N5

Building and Structural Surveying

Lecturer Guide

Alfred Ramahlape

Additional resource material for this title includes:

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

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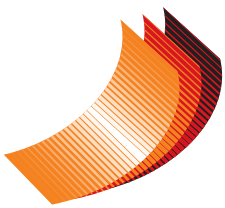

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CONTENTS

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 the practice, theory and methodology of the building and structural surveying field.

2.2 The teaching of this subject is aimed at developing knowledge, professional and general competencies in:
- surveying
- building construction.

3. Prerequisites

Students must have completed a National N4 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. Evaluation is conducted continuously by means of two formal tests at college level. The learner must obtain a minimum ICASS mark of at least 40% in order to qualify to write the final examination. A mark will be calculated together in a ratio of 40:60 to derive the promotion mark. The learner must obtain at least 40% in the final examination.

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

5.2 The examination in N5 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 awarded to each category:

Knowledge and understanding	Application	Evaluation
30–40%	30–40%	20–30%

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 a practical environment.

7. Weighted values of modules

Modules	Weighting (%)
1. Basic principles of surveying	20
2. Linear measurements	20
3. Height measurements	20
4. Angular measurement	10
5. Building surveys	15
6. Setting out	15
Total	**100**

8. Work schedule

Week	Topic	Content	Exercises	Hours
1–2	**Module 1** Basic principles of surveying	1.1 Surveying 1.2 Surveying terms 1.3 Stages of the surveying process 1.4 Fundamental principles of surveying 1.5 Accuracy and precision 1.6 Errors in measurements	Exercise 1.1 Exercise 1.2 Summative assessment	20 hours
3–4	**Module 2** Linear measurements	2.1 Errors in measurement and corrections 2.2 Linear measurement obstacles 2.3 Chaining or taping 2.4 Plotting surveys 2.5 Coordinates	Exercise 2.1 Exercise 2.2 Practical group activity 2.1 Practical group activity 2.2 Exercise 2.3 Exercise 2.4 Exercise 2.5 Summative assessment	20 hours
5–6	**Module 3** Height measurements	3.1 Levelling 3.2 Levelling techniques 3.3 Levelling instruments 3.4 Classification of a level traverse 3.5 Errors in levelling 3.6 System of booking and reducing readings 3.7 Rise and fall method of booking and reduction 3.8 Collimation method of booking and reduction 3.9 Cross-section levelling	Exercise 3.1 Practical pair activity 3.1 Practical pair activity 3.2 Exercise 3.2 Exercise 3.3 Exercise 3.4 Exercise 3.5 Summative assessment	20 hours
7	**Module 4** Angular measurement	4.1 Purpose of angular measurement 4.2 Classification of theodolites 4.3 Theodolite terminology 4.4 Measuring horizontal and vertical angles 4.5 Calculation of horizontal and vertical angles 4.6 Tacheometry	Exercise 4.1 Practical group activity 4.1 Practical group activity 4.2 Exercise 4.2 Exercise 4.3 Exercise 4.4 Summative assessment	10 hours

Week	Topic	Content	Exercises	Hours
8–9	**Module 5** Building surveys	5.1 Building regulations and building construction practice 5.2 Building codes 5.3 Building surveys 5.4 Interpreting and classifying drawings into design and production stages 5.5 Measuring instruments and procedures 5.6 Cutting and filling	Exercise 5.1 Practical group activity 5.1 Exercise 5.2 Summative assessment	15 hours
9–10	**Module 6** Setting out	6.1 Setting-out procedure for a simple building 6.2 Constraints in setting out a building 6.3 Determining the depth of excavations and slope gradients 6.4 Setting out and levelling drainage work 6.5 Slope ratio of drainage or sewer pipes	Exercise 6.1 Practical group activity 6.1 Exercise 6.2 Summative assessment	15 hours
TOTAL				**100 hours**

9. Lesson plan template

<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>
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			Group work		Models		
			Demonstration		Handouts		
			Simulation		Multimedia		
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			Recapping/Reinforcement				

