizontal controls in surveying.

Introduction

Setting out is the establishment of marks and lines to define the position and level of the elements for the construction work so that the works may proceed with reference to them. The aim of setting out is to ensure that all elements of the plan are correct in all three dimensions (both relatively and absolutely), and that each is its correct size, in its correct plan position and at the correct reduced level.

Practical pair activity 5.1

Encourage students to conduct the following practical activity.

Instructions

- Form a survey team consisting of TWO members. One will be the follower and the other will be the leader in chaining.
- Use Google Maps to find the coordinates of two boundary corners of your campus. Choose a building corner that can be clearly sighted from the two boundary corners and also Google/find out what its coordinates are.

Task

Using co-ordinated setting out method, verify position of the chosen building corner.

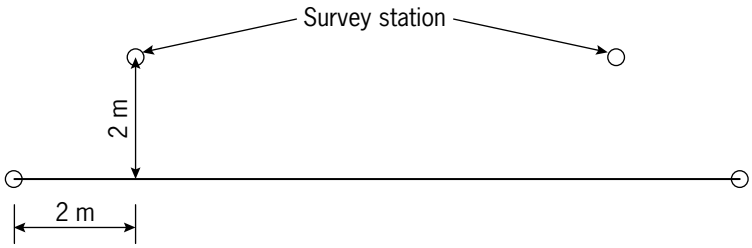
Practical group activity 5.2

Encourage students to conduct the following practical activity.

Instructions

Form a survey team consisting of THREE members. One will operate the theodolite and the other two will do the chaining or taping.

- Use Google Maps to find the coordinates of two boundary corners of your campus. Choose a building corner that can be clearly sighted from the two boundary corners and also Google/find out what its coordinates are.
- Set off a survey point as shown in the following figure.



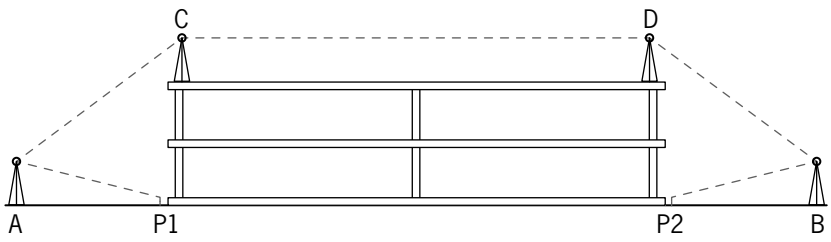
Task

Using the forward intersection method of setting out, verify the position of the chosen building corner by comparing the reading of the theodolite with the one reduced from coordinates.

Exercise 5.1

SB page 167

1.



- The theodolite is set over offset peg A, carefully levelled and aligned on reference line P1 (marked on the side of the slab).
- The line of sight is transferred to the higher floor and a target is accurately positioned at C.
- A three-tripod traverse system is used and the target and theodolite are interchanged.
- The theodolite, now at C, is sighted onto target A, transited and used to line a second target at D. Both faces must be used and the mean must be used for D.
- A three-tripod traverse system is used again between C and D and the theodolite, now at D, checks the line by sighting down from D to offset the target at B. Again, this is done using both faces.
- The procedure is repeated along other sides of the building.
- If a slight discrepancy is found, it may be necessary to repeat the process for each side.

2. **Direction MN**

$\Delta Y_{MN} = 2\,315{,}41 - 2\,405{,}21 = -269{,}8$

$\Delta_{MN} = 3\,145{,}32 - 3\,128{,}97 = +16{,}35$

$AC = \tan^{-1}\left(\frac{16{,}35}{269{,}8}\right) + 270 = 273{:}28{:}04$

Direction NM

$NM = 273{:}28{:}04 - 180 = 93{:}28{:}04$

Direction MQ

$\Delta Y_{MQ} = 2\,336{,}44 - 2\,405{,}21 = -68{,}77$

$\Delta X_{MQ} = 3\,093{,}52 - 3\,128{,}97 = -35{,}45$

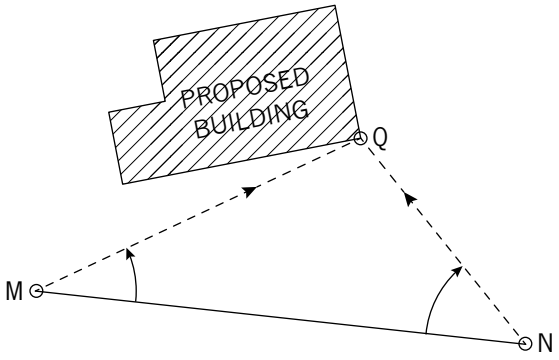
$MQ = \tan^{-1}\left(\frac{68{,}77}{35{,}45}\right) + 180 = 242{:}43{:}46$

Direction NQ

$\Delta Y_{NQ} = 2\,336{,}44 - 2\,315{,}41 = +21{,}03$

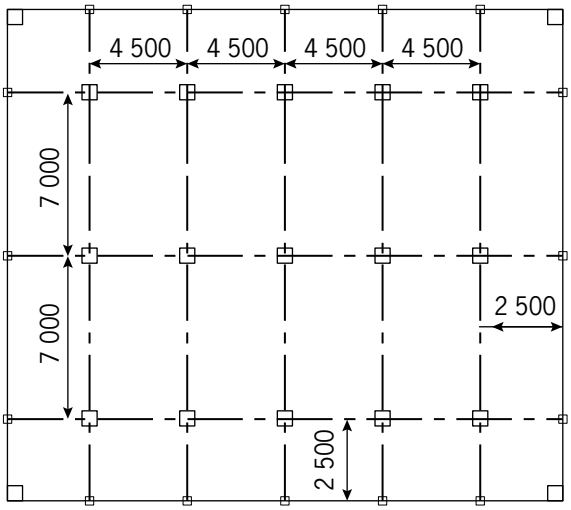
$\Delta X_{NQ} = 3\,093{,}52 - 3\,145{,}32 = -51{,}80$

Direction BC = $\tan^{-1}\left(\frac{51{,}8}{21{,}03}\right) + 90 = 157: 54: 13$



- Set up, centre and level the theodolite at point M, then sight at point N and set the horizontal circle to read 273:28:04.
- Rotate the telescope towards point Q until is read on the horizontal circle.
- Set up, centre and level another theodolite at point N, sight at point M and then set the horizontal circle to read 93:28:04.
- Rotate the telescope towards point Q until 157:54:13 is read on the horizontal circle.
- Move a ranging rod along the line of sight of the two theodolites until the intersection of the line of sight of the two theodolites is established; this will be point Q.

3.

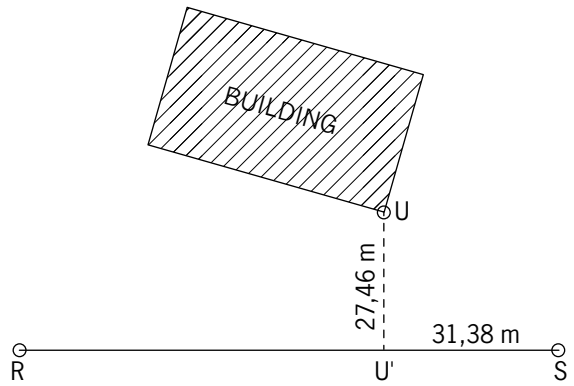


- From the site control points, establish the precise position of A and B. This is so that AB will be 2,5 m away from the centre line of the bottom row of columns as well as 2,5 m away from the left- and

right side columns.

- The distance from A to B will therefore be 18,50 m.
- From A, using circle left and circle right, set out D perpendicular to line AB to position D 2,5 m away from the top row of columns.
- The distance AD will therefore be 14,50 m.
- From B, set out C in the same way.

4.



- Set up, centre and level the theodolite at S, sight point R and measure the distance 31,38 m from S towards R (along the line of sight) to fix point U'.
- Move the theodolite and set up at U', sight point R and set the horizontal circle to read zero, then rotate the telescope towards point U until the horizontal circle reads 90°.
- Measure the distance of 27,46 m from U' (along the line of sight) to fix point U.

Summative assessment: Module 5 SB page 168

1.1 C
1.2 E
1.3 B
1.4 A (4 × 1) (4)

2. **Direction ST**

ΔY_{ST}=1 270,45 –1 660,35 = –389,90
ΔX_{ST} = 255,67 – 345,07 = –89,40

$$ST = \tan^{-1}\left(\frac{389,90}{89,40}\right) + 180 = 257:05:09$$

Direction TS (This is a backward direction of ST)
TS = 257:05:09 – 180 = 77:05:09

Direction TU

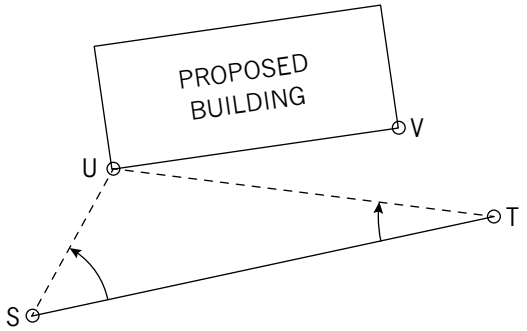
ΔY_{TU}=1 590,08 –1 270,45 = +319,63
ΔX_{TU} = 215,61 – 255,67 = –40,06

$$TU = \tan^{-1}\left(\frac{40,06}{319,63}\right) + 90 = 97:08:38$$

Direction SU

ΔY_{SU} = 1 590,08 – 1 660,35 = –70,27
ΔX_{SU} = 215,61 – 345,07 = –129,45

$$SU = \tan^{-1}\left(\frac{70,27}{129,45}\right) + 180 = 208:29:41$$



- Set up, centre and level the theodolite at point S, sight at point T and set the horizontal circle to read 257:05:09.
- Rotate the telescope towards point U until is read on the horizontal circle.
- Set up, centre and level another theodolite at point T, sight at point S and set the horizontal circle to read 77:05:09.

- Rotate the telescope towards point U until 97:08:38 is read on the horizontal circle.
- Move a ranging rod along the line of sight of the two theodolite until the intersection of the line of sight of the two theodolites is established, this will be point U. (10)

Total: 14 marks

MODULE

6 *Road construction*

After they have completed this module, students should be able to:

- describe the methods of surveying routes for roads, excluding aerial surveying;
- describe the setting out of centre- or offset lines;
- explain the road construction process;
- explain the following types of circular curves:
  - simple curve
  - compound curve
  - reverse curve;
- explain the procedure of setting out a small radius curve;
- calculate and tabulate the setting out of road curves;
- state and explain the following methods of setting out small radius curves:
  - finding the centre
  - offsets from the tangent
  - offsets from the long chord
  - offsets from the chords produced;
- state and explain the following methods of setting out large radius curves:
  - offsets from the chords produced
  - tangential angles
- explain the setting out of the curve when the tangential angle is known
- calculate tangential angles
  - using two theodolites;
- describe the types of controls used for the following:
  - embankments
  - cuttings
  - levels;
- calculate the volume of cut and fill on a straight road with traverse sloping ground;
- determine the reduced level of cutting and embankment controls;
- plot road widths and embankment lines to scale;
- plot cutting and embankment lines to scale; and
- calculate the volume of materials contained in earthworks using the following rules:
  - Simpson's rule
  - trapezoidal rule
  - prismoidal formula
  - frustrum formula.

Introduction

Route surveys comprise all the survey operations required for the design and construction of engineering work, such as highways, pipelines, canals or railroads. After design, approval, planning, legal and environmental considerations are addressed, the surveyor sets out the alignment of the road. The circular curves and gradients (slopes) are designed and staked out to best suit the natural ground levels and to minimise the amount of cut and fill, with care being taken to preserve reference points.

Exercise 6.1

SB page 190

1. Given:

T = 69,63 m

C*d* = 10,45 m

BC = 452,80 m

$$T \tan\left(\frac{\Delta}{4}\right) = Cd$$

$$69{,}63 \tan\left(\frac{\Delta}{4}\right) = \frac{10{,}45}{69{,}63}$$

$$\frac{\Delta}{4} = \tan^{-1}\left(\frac{10{,}45}{69{,}63}\right)$$

$$\frac{\Delta}{4} = 08{:}22{:}27$$

$$\Delta = 33{:}29{:}48$$

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

$$R \tan \frac{33{:}29{:}48}{2} = 69{,}63$$

$$R \times 0{,}301 = 69{,}63$$

$$R = \frac{69{,}63}{0{,}301}$$

$$R = 231{,}32 \text{ m}$$

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

$$La = \frac{\pi \times 33{:}29{:}48 \times 231{,}32}{180}$$

$$La = 135{,}24$$

$$EC = BC + La$$

$$= 452{,}80 + 135{,}24$$

$$= 588{,}04 \text{ m}$$

Chainage	Short chord	Tangent angle	Total tangent angle
BC		00:00:00	00:00:00
452,80	7,20	00:53:29	00:53:29
460,00	20,00	02:28:35	03:22:04
480,00	20,00	02:28:35	05:50:39
500,00	20,00	02:28:35	08:19:14
520,00	20,00	02:28:35	10:47:49
540,00	20,00	02:28:35	13:16:24
560,00	20,00	02:28:35	15:44:59
580,00	8,04	00:59:57	16:44:56
588,04			
135,24	**135,24**	**16:44:56**	**16:44:56**

2. Given:

IP = 3 232,37 m

$\frac{\Delta}{2}$ = 21:15:24

R = 231,78 m

$\frac{\Delta}{2}$ = 21:15:24

Δ = 21:15:24 × 2

Δ = 42: 30: 48

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

$La = \frac{\pi \times 42:30:48 \times 231,78}{180}$

La = 171,98

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

T = 231,78 tan 21:15:24

T = 90,17 m

BC = IP – T

BC = 3 232,37 – 90,17

BC = 3 142,20 m

EC = BC + La

= 3 142,20 + 171,98

= 3 314,18 m

Chainage	Short chord	Tangent angle	Total tangent angle
BC		00:00:00	360:00:00
3 142,20	17,80	02:12:00	357:48:00
3 160,00	20,00	02:28:19	355:19:41
3 180,00	20,00	02:28:19	352:51:22
3 200,00	20,00	02:28:19	350:28:03
3 220,00	20,00	02:28:19	347:54:44
3 240,00	20,00	02:28:19	345:26:26
3 260,00	20,00	02:28:19	342:58:06
3 280,00	20,00	02:28:19	340:29:47
3 300,00	14 18	01:45:10	338:44:37
3 314,18			
171,98	**171,98**	**21:15:23**	**21:15:23**

3. Given: R = 200,2 m Δ = 42:21:24 IP = 3 192,87 m

3.1 $T = R \tan \frac{\Delta}{2}$

$T = 200{,}2 \tan \left(\frac{42:21:24}{2} \right)$

T = 77,57 m

3.2 $La = \frac{\pi \Delta R}{180}$

$La = \frac{\pi \times 42:21:24 \times 200{,}2}{180}$

La = 148,00 m

3.3 BC = IP – T

BC = 3 192,87 – 77,57

BC = 3 115,30 m

3.4 EC = BC + La

= 3 115,30 + 148,00

= 3 263,30 m

3.5

Chainage	Short chord	Tangent angle	Total tangent angle
BC		00:00:00	360:00:00
3 115,30	4,70	00:41:21	359:19:39
3 120,00	20,00	02:51:43	356:27:56
3 140,00	20,00	02:51:43	353:36:13
3 160,00	20,00	02:51:43	350:44:30
3 180,00	20.00	02:51:43	347:52:47
3 200,00	20,00	02:51:43	345:01:04
3 220,00	20,00	02:51:43	342:09:21
3 240,00	20,00	02:51:43	339:17:38
3 260,00	3,30	00:28:19	338:49:19
3 263,30			
148,00	**148,00**	**21:10:41**	**21:10:41**

4. Given: Δ = 49:50:18 BC 1 826,36 m EC= 1 988,59 m R = 186,50 m

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

$$La = \frac{\pi \times 49{:}50{:}18 \times 186{,}50}{180}$$

La = 162,23 m

Chainage	Short chord	Tangent angle	Total tangent angle
BC		00:00:00	360:00:00
1 826,36	13,64	02:05:43	357:54:17
1 840,00	20,00	03:04:20	354:49:57
1 860,00	20,00	03:04:20	351:45:37
1 880,00	20,00	03:04:20	348:41:17
1 900,00	20,00	03:04:20	345:36:57
1 920,00	20,00	03:04:20	342:32:37
1 940,00	20,00	03:04:20	339:28:17
1 960,00	20,00	03:04:20	336:23:57
1 980,00	8,59	01:19:10	335:04:47
1 988,59			
162,23	**162,23**	**24:55:13**	**24:55:13**

5. Given: AB = 240:30:15 CB = 74:35:20 R = 215,60 m

Co-ordinates

A	+1 500,00	+2 640,00
B	1 150,00	+2 033,78

5.1 CB = 74:35:20
BC = 254:35:20

Δ = 254:35:20 – 240:32:15
= 14:03:05

5.2 $T = R \tan \frac{\Delta}{2}$

$T = 215{,}60 \tan \left(\frac{14:03:05}{2} \right)$

T = 26,57 m

5.3 $La = \frac{\pi \Delta R}{180}$

$La = \frac{\pi \times 14:03:05 \times 215{,}60}{180}$

La = 52,87 m

5.4 ΔY_{AB} = 1 150 – 1 500 = –350
ΔX_{AB} = 2 033,78 – 2 640 = –606,22
$AB = \sqrt{350^2 + 606{,}22^2}$
AB = 700 m (This is chainage at IP)

BC = IP – T
BC = 700 – 26,57
BC = 673,43 m

5.5 EC = BC + La
EC = 673,43 + 52,57
EC = 726

5.6

Chainage	Short chord	Tangent angle	Total tangent angle
BC		00:00:00	00:00:00
673,43	6,57	00:52:23	00:52:23
680,00	20,00	02:39:27	03:31:50
700,00	20,00	02:39:27	06:11:17
720,00	6,00	00:47:50	06:59:07
726,00			
52,57	**52,57**	**06:59:07**	**06:59:07**

6. Given: EC = 2 47,20 R = 146 Δ = 61:08:30

6.1 $La = \frac{\pi \Delta R}{180}$

$La = \frac{\pi \times 61{:}08{:}30 \times 146}{180}$

La = 155,80 m

BC = EC – La
BC = 2 047,20 – 155,80
BC = 1 891,40 m

Chainage	Short chord	Tangent angle	Total tangent angle
BC		00:00:00	360:00:00
1 891,40	8,60	01:41:15	358:18:45
1 900,00	20,00	03:55:28	354:23:17
1 920,00	20,00	03:55:28	350:27:49
1 940,00	20,00	03:55:28	346:32:21
1 960,00	20,00	03:55:28	342:36:53
1 980,00	20,00	03:55:28	338:41:25
2 000,00	20,00	03:55:28	334:45:57
2 020,00	20,00	03:55:28	330:50:29
2 040,00	7,20	01:24:46	329:25:43
2 047,00			
155,80	**155,80**	**30:34:17**	**30:34:17**

6.2 $Cd = T \tan \frac{\Delta}{4}$

$Cd = 146 \tan \left(\frac{61{:}08{:}30}{4} \right)$

Cd = 39,90 m

7.1 Given: R = 164,50 m $\frac{\Delta}{2}$ = 21:15:24 IP = 2 718,60

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

T = 164,50 tan 21:15:24

T = 63,99 m

7.2 $Lc = 2R \sin \frac{\Delta}{2}$

Lc = 2 × 164,5 sin 21:15:24

Lc = 119,28

$\frac{\Delta}{2}$ = 21: 15: 24

Δ = 42: 30: 48

7.3 $Cd = T \tan \frac{\Delta}{4}$

$Cd = 63{,}99 \tan \left(\frac{42:30:48}{4} \right)$

$Cd = 24{,}89 \text{ m}$

$BC = IP - T$

$BC = 2\,718{,}60 - 63{,}99$

$BC = 2\,654{,}61 \text{ m}$

8. Given: $\Delta = 38:44:28$ $R = 230$ m

Co-ordinates

IP	+ 2 528,46	+ 3 012,42
Zero chainage	+ 1 321,96	+ 5 812,38

$\Delta Y = 1\,321{,}96 - 2\,528{,}46 = -1\,206{,}50$

$\Delta X = 5\,812{,}38 - 3\,012{,}42 = +2\,799{,}96$

Chainage at IP $= \sqrt{1\,206{,}5^2 + 2\,799{,}96^2}$

$= 3\,048{,}84$

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

$T = 230 \tan \left(\frac{38:44:28}{2} \right)$

$T = 80{,}86 \text{ m}$

$BC = 3\,048 - 80{,}86$

$BC = 2\,967{,}98$

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

$La = \frac{\pi \times 38:44:28 \times 230}{180}$

$La = 155{,}52 \text{ m}$

$EC = 2\,967{,}98 + 155{,}52$

$EC = 3\,123{,}50$

Chainage	Short chord	Tangent angle	Total tangent angle
BC		00:00:00	00:00:00
2 967,98	12,02	01:29:50	01:29:50
2 980,00	20,00	02:29:28	03:59:18
3 000,00	20,00	02:29:28	06:28:46
3 020,00	20,00	02:29:28	08:58:14
3 040,00	20,00	02:29:28	11:27:42
3 060,00	20,00	02:29:28	13:57:10
3 080,00	20,00	02:29:28	16:26:38
3 100,00	20,00	02:29:28	18:56:06
3 120,00	3 50	00:26:09	19:22:15
3 123,50			
155 52	**155.52**	**19:22:15**	**19:22:15**

9. Given: IP – BC = 44:24:22 IP – EC = 263:04:44
IP = 3 747,70 R = 205,20 m

IP – BC = 44:24:22
BC – IP = 224:44:22

Δ = 263:04:44 – 224:24:22
= 38:40:22

$$T = R \tan \frac{\Delta}{2}$$
$$T = 205{,}20 \tan \left(\frac{38:40:22}{2} \right)$$
T = 72,01 m

BC = 3 747,70 – 72,01
BC = 3 675,69 m

$$La = \frac{\pi \Delta R}{180}$$
$$La = \frac{\pi \times 38:40:22 \times 205{,}20}{180}$$
La = 138,50 m

EC = 3 675,69 + 138,50
EC = 3 814,19 m

Chainage	Short chord	Tangent angle	Total tangent angle
BC		00:00:00	00:00:00
3 675,69	4,31	00:36:06	00:36:06
3 680,00	20,00	02:47:32	03:23:38
3 700,00	20,00	02:47:32	06:11:10
3 720,00	20,00	02:47:32	08:58:42
3 740,00	20,00	02:47:32	11:46:14
3 760,00	20,00	02:47:32	14:33:46
3 780,00	20,00	02:47:32	17:21:18
3 800,00	14,19	01:58:52	19:20:10
3 814,19			
138,50	**138,50**	**19:20:10**	**19:20:10**

Practical group activity 6.1

Encourage students to conduct the following practical activity.

Instructions

Form a survey team consisting of THREE members. One will hold the ranging rod, one will operate the theodolite and one will do the chaining or taping.

Task

Do the necessary calculation and set out a curve using the following information:

- The radius of the curve is 15 m.
- The direction from the beginning of the curve to the intersection point is 225:00:00.
- The direction from the intersection point to the end of the curve is 337:30:10.
- The radius of the curve is 15 m.
- Chainage at the intersection point is 30 m.
- A peg is required for every 5 m chainage.

Practical group activity 6.2

Encourage students to conduct the following practical activity.

Instructions

- Form a survey team consisting of THREE members, comprising two followers and one leader.
- Set out a 10 m line to represent a tangent.

Task

Do the necessary calculations and set out a curve by perpendicular offset using the following information:

- The radius of the curve is 10 m.
- The interval between the offset points is 2 m.

Exercise 6.2

SB page 211

1. Given: $h = 3{,}78$ m $s = 3$ W = 9 m L = 556,87 m

$A = h(W + hs)$

$A = 3{,}78[9 + 3{,}78(3)]$

$A = 76{,}89\ m^2$

$V = A \times L$

$V = 76{,}89 \times 556{,}87$

$V = 42\ 817{,}73\ m^3$

2. Given:

	At A	At B
Chainage	1 536,28 m	1 686,91 m
Formation width	5 m (a = 2,5 m)	
Side slope (s)	2,5 m	
Ground slope (g)	5 m	7 m
Centre height (h)	2,68 m	1,92

At A

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

$$W_1 = \frac{5[2{,}5+2{,}68(2{,}5)]}{5-2{,}5}$$

$$W_1 = \frac{46}{2{,}5}$$

$W_1 = 18{,}40$ m

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

$$W_2 = \frac{46}{6+1{,}5}$$

$W_2 = 6{,}13$ m

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

$$A_A = \frac{(18{,}40 \times 6{,}13) - 2{,}5^2}{2{,}5}$$

$$A_A = 42{,}62 \text{ m}^2$$

At B

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

$$W_1 = \frac{7[2{,}5 + 1{,}92(2{,}5)]}{7 - 2{,}5}$$

$$W_1 = \frac{51{,}1}{4{,}5}$$

$$W_1 = 20{,}44 \text{ m}$$

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

$$W_2 = \frac{51{,}1}{7 + 2{,}5}$$

$$W_2 = 5{,}38 \text{ m}$$

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

$$A_B = \frac{(20{,}44 \times 5{,}38) - 2{,}5^2}{2{,}5}$$

$$A_B = 41{,}49^2$$

Distance from A to B = 1 686,91 − 1 536,28
= 150,63 m

$$\text{Volume} = \left(\frac{A_A + A_B}{2} \right) \times L$$

$$= \left(\frac{42{,}62 + 41{,}49}{2} \right) \times 150{,}63$$

= 6 334,74 m

3. Given: h = 3,78 m s = 3 W = 9 m L = 556,87 m

$$A = h(W + hs)$$

$$A = 3{,}78[9 + 3{,}78(3)]$$

$$A = 76{,}89 \text{ m}^2$$

$$V = A \times L$$

$$V = 76{,}89 \times 556{,}87$$

$$V = 42\,817{,}73 \text{ m}^3$$

4. Given:

	At K	At L
Chainage	3 456,38 m	3 206,86 m
Formation width	8 m (a = 4 m)	
Side slope (s)	3 m	
Ground slope (g)	4 m	6 m
Centre height (h)	2,43 m	1,82 m

At K

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

$$W_1 = \frac{4[4+2{,}43(3)]}{4-3}$$

$$W_1 = \frac{45{,}16}{1}$$

$$W_1 = 45{,}1 \text{ m}$$

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

$$W_2 = \frac{45{,}16}{4+3}$$

$$W_2 = 6{,}45 \text{ m}$$

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

$$A_K = \frac{(45{,}16 \times 6{,}45)-4^2}{3}$$

$$A_K = 91{,}76 \text{ m}^2$$

At L

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

$$W_1 = \frac{6[4+1{,}82(3)]}{6-3}$$

$$W_1 = \frac{56{,}76}{3}$$

$$W_1 = 18{,}92 \text{ m}$$

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

$$W_2 = \frac{56{,}76}{6+3}$$

$$W_2 = 6{,}31 \text{ m}$$

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

$$A_L = \frac{(18{,}92 \times 6{,}31) - 4^2}{3}$$

$$A_L = 34{,}46 \text{ m}^2$$

Distance from K to L = 3 456,38 – 3 206,86
= 249,52 m

$$\text{Volume} = \left(\frac{A_K + A_L}{2}\right) \times L$$

$$= \left(\frac{91{,}76 + 34{,}46}{2}\right) \times 249{,}52$$

$$= 15{,}747{,}21 \text{ m}^3$$

5. Given:

	At C	At D
Chainage	3 589,52 m	3 726,02 m
Formation width	13 m (a = 6,5 m)	
Side slope (s)	1,6 m	
Ground slope (g)	4 m	8 m
Centre height (h)	2,52 m	2,13 m