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WEEK 6			Lecture		White board/ OHP		
			Group work		Models		
			Demonstration		Handouts		
			Simulation		Multimedia		
			Introduction to lessons				
			Recapping/Reinforcement				

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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				

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WEEK 9			Lecture		White board/ OHP		
			Group work		Models		
			Demonstration		Handouts		
			Simulation		Multimedia		
			Introduction to lessons				
			Recapping/Reinforcement				

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WEEK 10			Lecture		White board/ OHP		
			Group work		Models		
			Demonstration		Handouts		
			Simulation		Multimedia		
			Introduction to lessons				
			Recapping/Reinforcement				

MODULE

1 Basic principles of surveying

By the end of this module, students should be able to:

- define the term *surveying*;
- define the objectives, purpose and principles of surveying;
- sketch and list the principle/methods of fixing a point in surveying relating to the following:
  - ties (trilateration)
  - sideways intersection
  - forward intersection (triangulation)
  - resection
  - perpendicular offsets (rectangular offsets)
  - length and direction (polar coordinates);
- list and explain the following main categories of surveying:
  - plane surveying
  - geodetic surveying;
- list and explain the following types of surveys that are based on the nature of the field:
  - topographic survey
  - cadastral survey
  - hydrographic survey
  - engineering survey
  - astronomical survey;
- list and explain the following types of surveys that are based on the purpose of the survey:
  - mine survey
  - military survey
  - geological survey;
- list and explain the following types of surveys that are based on the method implemented:
  - triangulation
  - traversing;
- list and explain the following types of surveys that are based on the instruments used:
  - chain survey

  - compass survey
  - theodolite survey
  - plane table survey
  - photographic and aerial survey;
- define the term *control point;* and
- explain the following types of control points:
  - trigonometric beacons (trig beacons)
  - minor control points
  - benchmarks
  - GPS control
  - reference marks.

Introduction

The knowledge of surveying is advantageous in many phases of engineering. Surveying ensures that everything is in the right place on the right alignment and where it is intended be. Without surveying, there would be no tall buildings, bridges or roads. It is a service that ensures columns of buildings are plumb, property lines are defined, structures are aligned, estimates are correct, etc. Understanding the basic principles of surveying is therefore essential in order to understand the discipline.

Exercise 1.1 SB page 4

1. Surveying is the art of determining the relative position of different features on, above or beneath the surface of the of the earth by measuring horizontal distances, vertical distances, angle and directions.

2. The objectives are to:
   - determine the relative position of any objects or points of the Earth;
   - determine the distance and angle between different objects;
   - prepare a map or plan to represent an area on a horizontal plan;
   - develop methods through knowledge of modern science and the technology, and to use them in the field; and
   - solve measurement problems in an optimal way.

3. The purpose of surveying is to:
   - prepare topographical maps showing the hills, valley, rivers, villages, town, etc., of a country;
   - prepare cadastral maps showing the boundaries of fields and other properties;

- prepare contour maps, determine the volume of reservoirs and to find the best possible route for roads, railways, etc;
- prepare archaeological maps, including places where ancient relics exist;
- prepare a geological map showing areas including underground resources;
- prepare an engineering map to show details such as; roads, railways, canals, etc; and
- establish horizontal and vertical control survey points; also known as stations.

4
- Reconnaissance
- Observation and measurement
- Office work.

Exercise 1.2 SB page 9

1. *Accuracy* refers to how closely a measurement or observation is to measuring a true value, since measurements and observations are always subject to error.
   Precision refers to how closely repeated measurements or observations come to duplicating measured or observed values.

2. Accidental, systematic and constant errors

3.
- Using incorrect temperature and/or pressure observations
- Not applying curvature and refraction constants
- Using incorrect instrument heights and/or target heights
- Using an incorrect prism offset
- Using an imperfectly adjusted instrument.

4. Surveying is based on the following principles:
- Working from a whole to a part
- Location of a point by measurement from two points of reference
- Consistency of work
- Independent check
- Accuracy required.

Summative assessment SB page 11

1. 1.1 C
   1.2 E
   1.3 D
   1.4 B (4)

2.1 Working from the whole to a part: Locating the main control points of the surveyed area with very high precision, and minor details located by less precise methods (2)

2.2 Consistency of work means being consistent in the method, instrument, reading and noting observations, in order to achieve the desired level of accuracy, (2)

3. Reconnaissance involves making an overall inspection of the area to be surveyed to obtain a general picture before commencement of any type of field work and measurement, and to select the location for control points and instruments for the project. (2)

4.1
- Improperly levelling the surveying instrument
- Setting up the instrument or target over the wrong control point
- Incorrectly entering a control point number in the data collector
- Transposing numbers or misplacing the decimal point. (4)

4.2
- Using incorrect temperature and/or pressure observations
- Not applying curvature and refraction constants
- Using incorrect instrument heights and/or target heights
- Using an incorrect prism offset
- Using an imperfectly adjusted instrument. (4)

Total: 18 marks

MODULE

2 *Linear measurements*

By the end of this module, students should be able to:

- explain the following linear surveying methods:
  - direct measurement
  - measurement by optical means
  - electronic method;
- list the advantages and disadvantages of the following linear measurement equipment and also know how to operate them:
  - chain
  - steel tape;
- explain the following with the aid of a neatly labelled sketch:
  - measuring around a building/pond
  - measuring distance across a river/busy road
  - measuring with an obstacle to line of sight;
- explain the following with regard to surveying measurements:
  - accidental errors
  - constant errors
  - systematic errors
  - mistakes; and
- calculate error corrections that may be occur during taping because of:
  - sag
  - tension
  - slope
  - temperature
  - length
  - altitude at sea level.

Introduction

Distance measurement is considered to be the most fundamental of all surveying operations. It is a process of measuring distances between points on a surface using a chain or tape. It is done based on the linear surveying principle that states: if the distance between two points is measured, the points are fixed. This module will detail the methods of overcoming field challenges and plotting of chain surveys.

Exercise 2.1 SB page 19

1. $C_t = L \times e(t_m - t_s)$

$C_t = 32{,}40 \times 0{,}000012\ (30 - 20)$

$C_t = 0{,}0039$

$S_c = L(1 - \cos\theta)$

$S_c = 32{,}40(1 - \cos 5{:}40{:}00)$

$S_c = 0{,}1583$

Reduced horizontal distance = $32{,}40 + 0{,}0039 - 0{,}1583$

$= 32{,}246$ m

2. $C_t = L \times e(t_m - t_s)$

$100 - 99{,}992 = 100 \times 0{,}000011(18 - t_s)$

$0{,}008 = 0{,}0198 - 0{,}0011t_s$

$0{,}0011t_s = 0{,}0198 - 0{,}008$

$0{,}0011t_s = 0{,}0118$

$t_s = 10{,}73°C$

3. $S_c = H(\sec\theta - 1)$

$S_c = 950(\sec 0{:}29{:}19 - 1)$

$S_c = 0{,}03$

Slope distnace = 950 + 0,03

= 950,03 m

Alternative:

$$\text{Slope distance} = \frac{\text{Horizontal disstance}}{\text{Cos}\theta}$$

$$\text{Slope distance} = \frac{950}{\text{Cos } 0{:}29{:}19}$$

Slope distance = 950,03

4. $C_p = \dfrac{(P - Po)L}{AE}$

$C_p = \dfrac{(10 - 5{,}6)50}{0{,}05 \times 2{,}1 \times 10^6}$

$C_p = 0{,}002$ m or $2{,}095 \times 10^{-3}$ m

5. $\text{Cos } \theta = \dfrac{\text{Horizontal disstance}}{\text{Slope distance}}$