At C

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

$$W_1 = \frac{4[6{,}5 + 2{,}52(1{,}6)]}{4-1{,}6}$$

$$W_1 = \frac{42{,}13}{2{,}4}$$

$$W_1 = 17{,}55 \text{ m}$$

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

$$W_2 = \frac{42{,}13}{4 + 1{,}6}$$

$$W_2 = 7{,}52 \text{ m}$$

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

$$A_C = \frac{(17{,}55 \times 7{,}52) - 6{,}5^2}{1{,}6}$$

$$A_C = 56{,}08 \text{ m}^2$$

At D

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

$$W_1 = \frac{8[6{,}5 + 2{,}13(1{,}6)]}{8 - 1{,}6}$$

$$W_1 = \frac{79{,}26}{6{,}4}$$

$$W_1 = 12{,}38 \text{ m}$$

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

$$W_2 = \frac{79{,}26}{8 + 1{,}6}$$

$$W_2 = 37{,}51 \text{ m}^2$$

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

$$A_D = \frac{(12{,}38 \times 8{,}26) - 6{,}5^2}{1{,}6}$$

$$A_D = 37{,}51 \text{ m}^2$$

Distance from C to D = 3 726,02 – 3 589,52
= 136,50 m

$$\text{Volume} = \left(\frac{A_C + A_D}{2}\right) \times L$$

$$= \left(\frac{56{,}08 + 37{,}51}{2}\right) \times 136{,}50$$

$$= 6\,387{,}52 \text{ m}^3$$

6. Given:

	At M	At N
Chainage	2 065,00 m	2 380,00 m
Formation width	8 m (a = 4 m)	
Side slope (s)	2,5 m	
Ground slope (g)	5 m	6,5 m
Centre height (h)	8,15 m	6,20 m

At M

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

$$W_1 = \frac{5[4+8,15(2,5)]}{5-2,5}$$

$$W_1 = \frac{121,89}{2,5}$$

$$W_1 = 48,75 \text{ m}$$

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

$$W_2 = \frac{121,89}{5+2,5}$$

$$W_2 = 16,25 \text{ m}$$

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

$$A_M = \frac{(48,75 \times 16,25)-4^2}{2,5}$$

$$A_M = 310,48 \text{ m}^2$$

At N

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

$$W_1 = \frac{6,5[4+6,20(2,5)]}{6,5-2,5}$$

$$W_1 = \frac{126,75}{4}$$

$$W_1 = 31,69 \text{ m}$$

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

$$W_2 = \frac{126,75}{6,5+2,5}$$

$$W_2 = 14,0 \text{ m}$$

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

$$A_N = \frac{(31,69 \times 14,08)-4^2}{2,5}$$

$$A_N = 172,08 \text{ m}^2$$

Distance from M to N = 2 380 − 2 065
= 315 m

$$\text{Volume} = \left(\frac{A_M + A_N}{2}\right) \times L$$
$$= \left(\frac{310{,}48 + 172{,}08}{2}\right) \times 315$$
$$= 76\,003{,}20\ m^3$$

7. Given: W = 7 m h = 2,24 m s = 3 g = 9

$$W_1 = \frac{g(a + hs)}{g - s}$$
$$W_1 = \frac{9[3{,}5 + 2{,}24(3)]}{9 - 3}$$
$$W_1 = \frac{91{,}98}{6}$$
$$W_1 = 15{,}33\ m$$
$$W_2 = \frac{g(a + hs)}{g + s}$$
$$W_2 = \frac{91{,}98}{9 + 3}$$
$$W_2 = 7{,}67\ m$$
$$A = \frac{(W_1 \times W_2) - a^2}{s}$$
$$A = \frac{(15{,}33 \times 7{,}6) - 3{,}5^2}{3}$$
$$A = 35{,}11\ m^2$$

8. Given:

	At D	**At E**
Chainage	1 565,32 m	1 745,85
Formation width	6,5 m (a = 3,25 m)	
Side slope (s)	2,5 m	
Ground slope (g)	4 m	7 m
Centre height (h)	2,85 m	1,95 m

At D

$$W_1 = \frac{g(a + hs)}{g - s}$$
$$W_1 = \frac{4[3{,}25 + 2{,}85(2{,}5)]}{4 - 2{,}5}$$
$$W_1 = \frac{41{,}50}{1{,}5}$$
$$W_1 = 27{,}67\ m$$

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

$$W_2 = \frac{41,50}{4+2,5}$$

$$W_2 = 6,38 \text{ m}$$

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

$$A_D = \frac{(27,67 \times 6,38) - 3,25^2}{2,5}$$

$$A_D = 66,39 \text{ m}^2$$

At E

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

$$W_1 = \frac{7[3,25+1,95(2,5)]}{7-2,5}$$

$$W_1 = \frac{56,88}{4,5}$$

$$W_1 = 12,64 \text{ m}$$

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

$$W_2 = \frac{56,88}{7+2,5}$$

$$W_2 = 5,99 \text{ m}$$

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

$$A_E = \frac{(12,64 \times 5,99) - 3,25^2}{2,5}$$

$$A_E = 26,06 \text{ m}^2$$

Distance from D to E = 1 745,85-1 565,32
= 180,53 m

$$\text{Volume} = \left(\frac{A_D + A_E}{2} \right) \times L$$

$$= \left(\frac{66,39 + 26,06}{2} \right) \times 180,53$$

$$= 8\,345 \text{ m}^3$$

9. Given: W = 10 m (a = 5 m) h = 5 m s = 3 g = 7

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

$$W_1 = \frac{7[5+5(3)]}{7-3}$$

$$W_1 = \frac{140}{4}$$

$$W_1 = 46{,}67 \text{ m}$$

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

$$W_2 = \frac{140}{7+3}$$

$$W_2 = 14 \text{ m}$$

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

$$A = \frac{(46{,}67 \times 14)-5^2}{3}$$

$$A = 209{,}46 \text{ m}^2$$

10. Given: W = 12 m (s = 6 m) h = 2,96 m s = 3 g = 7

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

$$W_1 = \frac{7[6+2{,}96(3)]}{7-3}$$

$$W_1 = \frac{104{,}16}{4}$$

$$W_1 = 26{,}04 \text{ m}$$

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

$$W_2 = \frac{104{,}16}{7+3}$$

$$W_2 = 10{,}42 \text{ m}$$

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

$$A = \frac{(26{,}04 \times 10{,}42)-6^2}{3}$$

$$A = 78{,}45 \text{ m}^2$$

11. Given: W = 10 m (a = 5 m) n = 1 m = 3 g = 4 m h = 0,5 m

$$W_1 = \frac{g(a+nh)}{g-n}$$

$$W_1 = \frac{4[5+1(0,5)]}{6-1}$$

$$W_1 = 4,4 \text{ m}$$

$$W_2 = \frac{g(a+mh)}{g-m}$$

$$W_2 = \frac{4[5-3(0,5)]}{6-3}$$

$$W_2 = 4,67 \text{ m}$$

$$\text{Fill area} = \frac{1}{2}\left[\frac{(a-gh)^2}{g-m}\right]$$

$$\text{Fill area} = \frac{1}{2}\left\{\frac{[5-4(0,5)]^2}{4-3}\right\}$$

$$\text{Fill area} = 4,5 \text{ m}^2$$

$$\text{Cut area} = \frac{1}{2}\left[\frac{(a+gh)^2}{g-n}\right]$$

$$\text{Cut area} = \frac{1}{2}\left\{\frac{[5+4(0,5)]^2}{4-1}\right\}$$

$$\text{Cut area} = 8,17 \text{ m}^2$$

12. Given: W = 10 m (a = 5 m) n = 2,5 m = 4 g = 5 h = 0,4 m

12.1 $$\text{Fill area} = \frac{1}{2}\left[\frac{(a-gh)^2}{g-m}\right]$$

$$\text{Fill area} = \frac{1}{2}\left\{\frac{[5+5(0,45)]^2}{5-4}\right\}$$

$$\text{Fill area} = 3,78 \text{ m}^2$$

12.2 $$\text{Cut area} = \frac{1}{2}\left[\frac{(a+gh)^2}{g-n}\right]$$

$$\text{Cut area} = \frac{1}{2}\left\{\frac{[5+5(0,45)]^2}{5-2,5}\right\}$$

$$\text{Cut area} = 10,51 \text{ m}^2$$

12.3 Distance AB = 3 925 – 3 125 = 800 m

12.4 $V_{Fill} = A \times L$

$V_{Fill} = 3,78 \times 800$

$V_{Fill} = 3\,024 \text{ m}^3$

12.5 $V_{Cut} = A \times L$
$V_{Cut} = 10{,}51 \times 800$
$V_{Cut} = 8\ 408\ m^3$

12.6 $V = V_{Cut} - V_{Fill}$
$V = 8\ 408 - 3\ 024$
$V = 5\ 384\ m^2$

13. Fill area $= \frac{1}{2}\left[\frac{(a-gh)^2}{g-m}\right]$
Fill area $= \frac{1}{2}\left\{\frac{[5{,}33-2{,}8(0{,}66)]^2}{2{,}8-1}\right\}$
Fill area $= 3{,}37\ m^2$

Cut area $= \frac{1}{2}\left[\frac{(a+gh)^2}{g-n}\right]$
Cut area $= \frac{1}{2}\left\{\frac{[5{,}33+2{,}8(0{,}66)]^2}{2{,}8-0{,}9}\right\}$
Cut area $= 13{,}56\ m^2$

14. Fill area $= \frac{1}{2}\left[\frac{(a+gh)^2}{g-m}\right]$
Fill area $= \frac{1}{2}\left\{\frac{[4{,}94+2(0{,}56)]^2}{2-0{,}5}\right\}$
Fill area $= 12{,}24\ m^2$

Cut area $= \frac{1}{2}\left[\frac{(a-gh)^2}{g-n}\right]$
Cut area $= \frac{1}{2}\left\{\frac{[4{,}94-2(0{,}56)]^2}{2-0{,}6}\right\}$
Cut area $= 8{,}32\ m^2$