$\text{Cos } \theta = \dfrac{152{,}10}{156{,}19}$

$\theta = \cos^{-1}\left(\dfrac{152{,}10}{156{,}19}\right)$

$\theta = 13{:}08{:}27$

Zenith distance = 90 – 13:08:27

= 76:51:33

6. 6.1 $100 - 99{,}997 = 100 \times 0{,}000012(22{,}5 - t_s)$

$0{,}003 = 0{,}027 - 0{,}0012t_s$

$0{,}0012t_s = 0{,}027 - 0{,}003$

$0{,}0012t_s = 0{,}024$

$t_s = 20°C$

6.2 **Distance $T_1 - T_2$**

$$CD = \frac{405{,}20 \times 99{,}997}{100}$$

$= 405{,}188$

$C_t = L \times e(t_m - t_s)$

$C_t = 405{,}188 \times 0{,}000012(25{,}2 - 20)$

$C_t = 0{,}0253$

$S_c = L(1 - \cos\theta)$

$S_c = 405{,}188(1 - \cos 3{:}10{:}50)$

$S_c = 0{,}6241$

Distance T_1-$T_2 = 405{,}188 + 0{,}0253 - 0{,}6241$

= 404,589 m

Distance T_2-T_3

$$CD = \frac{315{,}16 \times 99{,}997}{100}$$

= 315,151 m

$C_t = L \times e(t_m - t_s)$

$C_t = 315{,}151 \times 0{,}000012(17{,}8 - 20)$

$C_t = 0{,}0083$

$S_c = L(1 - \cos\theta)$

$S_c = 315{,}151(1 - \cos 6{:}14{:}23)$

$S_c = 1{,}867$

Distance $T_2 - T_3 = 315{,}151 + 0{,}0083 - 1{,}867$

= 313,292 m

Distance $T_1 - T_3 = 404{,}589 + 313{,}292$

= 717,881 m

7. 7.1 $C_t = L \times e(t_m - t_s)$

$C_t = 1\,125{,}36 \times 0{,}000011(27 - 20)$

$C_t = 0{,}0867$

$S_c = L(1 - \cos\theta)$

$S_c = 1\,125{,}36(1 - \cos 3{:}27{:}35)$

$S_c = 2{,}051$

Correct distance of base ine AB = 1 125,36 + 0,0867 – 2,051

= 1 123,396 m

7.2 $C_H = \dfrac{L \times H}{R}$

$$C_H = \frac{1\,125{,}396 \times 1\,926{,}35}{6\,373\,000}$$

$C_H = 0{,}34$ m

Correct base line distance = 1 125,396 – 0,34

= 1 125,056

8. $$CD = \frac{96{,}34 \times 100{,}02}{100}$$

= 96,359 m

$C_t = L \times e(t_m - t_s)$

$C_t = 96{,}359 \times 0{,}000011(25 - 20)$

$C_t = 0{,}0053$

$S_c = L(1 - \cos\theta)$

$S_c = 96{,}359(1 - \cos 3{:}25{:}00)$

$S_c = 0{,}1713$

$$C_s = \frac{w^2 \times L^3}{24T^2}$$

$$C_s = \frac{0{,}015^2 \times \left(\frac{96{,}359}{3}\right)^3}{24(7)^2} + 3$$

$C_s = 0{,}019$

$$C_H = \frac{LH}{R}$$

$$C_H = \frac{96{,}359 \times 1\,985{,}5}{6\,373\,000}$$

$C_H = 0{,}03$

Reduced horizontal distance = 96,359 + 0,0053 – 0,1713-0,019 – 0,03

= 96,144 m

$$CD = \frac{67{,}24 \times 100{,}02}{100}$$

= 67,253 m

$C_t = 67{,}253 \times 0{,}000011(12 - 20)$

$C_t = -0{,}0059$

$S_c = 67{,}253(1 - \cos 3{:}10{:}00)$

$S_c = 0{,}1027$

$$C_s = \frac{0{,}015^2 \times \left(\frac{67{,}253}{3}\right)^3}{24(7)^2} \times 3$$

$C_s = 0{,}0065$

$$C_H = \frac{67{,}253 \times 1\,985{,}5}{6\,373\,000}$$

$C_H = 0{,}0209$

Reduced horizontal distance = 67,24 – 0,0059 – 0,1027 – 0,0065 – 0,0209

= 67,104 m

Total reduced distance AB = 96,144 + 67,104

= 163,248 m

9. $\text{Tan}\,\theta = \frac{3{,}64}{100}$

$\theta = \tan^{-1} 0{,}0364$

$\theta = 2:05:05$

$$\text{Cos } \theta = \frac{\text{Horizontal distance}}{\text{Slope distance}}$$

$$\text{Slope distance} = \frac{136{,}57}{\text{Cos } 2:05:05}$$

$$= 136{,}66 \text{ m}$$

10. $C_t = L \times e(t_m - t_s)$

$C_t = 567 \times 0{,}000012(28 - 15)$

$C_t = 0{,}8845$

$S_c = L(1 - \cos\theta)$

$S_c = 567(1 - \cos 4:45:00)$

$S_c = 1{,}9474$

Reduced horizontal distance = 567 + 0,8845 – 1,9474

= 565,937

Exercise 2.2 SB page 27

1. Disadvantages:
   - Steel tapes break easily as they are brittle.
   - They are liable to rust thus require continual maintenance.
   - A steel tape stretches more easily.
   - It is difficult to repair accurately.

2. Advantages:

- Steel bands are more accurate than a chain.
- They are easier to use than a chain.

3. The instrument is held against a ranging rod and aimed at a distant ranging rod in such a way that the line of sight is parallel to the ground. The bubble is then turned, by a large milled-head knob, until the bubble appears in the mirror. When the bubble is centred against the cross-wire, the index arm will be pointing to the vertical angle reading for the ground slope. The instrument is taken down from the eye and the angle reading is noted.

4. Requirements:
   - The tape must be held horizontal.
   - The tape must be held on its correct zero mark.
   - The correct tension must be applied to the tape.
   - Remove all kinks before taping.
   - The tape must be held on the correct peg.
   - View the tape vertically over the peg.
   - Measure from and to the centre of the ranging rod.

5. Equipment used:
   - Arrows
   - Pegs
   - Ranging rods
   - Plumb bob
   - Mallet
   - Cross staff
   - Clinometer.

6. The main principle of chain surveying is to provide a framework that consists of a number of well-conditioned triangles or nearly equilateral triangles.

Group activity 2.1

Get students to form a team of three and instruct them to perform the steps that follow.

Use ranging rods, an optical square and tapes or chains to do the following: Measure the distance between two points situated on opposite sides of a road without laying the tape/chain across the road.

If measuring a road is not possible, mark two lines 6 metres apart and place two pegs on opposite sides of the two lines and measure the distance between them without laying the tape across the two lines.

Record all the data of the survey and include sketches.

Group activity 2.2

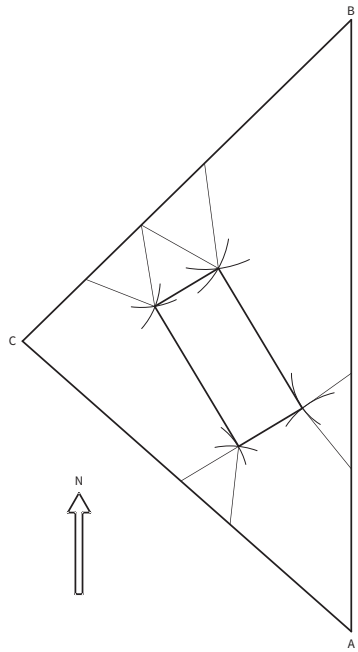
Get students to form a surveying team of three and instruct them to perform the steps that follow.

Use ranging rods, an optical square and tapes or chains to do the following: Measure and place two pegs 7 metres apart in a line going toward a building. Chain or tape around the building as well as 8 metres past the building.

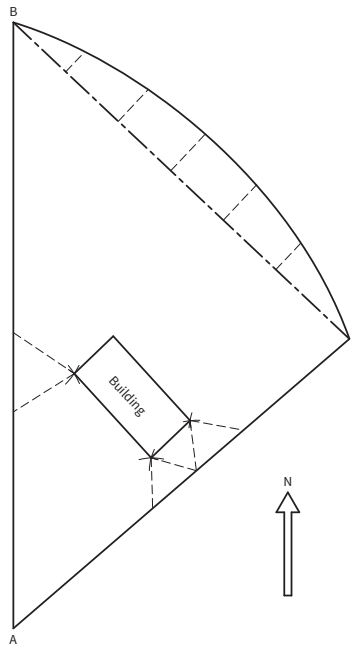
Record all the data of the survey include sketches..