Exercise 6.3

SB page 222

1. Given: W =14 m $s = 2$ $g = 8$ $RL_W = 192$ $RL_T = 184{,}16$ m

1.1 $h = 192 - 184{,}16 = 7{,}84$

$W_1 = \frac{g[a+hs]}{g-s}$

$W_1 = \frac{8[7+7{,}84(2)]}{8-2}$

$W_1 = 30{,}24$ m

$RL_S = RL_T - \frac{W_1}{g}$

$$RL_S = 184{,}16 - \frac{30{,}24}{8}$$

$$RL_S = 180{,}38 \text{ m}$$

1.2 $$RL_P = RL_S - \frac{2x}{s} + 1{,}5 \text{ m}$$

$$RL_P = 180{,}38 - \frac{2(0{,}8)}{2} + 1{,}5 \text{ m}$$

$$RL_P = 181{,}08 \text{ m}$$

1.3 $$RL_Q = RL_S + \frac{x}{s} + 1{,}5 \text{ m}$$

$$RL_Q = 180{,}38 - \frac{0{,}8}{2} + 1{,}5 \text{ m}$$

$$RL_Q = 181{,}48 \text{ m}$$

2. Given: W =16 m $s = 3$ $g = 10$ $RL_W = 196$ $h = 6{,}54$ m

2.1 $RL_K = 196 + 6{,}54 = 202{,}54$

2.2 $$W_2 = \frac{g[a + hs]}{g + s}$$

$$W_2 = \frac{10[8 + 6{,}54(3)]}{10 + 3}$$

$$W_2 = 21{,}25 \text{ m}$$

$$RL_L = RL_K - \frac{W_1}{g}$$

$$RL_L = 202{,}54 - \frac{21{,}25}{10}$$

$$RL_L = 200{,}42 \text{ m}$$

2.3 $$RL_D = RL_L + \frac{2x}{s} + 1{,}5 \text{ m}$$

$$RL_D = 200{,}42 + \frac{2(1)}{3} + 1{,}5 \text{ m}$$

$$RL_D = 201{,}42 \text{ m}$$

2.4 $$RL_E = RL_S + \frac{x}{s} + 1{,}5 \text{ m}$$

$$RL_E = 200{,}42 + \frac{1}{3} + 1{,}5 \text{ m}$$

$$RL_E = 202{,}25 \text{ m}$$

3. Given: W =13 m $s = 4$ $g = 8$ $RL_H = 216{,}40$
$h = 6{,}54$ m $RL_W = 224$ m

3.1 $h = 224 - 215{,}40 = 8{,}6$ m

$$W_2 = \frac{g[a + hs]}{g + s}$$

$$W_2 = \frac{8[6{,}5 + 8{,}6(4)]}{8 + 4}$$

$$W_2 = 27{,}27 \text{ m}$$

$$RL_F = RL_H + \frac{W_2}{g}$$

$$RL_F = 216{,}40 + \frac{27{,}27}{8}$$

$$RL_F = 219{,}81 \text{ m}$$

3.2 $$RL_S = RL_F - \frac{2x}{s} + 1{,}5 \text{ m}$$

$$RL_S = 219{,}81 - \frac{2(09)}{4} + 1{,}5 \text{ m}$$

$$RL_S = 220{,}86 \text{ m}$$

3.3 $$RL_R = RL_F - \frac{x}{s} + 1{,}5 \text{ m}$$

$$RL_R = 219{,}81 - \frac{0{,}9}{4} + 1{,}5 \text{ m}$$

$$RL_R = 221{,}09 \text{ m}$$

4. 4.1 $$RL_G = 320 + \left(\frac{1}{4} \times 9{,}45\right)$$

$$= 320 + 2{,}36$$

$$= 322{,}36 \text{ m}$$

4.2 $$RL_C = RL_G + \frac{2x}{s} + 1{,}5 \text{ m}$$

$$RL_C = 322{,}36 + \frac{2(1)}{4} + 1{,}5 \text{ m}$$

$$RL_C = 324{,}36 \text{ m}$$

4.3 $$RL_D = RL_G + \frac{x}{s} + 1{,}5 \text{ m}$$

$$RL_D = 322{,}36 + \frac{1}{4} + 1{,}5 \text{ m}$$

$$RL_D = 324{,}11 \text{ m}$$

4.4 $$RL_H = 320 - \left(\frac{1}{4} \times 8{,}4\right)$$

$$RL_H = 317{,}9 \text{ m}$$

4.5 $RL_E = RL_H - \frac{x}{s} + 1{,}5\text{ m}$

$RL_E = 317{,}9 - \frac{1}{4} + 1{,}5\text{ m}$

$RL_E = 319{,}15\text{ m}$

4.6 $RL_F = RL_H - \frac{2x}{s} + 1{,}5\text{ m}$

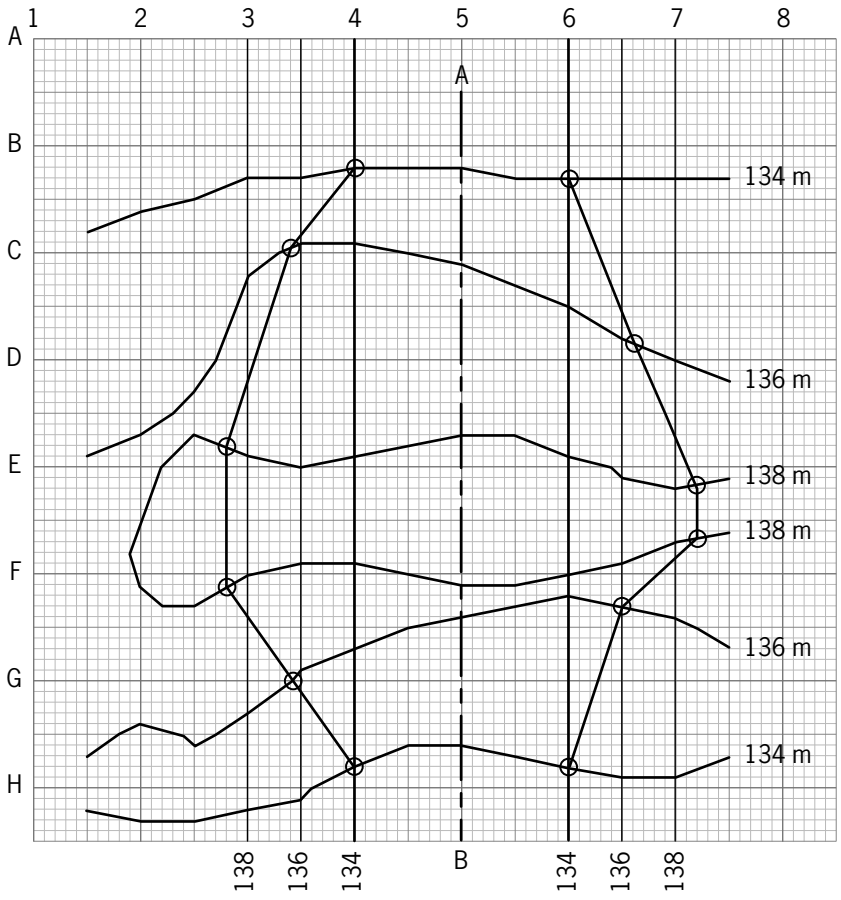
$RL_F = 317{,}9 - \frac{2(1)}{4} + 1{,}5\text{ m}$

$RL_F = 318{,}9\text{ m}$

Exercise 6.4

SB page 236

1.



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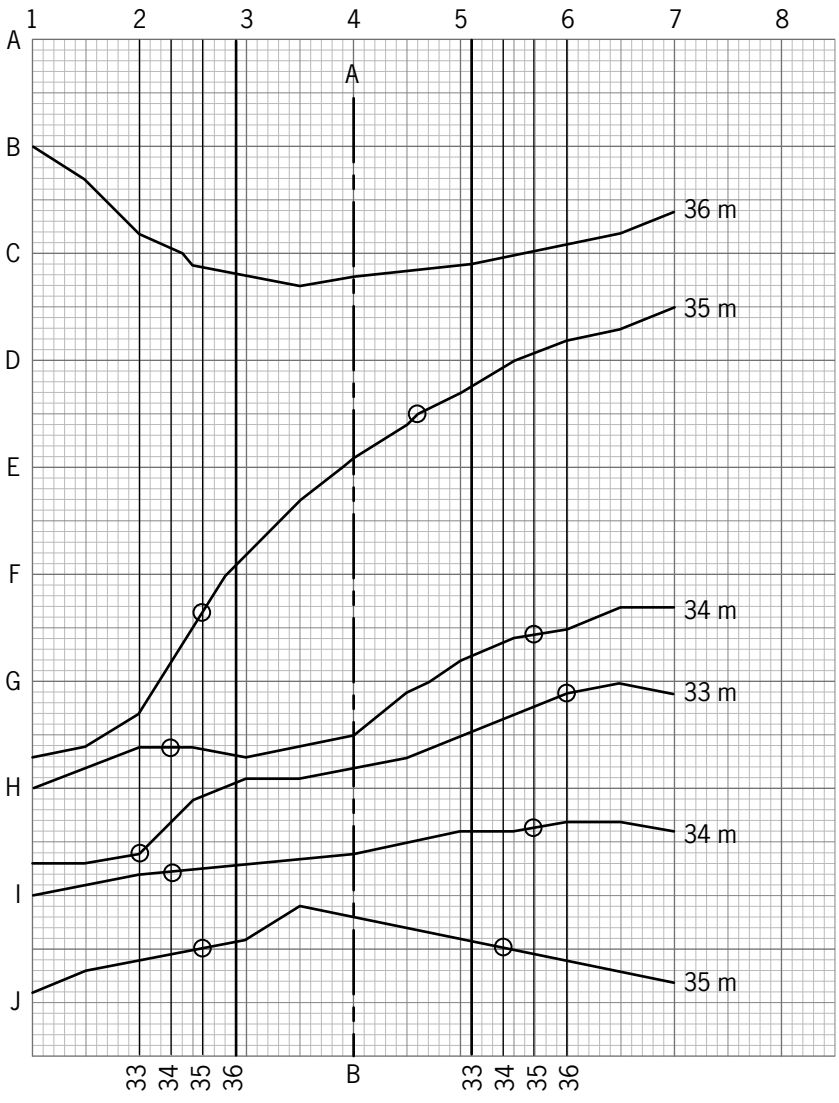
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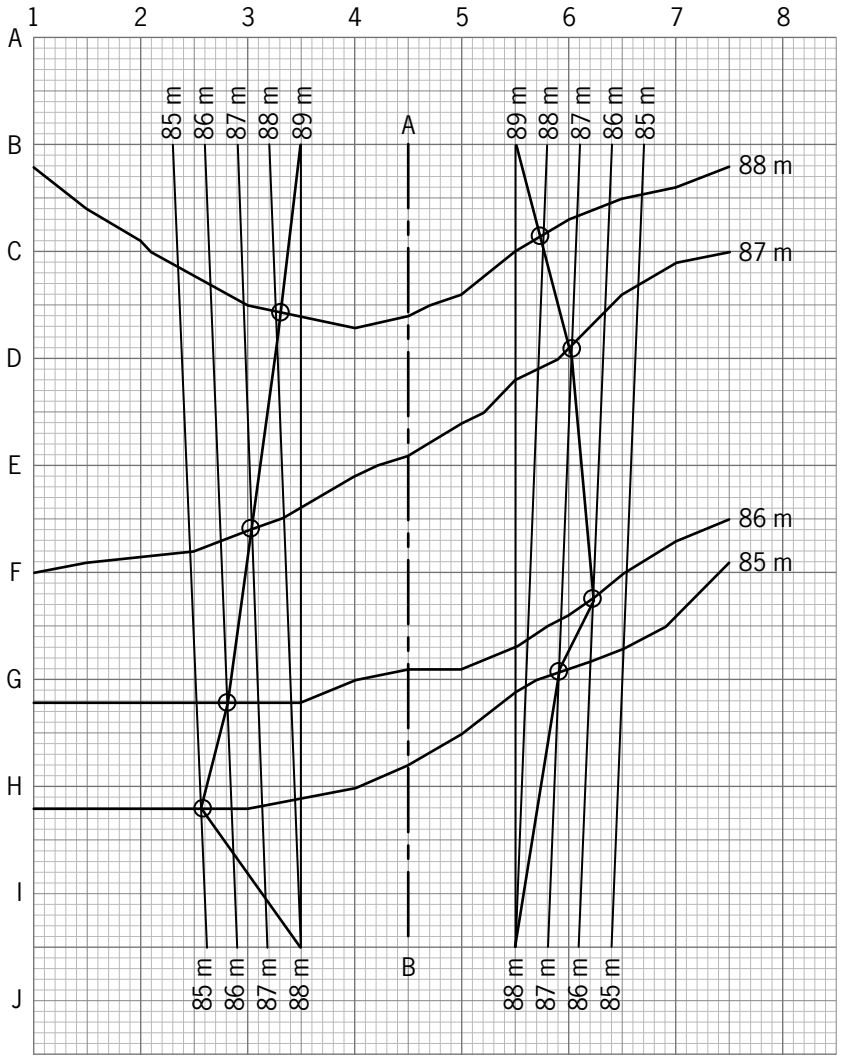