Exercise 2.3 SB page 32

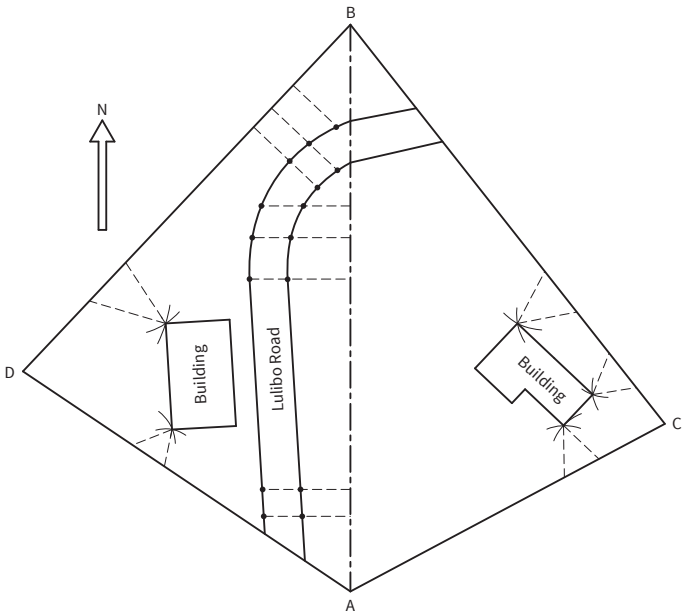
1.



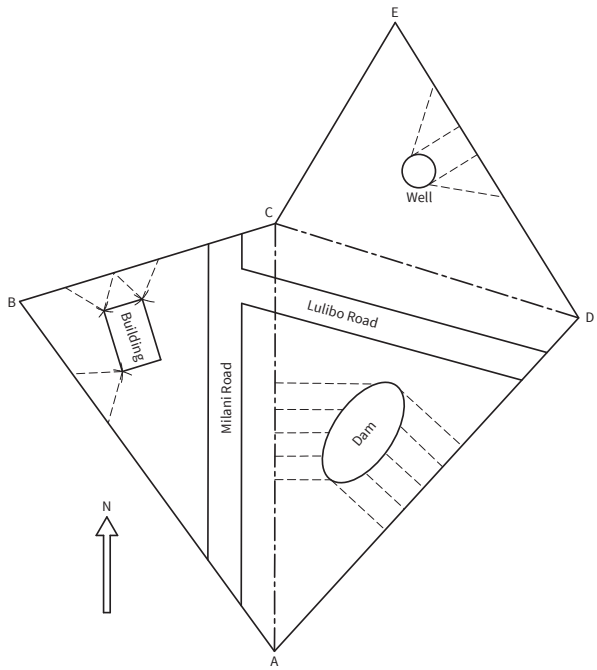
2.



3.


B
N
D
Building
Lulibo Road
Building
C
A

4.