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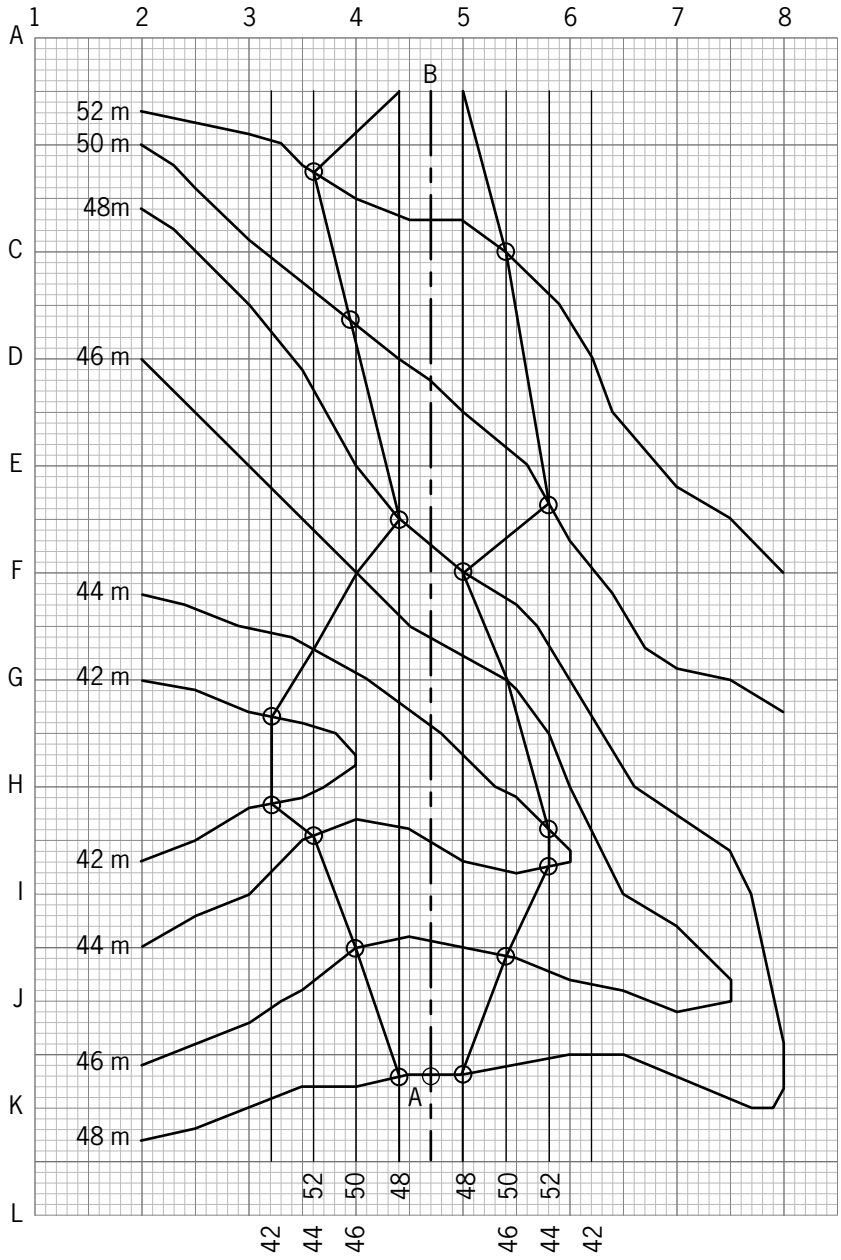
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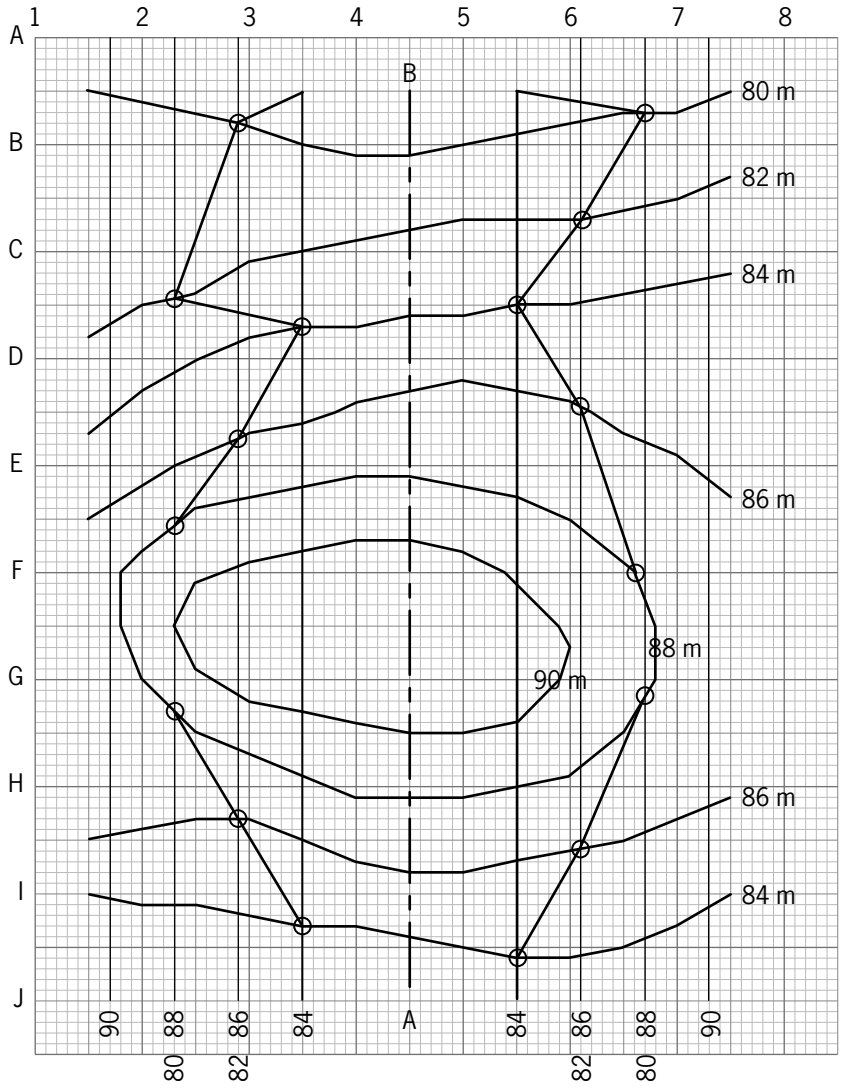
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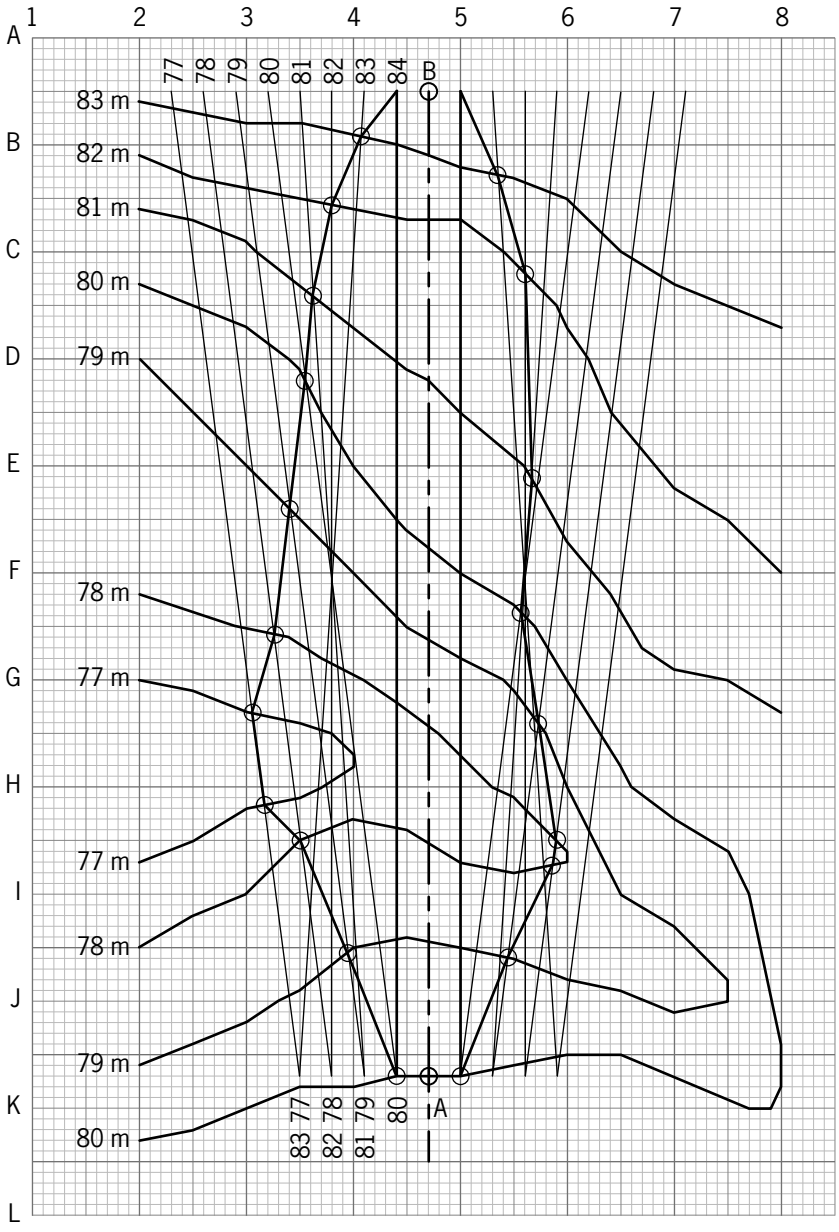
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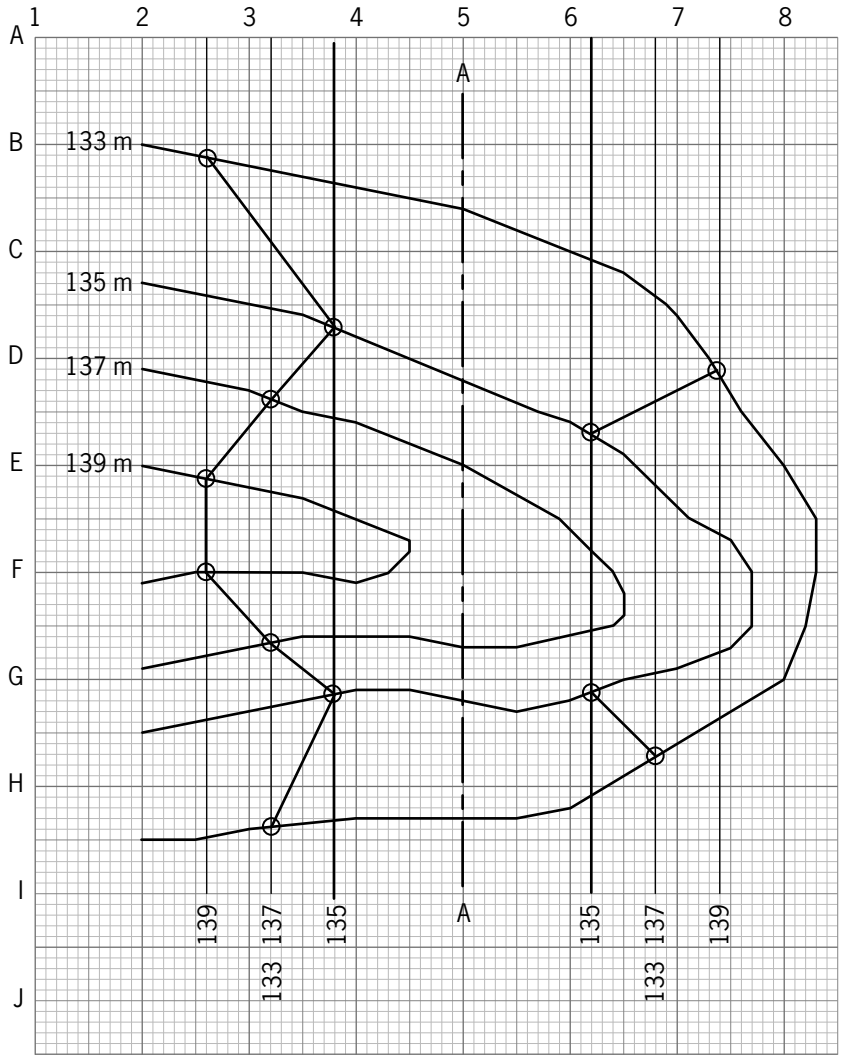
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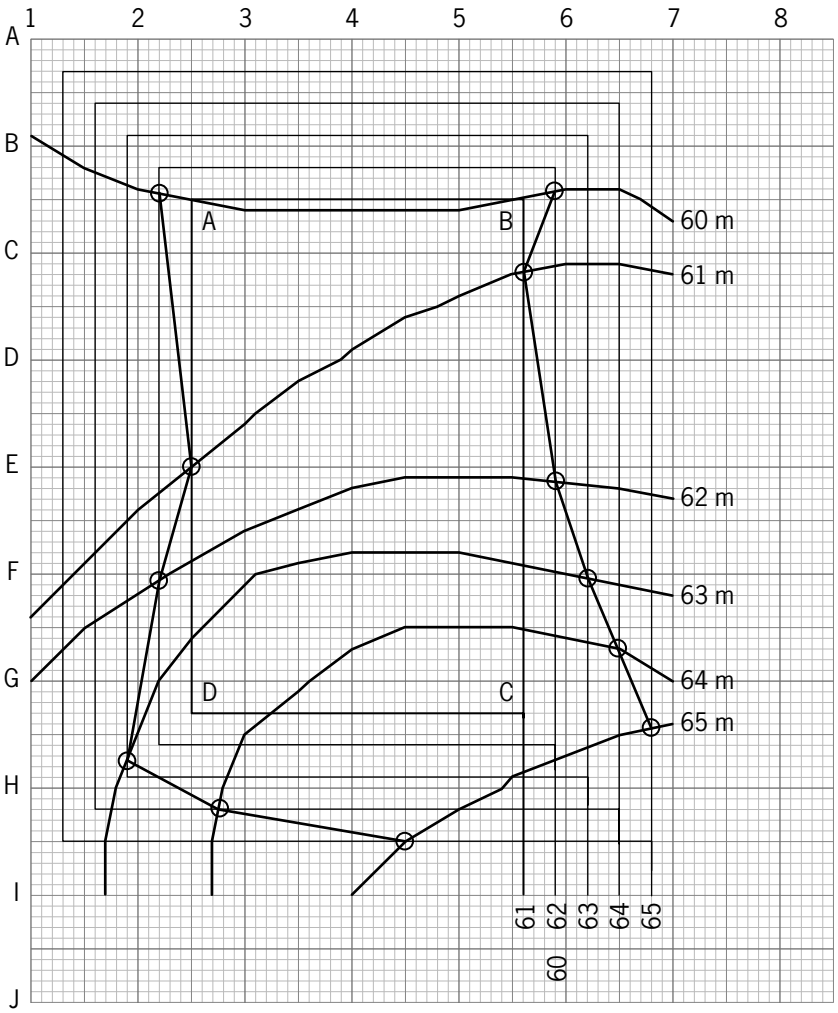
139

Exercise 6.5

SB page 246

1.



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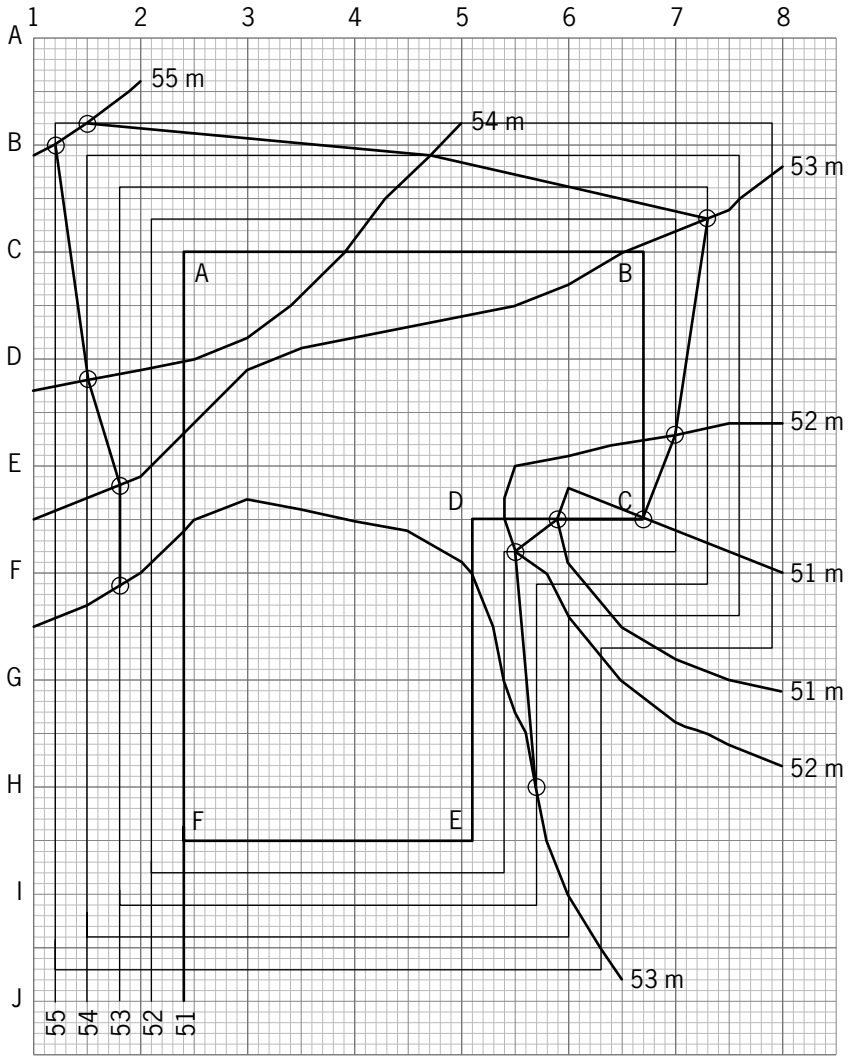
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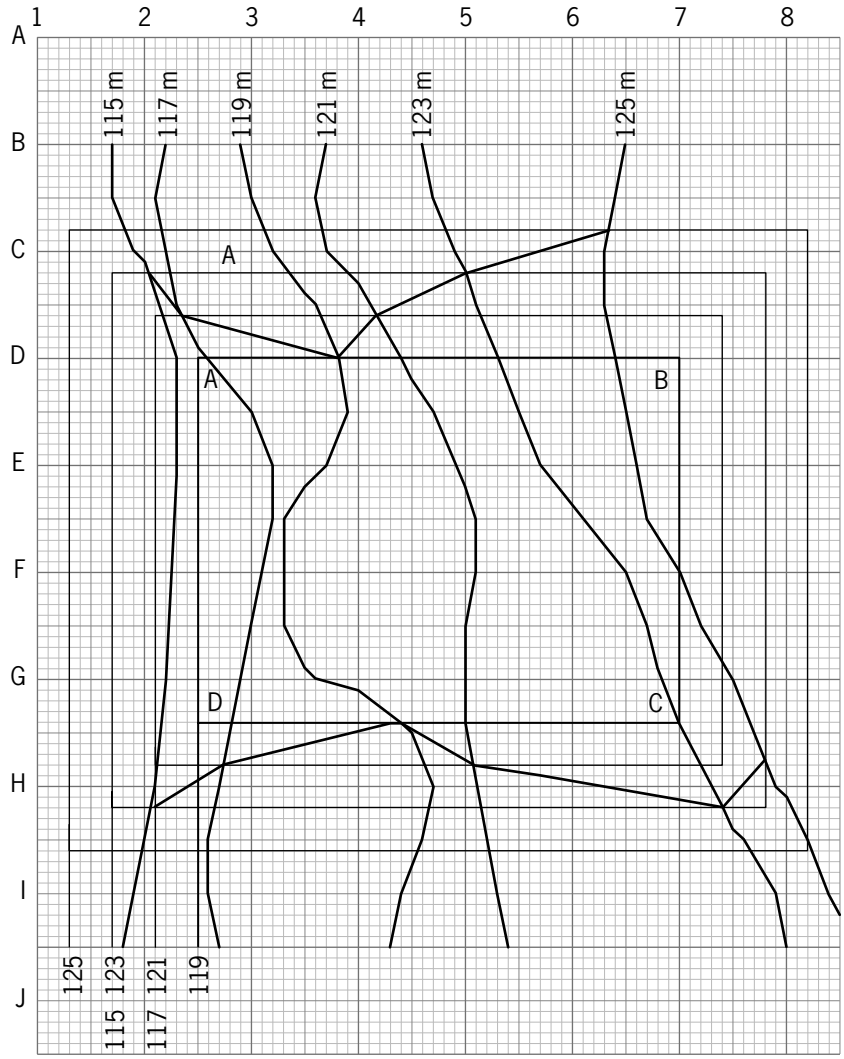
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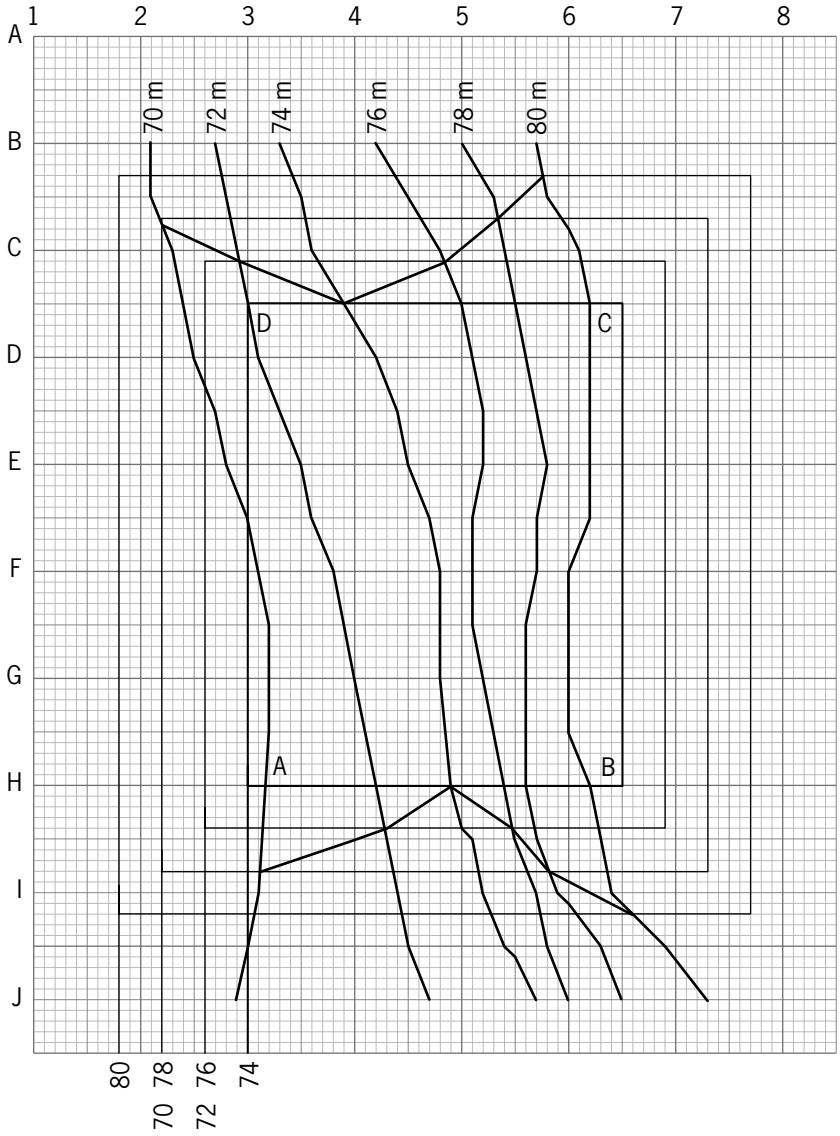
125
115 123
117 121
119

4.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72 m
74 m
76 m
78 m
80 m
D
C
A
B
80
70
78
72
76
74

Exercise 6.6

SB page 255

1. $A = h(w + hs)$

$A_1 = 5{,}30[6 + 5{,}30(2))]$

$A_1 = 87{,}98\ m^2$

$A_2 = 8{,}5[6 + 8{,}5(2))]$

$A_2 = 195{,}50\ m^2$

$A_3 = 10{,}45[6 + 10{,}45(2))]$

$A_3 = 231{,}11\ m^2$

$V = \frac{L}{2}[A_1 + A_n + 2(A_2 + A_3 + \ldots + A_n]$

$V = \frac{15}{2}[87{,}98 + 231{,}11 + 2(195{,}50)]$

$V = 7{,}5 \times 710{,}09$

$V = 5\ 325{,}68\ m^3$

2. $V = \frac{1}{3}[A_1 + A_n + 2(\text{odds}) + 4(\text{evens})]$

$V = \frac{1}{3}$

$A = h(w + hs)$

$A_1 = 5{,}63[9 + 5{,}63(1{,}5)]$

$A_1 = 98{,}22\ m^2$

$A_2 = 98{,}22\ m^2$

$A_3 = 6{,}3[9 + 6{,}3(1{,}5)]$

$A_3 = 116{,}24\ m^2$

$A_4 = 7{,}3[9 + 7{,}3(1{,}5)]$

$A_4 = 145{,}64\ m^2$

$A_5 = 145{,}64\ m^2$

$A_6 = 8{,}5[9 + 8{,}5(1{,}5)]$

$A_6 = 184{,}88\ m^2$

$A_7 = 9{,}25[9 + 9{,}25(1{,}5)]$

$A_7 = 211{,}59\ m^2$

$$V = \frac{1}{3}[A_1 + A_n + 2(\text{odds}) + 4(\text{evens})]$$

$$V = \frac{1}{3}[98{,}22 + 211{,}59 + 2(116{,}24 + 145{,}64) + 4(98{,}22 + 145{,}64 + 184{,}88)]$$

$$V = \frac{1}{3} \times 2\ 548{,}21$$

$$V = 849{,}40\ m^3$$

3. $$V = \frac{\pi h}{3}(R^2 + Rr + r^2)$$

$$V = \frac{\pi(48)}{3}[22{,}34^2 + (22{,}34 \times 10{,}85) + 10{,}85^2]$$

$$V = 50{,}27 \times 752{,}31$$

$$V = 37\ 818{,}62\ m^3$$

4. $$A = h(w + hs)$$

$$A_1 = 3[7 + 3(2{,}5)]$$

$$A_1 = 43{,}50\ m^2$$

$$A = h(w + hs)$$

$$A_2 = 7[7 + 7(2{,}5)]$$

$$A_2 = 171{,}5\ m^2$$

$$\text{Depth at mid-section} = \frac{3+7}{2} = 5$$

$$A = h(w + hs)$$

$$A_M = 7[7 + 5(2{,}5)]$$

$$A_M = 136{,}5\ m^2$$

$$V = \frac{L}{6}(A_1 + 4M + A_2)$$

$$V = \frac{76{,}44}{6}[43{,}50 + 4(136{,}5) + 171{,}5)$$

$$V = 9\ 695{,}14\ m^3$$

5.1 $$V = \frac{L}{3}[A_1 + A_n + 2(\text{sum of odds}) + 4(\text{sum of evens})]$$

$$V_{Fill} = \frac{63}{3}[17{,}42 + 9{,}63 + 2(12{,}74) + 4(15{,}56 + 11{,}55)]$$

$$V_{Fill} = 2{,}1(160{,}97)$$

$$V_{Fill} = 338{,}04\ m^3$$

$$V = \frac{L}{3}[A_1 + A_n + 2(\text{sum of odds}) + 4(\text{sum of evens})]$$

$$V_{Cut} = \frac{63}{3}[9{,}25 + 5{,}39 + 2(7{,}22) + 4(8{,}45 + 6{,}73)]$$

$$V_{Cut} = 2{,}1(89{,}80)$$

$$V_{Cut} = 188{,}58\ m^3$$

5.2 Volume still required for fill = 338,04-188,58

$$= 149{,}49\ m^3$$

6. Upper base area $= \dfrac{S^2N}{4\tan\frac{180}{5}}$

$$= \frac{2{,}4^2 \times 5}{4\tan\frac{180}{5}}$$

$$= 9{,}91\ m^2$$

Lower base area $= \dfrac{S^2N}{4\tan\frac{180}{5}}$

$$= \frac{4{,}5^2 \times 5}{4\tan\frac{180}{5}}$$

$$= 34{,}84\ m^2$$

$$V = \frac{h}{3}(A_1 + A_2 + \sqrt{A_1A_2})$$

$$V = \frac{9{,}85}{3}(9{,}91 + 34{,}84 + \sqrt{9{,}91 \times 34{,}84}$$

$$V = 3{,}28 \times 63{,}33$$

$$V = 207{,}72\ m^3$$

7.1 $A = \dfrac{1}{2}\left[\dfrac{(a+gh)^2}{g-n}\right]$

Cut area at A $= \dfrac{1}{2}\left[\dfrac{[4+2{,}4(0{,}9)]^2}{2{,}4-0{,}7}\right]$

$$= 11{,}16\ m^2$$

Cut area at B $= \dfrac{1}{2}\left[\dfrac{[4+2{,}6(0{,}8)]^2}{2{,}6-0{,}8}\right]$

$$= 10{,}27\ m^2 2$$

Cut area at C $= \dfrac{1}{2}\left[\dfrac{[4+2{,}9(0{,}6)]^2}{2{,}9-0{,}9}\right]$

$$= 8{,}24\ m^2$$

$$\text{Cut area at D} = \frac{1}{2}\left[\frac{[4+3,3(0,5)]^2}{3,3-1,1}\right]$$
$$= 7,26 \text{ m}^2$$

$$\text{Cut area at E} = \frac{1}{2}\left[\frac{[4+3,8(0,3)]^2}{3,8-1,3}\right]$$
$$= 5,28 \text{ m}^2$$

$$\text{Cut area at F} = \frac{1}{2}\left[\frac{[4+4,5(0,2)]^2}{4,5-1,7}\right]$$
$$= 4,29 \text{ m}^2$$

7.2 $V = \frac{L}{2}[A_1 + A_2 + 2(A_2 + A_3 + \ldots A_{n-1})]$

$V = \frac{13}{2}[11,16 + 4,29 + 2(10,27 + 8,24 + 7,26 + 5,28)]$

$V = 6,5 \times 77,55$

$V = 504,08 \text{ m}^3$

8. $A_1 = L \times B$
$= 6 \times 4$
$= 24 \text{ m}^2$

$A_2 = L \times B$
$= 3,8 \times 2,9$
$= 11,02 \text{ m}^2$

$V = \frac{h}{3}(A_1 + A_2 + \sqrt{A_1 A_2})$

$V = \frac{15,6}{3}(24 + 11,02 + \sqrt{24 \times 11,02})$

$V = 5,2 \times 51,28$

$V = 266,66 \text{ m}^3$

9.1 $A = \frac{\theta}{360}\pi r^2$

$A_P = \frac{140}{360} \times \pi \times 6,6^2$
$= 5,39 \text{ m}^2$

$A_Q = \frac{140}{360} \times \pi \times 6^2$
$= 4,46 \text{ m}^2$

$$A_R = \frac{140}{360} \times \pi \times 5{,}4^2$$
$$= 3{,}61 \text{ m}^2$$

$$A_S = \frac{140}{360} \times \pi \times 4{,}8^2$$
$$= 2{,}85 \text{ m}^2$$

$$A_T = \frac{140}{360} \times \pi \times 4{,}2^2$$
$$= 2{,}18 \text{ m}^2$$

$$A_T = \frac{140}{360} \times \pi \times 3{,}6^2$$
$$= 1{,}60 \text{ m}^2$$

9.2 There are six ordinates in an even number; therefore, the first five are odd numbers and will be used first for Volume 1. Then the last two will be used for Volume 2.