E
Well
C
B
Building
Lulibo Road
D
Milani Road
Dam
N
A

Exercise 2.4 SB page 42

1. $\Delta y_{PQ} = y_Q - y_P$

$\Delta y_{PQ} = (+3\,092{,}95) - (+3\,102{,}48)$

$\Delta y_{PQ} = -9{,}53$

$\Delta x_{PQ} = x_Q - x_P$

$\Delta x_{PQ} = (-1\,688{,}04) - (-1\,058{,}47)$

$\Delta x_{PQ} = -629{,}57$

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

Distance PQ $= \sqrt{(-9{,}53)^2 + (-629{,}57)^2}$

Distance PQ = 629,64 m

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

Direction PQ $= \tan^{-1}\left(\frac{9{,}53}{629{,}57}\right) + 180$

Direction PQ = 180:52:24

2. $\Delta y_{MN} = y_N - y_M$

$\Delta y_{MN} = (-120{,}45) - (-467{,}89)$

$\Delta y_{MN} = +347{,}44$

$\Delta x_{MN} = x_N - M$

$\Delta x_{MN} = (+467{,}89) - (+120{,}45)$

$\Delta x_{MN} = +347{,}44$

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

Distance MN $= \sqrt{(347{,}44)^2 + (347{,}44)^2}$

Distance MN = 491,35 m

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

Direction MN = $\tan^{-1}\left(\frac{347,44}{347,44}\right)$

Direction MN = 45:00:00

3. $\Delta y_{RS} = (-233,02) - (-116,83) = -116,19$

$\Delta x_{RS} = (+107,80) - (+174,20) = -66,40$

Distance RS = $\sqrt{(-116,19)^2 + (-66,40)^2} = 133,82$ m

Direction RS = $\tan^{-1}\left(\frac{116,19}{66,40}\right) + 180 = 240:15:11$

$\Delta y_{RT} = (-479,22) - (-116,83) = -362,39$

$\Delta x_{RT} = (+242,74) - (+174,20) = +68,54$

Distance RT = $\sqrt{(-362,39)^2 + (68,54)^2} = 368,81$ m

Direction RT = $\tan^{-1}\left(\frac{68,54}{362,39}\right) + 270 = 280:42:36$

4. $\Delta y_{AB} = (-3\,234,13) - (-3\,116,24) = -117,89$

$\Delta x_{AB} = (+4\,108,60) - (+4\,178,31) = -69,71$

Distance AB = $\sqrt{(-117,89)^2 + (-69,71)^2} = 136,96$ m

Direction AB = $\tan^{-1}\left(\frac{116,19}{66,40}\right) + 180 = 240:15:11$

$\Delta y_{AC} = (-3\,478,35) - (-3\,116,24) = -362,11$

$\Delta x_{AV} = (+4\,242,73) - (+4178,31) = +64,42$

Distance AC = $\sqrt{(-362,11)^2 + (64,42)^2} = 367,79$ m

Direction AC = $\tan^{-1}\left(\frac{64,42}{362,11}\right) + 270 = 280:05:16$

$\Delta y_{AD} = (-3\,475,78) - (-3\,116,24) = -359,54$

$\Delta x_{AD} = (+4\,372,21) - (+4178,31) = +193,90$

Distance AD = $\sqrt{(-359{,}54)^2 + (193{,}90)^2}$ = 408,49 m

Direction AD = $\tan^{-1}\left(\frac{193{,}90}{359{,}54}\right)$ + 270 = 290:20:17

Δy_{AE} = (–3 102,32) – (–3 116,24) = +13,92

Δy_{AE} = (+4 102,32) – (+4178,31) = –75,99

Distance AE = $\sqrt{(13{,}92)^2 + (-75{,}99)^2}$ = 77,25 m

Direction AE = $\tan^{-1}\left(\frac{75{,}99}{13{,}92}\right)$ + 90 = 169:37:10

5. Δy_{AB} = (–643,58) – (–42,98) = –600,60

Δx_{AB} = (–765,54) – (–189,02) = –573,52

Distance AB = $\sqrt{(-600{,}60)^2 + (-573{,}52)^2}$ = 830,45 m

Direction AB = $\tan^{-1}\left(\frac{600{,}60}{573{,}52}\right)$ + 180 = 226:19:16

Check:

830,45 sin226:19:16 = 600,60 = Δy

830,45 cos226:19:16 = 573,52 = Δx

6. Δy_{PQ} = (+420,15) – (+839,90) = –419,75

Δx_{PQ} = (–586,30) – (–358,10) = –228,20

Distance PQ = $\sqrt{(-419{,}75)^2 + (-228{,}20)^2}$ = 477,77 m

Direction PQ = $\tan^{-1}\left(\frac{419{,}75}{228{,}20}\right)$ + 180 = 241:28:08

Check:

477,77 sin 241:28:08 = –419,75 = Δy_{PQ}

477,77 cos 241:28:08 = –228,20 = Δx_{PQ}

Δy_{PR} = (+360,18) – (+839,90) = –479,72

Δx_{PR} = (–60,79) – (–358,10) = +297,31

Distance PR = $\sqrt{(-479{,}72)^2 + (297{,}31)^2} = 564{,}38$ m

Direction PR = $\tan^{-1}\left(\frac{297{,}31}{479{,}72}\right) + 270 = 301{:}47{:}20$