The sum of V1 and V2 will be the total volume as indicated here:

$$V = \frac{L}{3}[A_1 + A_{n+2}(\text{sum of odds}) + 4(\text{sum of evens})]$$

$$V_1 = \frac{9{,}6}{3}[5{,}39 + 2{,}18 + 2(3{,}61) + 4(4{,}46 + 2{,}85)]$$

$$V_1 = 3{,}2 \times 44{,}03$$

$$V_1 = 140{,}90 \text{ m}^3$$

$$V_2 = \frac{9{,}6}{3}[2{,}18 + 1{,}60]$$

$$V_2 = 3{,}2 \times 3{,}78$$

$$V_2 = 12{,}10 \text{ m}^3$$

$$V_{Total} = V_1 + V_2$$
$$= 140{,}90 + 12{,}10$$
$$= 153 \text{ m}^3$$

10. Depth at P = 78,5 – 75 = 3,5 m
Depth at Q = 79,7 – 75 = 4,7 m
Depth at R = 78,9 – 75 = 3,9 m
Depth at S = 77,6 – 75 = 2,6 m

Let the section between:

- P and S be A_1
- Q and R be A_2
- T and U be A_M

$$A_1 = \left(\frac{3,5+2,6}{2}\right) \times 10,4$$
$$= 31,72 \text{ m}^2$$

$$A_2 = \left(\frac{4,7+3,9}{2}\right) \times 16,8$$
$$= 72,24 \text{ m}^2$$

$$\text{Length of TU} = \frac{10,4+16,8}{2} = 13,6 \text{ m}$$

$$\text{Depth at T} = \frac{3,5+4,7}{2} = 4,1 \text{ m}$$

$$\text{Depth at U} = \frac{3,9+2,6}{2} = 3,25 \text{ m}$$

$$A_M = \left(\frac{4,1+3,25}{2}\right) \times 13,6$$
$$= 49,98 \text{ m}^2$$

$$V = \frac{L}{6}(A_1 + 4A_M + A_2)$$

$$V = \frac{52,65}{6}[31,72 + 4(49,98) + 72,24]$$

$$V = 8,775 \times 303,88$$

$$V = 2\,666,55 \text{ m}^3$$

Summative assessment: Module 6 SB page 261

1 1.1 *Vertical curves* are curves that provide smooth transition between two sloped roads. (1)

1.2 *Horizontal curves* are curves used in horizontal planes to connect two straight tangent sections. (1)

2. The *initial horizontal control* setting-out process involves physically pegging the centreline of the road on the ground.

Vertical control is required at all stages of the work. A series of temporary benchmarks must be established along the route to provide level control.

Reference marks are usually established at tangent points, road intersections and bridge control points. (3)

3.
- *Pegging the centre line*, which is usually done at stations, are established with reference to preliminary traverses, base lines or control surveys.
- *Centre-line levelling* is done at the stations and at intermediate points between stations where there is a significant change in the slope to obtain the representative profile of the ground.
- *Cross-section levelling* is done at each station and at points with significant changes in the ground.
- *Intersecting roads* involves setting out the points of the intersections of the straight portions of roads and then fitting a suitable horizontal curve between them. (4)

4. $T \tan \frac{\Delta}{4} = C$*d*

$56{,}78 \tan \frac{\Delta}{4} = 11{,}25$

$\tan \frac{\Delta}{4} = \frac{11{,}25}{56{,}78}$

$\frac{\Delta}{4} = \tan^{-1}\left(\frac{11{,}25}{56{,}75}\right)$

$\frac{\Delta}{4}$ =11:12:46

Δ = 11:12:46

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

$$R \tan \frac{11:12:46}{4} = 56,78$$

$$R = \frac{11,25}{0,098}$$

$$R = 578\ 42\ m$$

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

$$La = \frac{\pi \times 11:12:46 \times 578,52}{180}$$

$$La = 113,21$$

EC = 2 562,90 + 113,21 = 2 676,11 m

Chainage	Short chord	Tangent angle	Total tangent angle
BC		00:00:00	360:00:00
2 562,90	17,1	00:50:49	359:09:11
2 580,00	20	00:59:26	358:09:45
2600,00	20	00:59:26	357:10:19
2 620,00	20	00:59:26	356:10:53
2 640,00	20	00:59:26	355:11:27
2 660,00	16,11	00:47:52	354:23:35
2 676,11			
113,21	113,25	05:36:25	05:36:25

(17)

5.
- Divide the long chord into an even number of equal parts.
- Set out perpendicular offsets, using the calculated data at each of the points of division to obtain the required point(s) on the curve.
- Continue the process until the apex of the curve is reached.
- Set out the remaining half of the curve from the second tangent along the forward tangent. (4)

6. Fill area $= \frac{1}{2}\left[\frac{(a-gh)^2}{g-m}\right]$

Fill area $= \frac{1}{2}\left[\frac{[4,4-5(0,58)]^2}{5-4}\right]$

Fill area = 1,13 m^2

Cut area $= \frac{1}{2}\left[\frac{(a+gh)^2}{g-m}\right]$

Cut area $= \frac{1}{2}\left[\frac{[4,4-5(0,58)]^2}{5-2}\right]$

Cut area = 8,88 m^2 (8)

Total: 38 marks

Exemplar examination paper

QUESTION 1

A theodolite was set up in sequence at K, L and M and the following results relate to what was observed:

At K		At L		At M	
J	46:43:12	K	205:08:46	L	315:28:14
L	197:10:28	M	138:32:25	N	250:17:10

Calculate the directions KL, LM and MN if the direction of JK is 223:18:33. [10]

QUESTION 2

2.1 The following data was given:

Coordinates		
P	+ 434,48	+ 2 625,06
T	– 59,75	+ 2 827,42

Line	Direction	Distance (m)
PQ	351:23:50	242,15
QR	297:06:23	259,36
RS	256:50:49	204,70

Use the table in ANNEXURE A (attached) to do the necessary calculations to find the final coordinates of Q and R. (15)

2.2 Use the following given data to plot a closed loop traverse (ABCD) to a scale of 1:2 500.

Line	QB	Distance
AB	N 50° E	135 m
BC	S 30° E	120 m
CD	S 35° W	150 m
DA	N 20° W	115 m

(5)

[20]

QUESTION 3

3.1 Figure 1 of ANNEXURE C (attached) shows the plan of an area to be excavated to an elevation of 116,00 m. The surface levels at the corners of the grid are given. The sides of the excavation are vertical. The bulking factor is 13%.

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

3.2 Reproduce Figure 1 from ANNEXURE C (attached) to a scale of 1:500.

Calculate and plot the 139-m contour line. (7,5 + 3,5)(10)

[20]

QUESTION 4

4.1 Figure 2 of ANNEXURE C shows the outline of a building that is to be set out from control points A and B.

Make use of Figure 2 and explain how you would set out point S on line ST by forward intersection. (7)

4.2 Name THREE reference grids that are used for setting out large work. (3)

[10]

QUESTION 5

5.1 A road curve is to be staked out from the beginning of the curve to the end of the curve. Note the following requirements:

- A peg is required at every full 20-m chainage.
- The curve is to the right.
- The direction from the intersection point to the beginning of the curve is 55:32:24.
- The direction from the intersection point to the end of the curve is 273:12:36.
- The chainage at the point of intersection is 3 656,50 m.
- The radius of the curve is 205,20 m.

Calculate the:

5.1.1 angle of intersection (2)

5.1.2 tangent length (3)

5.1.3 chainage at the beginning of the curve (BC) (2)

5.1.4 arc length (3)

5.1.5 chainage at the end of the curve (EC) (2)
5.1.6 tangent angle of the first short chord (1)
5.1.7 tangent angle of the intermediate short chords (1)
5.1.8 tangent angle of the last short chords. (1)

5.2 Explain the procedure to set out curves by offset from the long chord. (4)

5.3 There is a road with a formation width of 10 m and a side slope of 1:1,5 in cut and 1:3 in fill. The original ground has a cross fall of 1:4. The height of the road formation level is 0,8 m above ground level at the centre of the formation width.

Calculate the area of the cut and fill. (6)

[25]

QUESTION 6

A theodolite was set up at station R and readings were taken to spot shots R1, R2 and R3. Rewrite the information given below in the field book form provided in ANNEXURE B (attached) and reduce.

Note the following data: The elevation of point R1 is 268,19 m.

- The height of the instrument at R is 1,60 m.
- The booked vertical angles are zenith distances.

Readings to spot shots are as follows:

Staff station	Horizontal angle	Vertical angle	Stadia reading
R1	310:22:26	97:49:38	3,06 …. 1,48
R2	42:24:18	95:29:34	2,22 …. 1,24
R3	132:44:34	79:47:21	1,84 …. 0,78

[15]

Total: 100

ADDENDUM A

To be used to answer QUESTION 2.1

Table 1

NAME	JOIN	∆Y	∆X	NAME	Y	X

ADDENDUM B

To be used to answer QUESTION 6

Field book form

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

ADDENDUM C

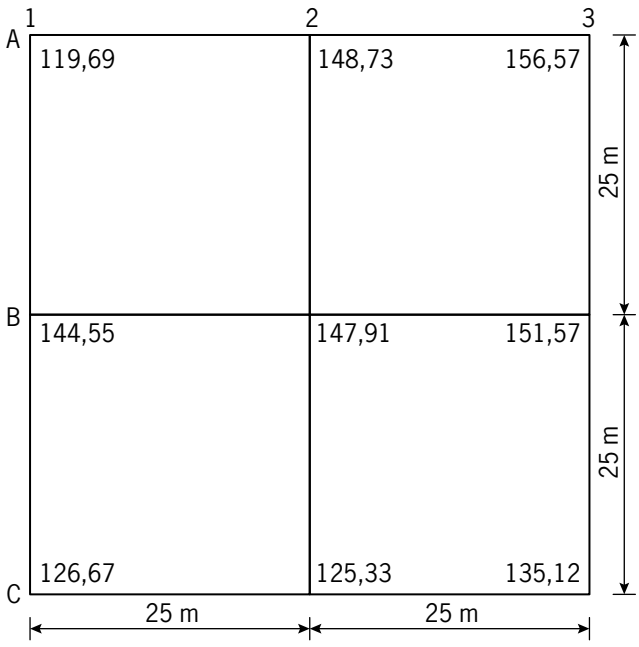


Figure 1

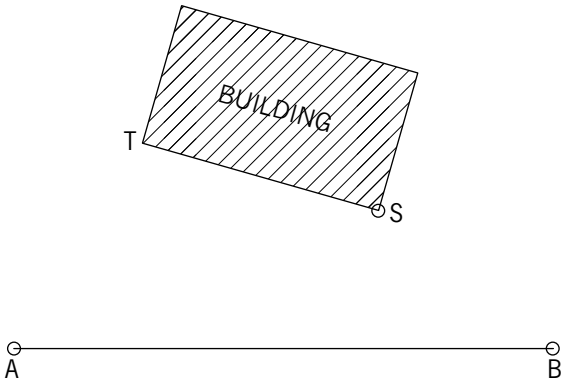


Figure 2

Exemplar examination paper memorandum

QUESTION 1

At K		At L		At M	
J	46:43:12	K	205:08:46	L	315:28:14
L	197:10:28	M	138:32:25	N	250:17:10
	150:27:16 ✓		293:23:39 ✓		274:48:56 ✓

JK | 223:18:33

KJ | 43:18:33 ✓
JKL | 150:27:16
KL | 193:45:49 ✓✓

LK | 13:45:49
KLM | 293:23:39
LM | 307:09:28 ✓✓

ML | 127:09:28
LMN | 274:48:56
MN | 41:58:24 ✓✓ **[10]**

QUESTION 2

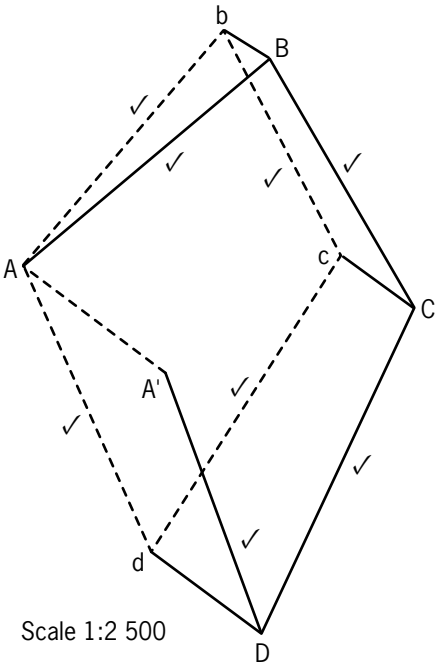
2.1

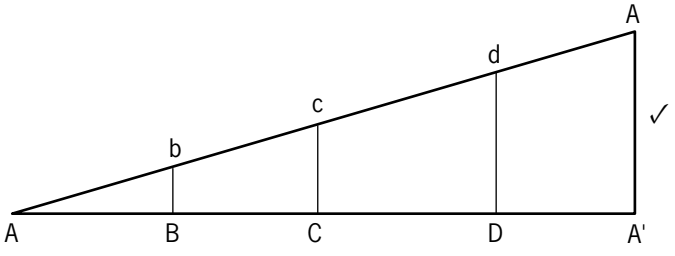
Name	JOIN	∆Y	∆X	Name	Y	X
P				P	+434,48	+2 625,06
351:23:20		−36,26 ½	+239,42 ½			
242,15 m		−4,82 ½	+3,51 ½			
Q				Q	+393,40 ✓	+2 867,99 ✓
297:06:23		−230,87 ½	+118,18 ½			
259,36 m		−5,17 ½	+3,76 ½			
R				R	+157,36 ✓	+2 989,93 ✓
256:50:49		−199,35 ½	−46,58 ½			
204,70 m		−4,08 ½	+2,96 ½			

Name	JOIN	ΔY	ΔX	Name	Y	X
S				S	–36,26	+2 946,31
706,21 ✓		–466,46 ½	+311,02 ½		–482,53 ✓	+321,25 ✓
		–482,53 ½	+321,25 ½			
		–14,07 ½	+10,23 ½			

½ = ½ mark
✓ = 1 mark
[15]

2.2





(5)
[20]

QUESTION 3

3.1

Corner	Elevation	No. of appearances	Product
A1	119,69	1	119,69 ½
A2	148,73	2	297,46 ½
A3	156,57	1	156,57 ½
B1	144,55	2	289,10 ½
B2	147,91	4	591,64 ½
B3	151,57	2	303,14 ½
C1	126,67	1	126,67 ½
C2	125,33	2	250,66 ½
C3	135,12	1	135,12 ½
		16	2 270,05 ½

Mean height = $\frac{2\ 270{,}05}{16}$ = 141,88 ✓

Excavation depth = 141,88 – 116 = 25,88 m ✓

Volume = $4(25 \times 25) \times 25{,}88 = 64\ 700\ m^3$ ✓

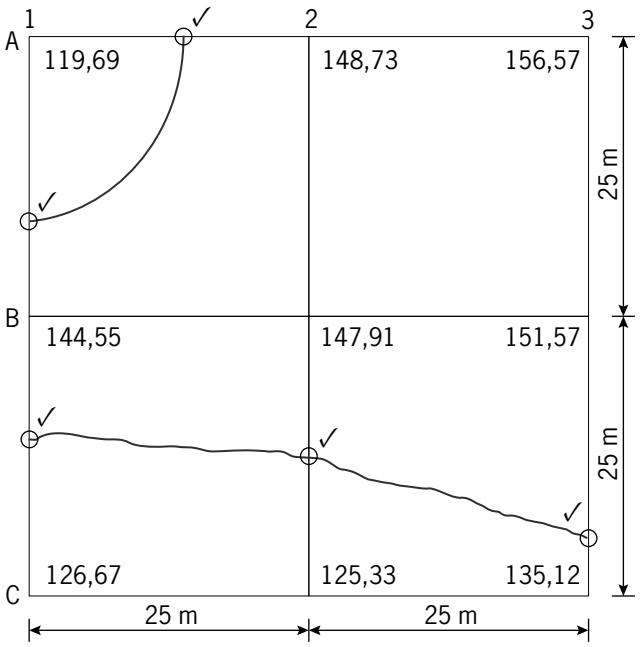
Bulking = $64\ 700 \times 0{,}13 = 8\ 411\ m^3$ ✓

Total volume = $64\ 700 + 8\ 411 = 73\ 111\ m^3$ ✓ (10)

3.2

Station		Fall or rise	Contour fall or rise	Distance
From	To			
A1	A2	148,73 – 119,69 = 29,04 ½	139 – 119,69 = 19,31 ½	$\frac{19{,}31}{29{,}04} \times 25 = 16{,}62$
A1	B1	144,55 – 119,69 = 24,86 ½	139 – 119,69 = 19,31 ½	$\frac{19{,}31}{24{,}86} \times 25 = 19{,}42$
C1	B1	144,55 – 126,67 = 17,88 ½	139 – 126,67 = 12,33 ½	$\frac{12{,}33}{17{,}88} \times 25 = 17{,}24$
C2	B2	147,91 – 125,33 = 22,58 ½	139 – 125,33 = 13,67 ½	$\frac{13{,}67}{22{,}58} \times 25 = 15{,}1$
C3	B3	151,57 – 135,12 = 16,45 ½	139 – 135,12 = 3,88 ½	$\frac{3{,}88}{16{,}46} \times 25 = 5{,}89$

(7,5)

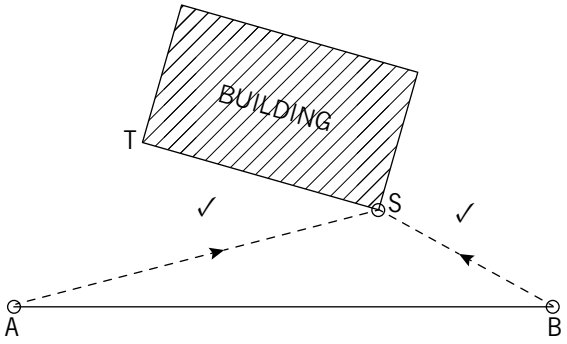


(2,5)

[20]

QUESTION 4

4.1



- Calculate the whole circle bearing of AB, AS, BA and BS. ✓
- On baseline AB, set up, centre and level the two theodolites; one over point A and the other over point B. ✓
- With the theodolite set up at point A, sight at point B and set the horizontal circle to read the whole circle bearing of AB and rotate the telescope towards point S until the whole circle bearing of AS is read on the horizontal circle. ✓
- With the theodolite set up at point B, sight at point A and set the horizontal circle to read the whole circle bearing of BA, and rotate the telescope towards point S until the whole circle bearing of BS is read on the horizontal circle. ✓

- Move a ranging rod along the line of sight of the two theodolites until the intersection of the line of sight of the two theodolites is established. This will be point Q. ✓ (7)

4.2 Any THREE of the following:

- Survey grid
- Site grid
- Structural grid
- Secondary grid. (3)

[10]

QUESTION 5

5.1.1 IPBC = 55:32:24
BC – IP = 235:32:24
Δ = 273:12:36 – 235:32:24
= 37:40:12 (2)

5.1.2 $T = R \tan \frac{\Delta}{2}$
$T = 205{,}20 \tan \left(\frac{37:40:12}{2}\right)$
T =7 0 m
(3)

5.1.3 Chainage at BC = 3 656,50 – 70
= 3 586,50 m (2)

5.1.4 $La = \frac{\pi \Delta R}{180}$
$La = \frac{\pi \times 37:40:12 \times 205{,}2}{180}$
La = 134,91 m (3)

5.1.5 Chainage at EC = 3 586,5 + 134,91
= 3 721,41 m (2)

5.1.6 $\theta = \frac{1\,718{,}9a}{R}$
a = 3 600 – 3 586,50 = 13,5
$\theta = \frac{1\,718{,}9 \times 13{,}5}{205{,}2 \times 60}$ = 01:53:05 (1)

5.1.7 a = 20
$\theta = \frac{1\,718{,}9 \times 20}{205{,}2 \times 60}$ (1)

5.1.8 a = 3 721,41 – 3 720 = 1,41
$\theta = \frac{1\,718{,}9 \times 1{,}41}{205{,}2 \times 60}$ = 00:11:49 (1)

5.2 Divide the long chord into an even number of equal parts.

- Set out perpendicular offsets, using the calculated data at each of the points of division to obtain the required point on the curve.
- Continue the process until the apex of the curve is reached.
- Set out the remaining half of the curve from the second tangent along the forward tangent. (4)

5.3 Fill area = $\frac{1}{2}\left[\frac{(a+gh)^2}{g-m}\right]$

Fill area = $\frac{1}{2}\left[\frac{[5+4(0{,}8)]^2}{4-3}\right]$

Fill area = 33,62 m^2

Cut area = $\frac{1}{2}\left[\frac{(a-gh)^2}{g-m}\right]$

Cut area = $\frac{1}{2}\left[\frac{[5-4(0{,}8)]^2}{4-1{,}5}\right]$

Cut area = 0,65 m^2 (6)

[25]

QUESTION 6

The table appears on the next page.

Station		Distance		HI or MH	Angles		HI – MH ±	Height component ±	Height difference ±	Elevation of point	Remarks
From	To	Stadia	Hor.		Hor.	Vert.					
R				1,60						290,18 ✓	
	R1	3,06 1,48	155,07 **1¼**	2,27	310:22:26	97:49:38	– 0,67 ½	– 21,32 **1¼**	– 21,99 ✓	268,19	
	R2	2,82 1,24	156,55 **1¼**	2,03	42:24:18	95:29:34	– 0,43 ½	– 15,05 **1¼**	– 15,48 ✓	274,70 ✓	
	R3	1,84 0,78	102,67 **1¼**	1,31	152:44:34	79:47:21	+0,29 ½	+18,49 **1¼**	+18,78 ✓	308,96 ✓	

½ = ½ mark
✓ = 1 mark
1¼ = 1¼ mark

½ × 3 = 1,5
1 × 6 = 6
1¼ × 6 = 7,5
Total = 15 marks

Glossary

A

Acute – an angle measuring less than 90°

Angle of depression – an angle below the line of sight

Arc – a smooth curve that forms part of a circle

Asphalt – a dark semi-solid material which is a by-product of petroleum distillation

Automatic compensator – an automatic level that uses gravity to balance an instrument's optical components

B

Base course – a layer of material placed on top of the ground beneath the surface of asphalt roadways

Batter boards – temporary frames used to set out and secure a structure's outer edges during construction

Batter pegs – pegs knocked into the ground to indicate slope edges

Bisection – the division or cutting of something into two parts

Bitumen – a sticky, thick, black petroleum-based substance

Bulking – the increase in the volume of materials due to excavation

C

Cart-away – disposal of waste or excavated materials (to be carted away)

Centre line – the line indicating the central or midpoint line of a structure

Concentric – when two objects or shapes (usually circular) share the same axis or centre

Contour interval – the vertical distance or difference in elevation between contour lines

Contour line – a line of intersection of a level surface with the surface of the earth

Contour map – a map which shows surface features of an area and its elevations and depressions

Convexity – the degree or extent of outward curvature

Cosine rule – the application of trigonometry to solve for the lengths of unknown sides of triangles or survey areas

D

Deflect – the act of changing direction upon coming into contact with another object

Detail survey – a survey that takes into account all the features of an area or plot of land

Differential expansion – expansion and distortion of instrument material and components due to thermal exposure from direct sunlight

Differential refraction – the perceived change of position of one object relative to another object nearby

Discrepancy – inconsistency or variance resulting in error

Displacement – the movement of something from its original place or position

E

Embankment – a wall or 'bank' of earth consisting of compacted soil which carries a load or acts as a wall to prevent waterways from overflowing and flooding

Embankment toe – the bottom of a slope where it levels out and meets the ground surface

Equidistant – at equal distance

Erroneous – something incorrect or containing error

F

Feasible – practical or achievable

Fly levelling – method used for transferring

levels using the backsight and foresight readings

Foresight – the last reading taken before the instrument is moved

Formation level – underlying ground at which excavation stops and construction starts

Formwork – moulds into which concrete is poured and compacted

Frustum – the portion of a solid that lies between two parallel planes cutting the solid

G

Geologic – related to the earth's structure

H

Horizontal equivalent – the horizontal distance between any two adjacent contours

I

In situ – in position, or existing in its original place and condition

Intermediate – between two things

Interpolation –a method of calculating values using given data points

Interpolation of contours – the process of spacing the contours proportionally between the plotted ground points

Intervisibility – visibility both to and from one point to another

L

Leg – a line joining points (stations) along a traverse

Line of collimation – the line joining the intersection of cross hairs and the optical centre of the object glass

M

Magnetic meridian – the line connecting the magnetic south and north poles

Misclosure – when the first and last linked traverse lines do not match up

Monument – a structure or statue erected to commemorate something of importance

N

Non-perpendicularity – a case in which an object is not perpendicular or at right angles to the relevant plane

O

Object glass– the lens of the instrument which is closest to the object being observed

Obtuse – an angle greater than 90°

Offset – the perpendicular distance measured left or right side of the chain to locate survey details

Optical plumb – an instrument with a telescope and sighting hole inside

Outcrop – a visible part of a rock formation

P

Parabolic – relating to a parabola, which is a plane, U-shaped curve

Pentagonal – resembling a pentagon, which has five sides

Perspex® – a brand of engineered transparent thermoplastic polymer

Planimeter – a mechanical measuring instrument used to calculate irregular areas for which there are no formulae

Plumb bob – a weight that is suspended from a string as a vertical reference line

Plumb line – the vertical reference line of the plumb bob

Polar calculation – the calculation of coordinates of an unknown point using the distance and direction from a known point to an unknown point

Preliminary – that which precedes or prepares for something more important that will follow

Prismoid – a shape with equal vertices in its parallel planes

Q

Quotient – the resultant amount or product obtained after dividing one quantity by another (sum of products by the number of appearances)

R

Radii – plural for radius, which is a line segment from the centre to the perimeter of an a circle or sphere

Refraction – the bending of light

Relief – the elevations and depressions in the earth's surface

S

Sand drains – vertical boreholes containing appropriately graded sand to facilitate drainage of liquid

Setting out – the establishment of marks and lines to define the position and level of the elements for the construction work; it's also the transference of surveying details of a site or area from a drawing to the ground

Simpson's rule – an arithmetical rule for estimating the area under a curve where the values of an odd number of ordinates, including those at each end, are known

Slope stakes – wooden or metal posts knocked into the ground to indicate slope edges

Station – a point along a traverse

Subbase – a layer that serves as the foundation of the road

Subgrade – the natural soil layer below the road formation level

Successive – the next or consecutive thing which follows something before

Swinging – rotating and turning a telescope about the vertical axis in a horizontal plane

T

Tacheometer – a transit theodolite fitted with a stadia diagram

Tacheometry – a method of surveying in which the horizontal and vertical positions of a point are determined solely from instrument observation

Topographic – to do with the natural surfaces, features and elevations of an area

Tracer point – the pointy part of the planimeter used to trace the boundaries of areas

Transiting – turning a telescope about its horizontal axis in a vertical plane through 180°

Trapezoidal rule – a method of estimating the area under a curve by dividing the area into smaller trapezoids of equal width

Traverse – a survey in which the lengths and directions of a series of straight lines are measured

Trunnion axis – the axis about which a telescope transits

U

Undulating – a smooth rising and falling movement or line

V

Verticality – a state of being vertical or at 90° to a horizon or the horizontal surface

Z

Zenith – a vertical angle that is formed by the intersection of two lines in a vertical plane

Zenith distance – the angle between the zenith line and the line of sight