Check:

564,38 sin 301:47:20 = –479,72 = Δy_{PR}

564,38 cos 301:47:20 = +297.31 = Δx_{PR}

$\Delta y_{PS} = (+992{,}89) - (+839{,}90) = +152{,}99$

$\Delta x_{PS} = (-789{,}58) - (-358{,}10) = -431{,}48$

Distance PS = $\sqrt{(152{,}99)^2 + (-431{,}48)^2} = 457{,}80$ m

Direction PS = $\tan^{-1}\left(\frac{431{,}48}{152{,}99}\right) + 90 = 160{:}28{:}37$

Check:

457,80 sin 160:28:37 = +152,99 = Δy_{PS}

457,80 cos 160:28:37 = –431,48 = Δx_{PS}

$\Delta y_{PT} = (+920{,}87) - (+839{,}90) = +80{,}97$

$\Delta x_{PT} = (-435{,}25) - (-358{,}10) = -77{,}15$

Distance PT = $\sqrt{(80{,}97)^2 + (-77{,}15)^2} = 111{,}84$ m

Direction PT = $\tan^{-1}\left(\frac{77{,}15}{80{,}97}\right) + 90 = 133{:}36{:}58$

Check:

133,82 sin 133:36:58 = +80,97 = Δy_{PT}

133,82 cos 133:36:58 = –77,15 = Δx_{PT}

Exercise 2.5 SB page 47

1.

A			– 4 615,25	+830,34
335:32:20			– 1 051,28	+2 310,97
2 538,85				
B			– 5 666,53	+3 141,31
A	– 4 615,25	+830,34		
B	– 5 666,53	+3 141,31		
	– 1 051,28	+2 310,97		335:32:20
				2 538,85 m

2.

R			+105,42	+201,50
98:65:25			+946,04	– 1051,28
958,34				
S			+1 051,46	-849,78
R	+105,42	+201,50		
S	+1 051,46	– 849,78		
	+946,04	– 1051,28		98:65:25
				958,34

R			+105,42	+201,50
186:32:15			– 28,38	– 247,68
249,30				
T			+77,04	– 46,16
R	+105,42	+201,50		
T	+77,04	– 46,16		
	– 28,38	– 247,68		186:32:15
				249,30

3.

K			+680,23	+2 830,15
159:45:55			+1 305,52	– 3 541,67
3 774,63				
L			+1 985,75	– 711,52
K	+680,23	+2 830,15		
L	+1 985,75	– 711,52		
	+1 305,52	– 3 541,67		159:45:55
				3 774,63

K			+680,23	+2 830,15
205:13:25			– 1 469,07	– 3 118,61
3 477,30				
M			– 788,84	– 288,46
K	+680,23	+2 830,15		
L	– 788,84	– 288,46		
	– 1 469,07	– 3 118,61		205:13:25
				3 477,30

K			+680,23	+2 830,15
256:38:14			– 1 956,02	– 464,65
2 010,45				
N			– 1 275,79	+2 365,50
K	+680,23	+2 830,15		
N	– 1 275,79	+2 365,50		
	– 1 956,02	– 464,65		256:38:14
				2 010,45

4.

R			+610,85	+815,43
285:32:15			– 901,22	+250,56
935,40 m				
S			– 290,37	+1 065,99
R	+610,85	+815,43		
S	– 290,37	+1 065,99		
	– 901,22	+250,56		285:32:15
				935,40 m
R			+610,85	+815,43
57:25:46			+720,09	+459,99
854.47				
T			+1 330,94	+1 275,42
R	+610,85	+815,43		
T	+1 330,94	+1 275,42		
	+720,09	+459,99		57:25:46
				854.47
R			+610,85	+815,43
158:30:12			+204,62	– 519,55
558,39				
U			+815,47	+1 334,98
R	+610,85	+815,43		
U	+815,47	+1 334,98		
	+204,62	– 519,55		158:30:12
				558,39

Exercise 2.6 SB page 47

1. 1.1 Mean direction is direction measured directly using a theodolite or total station with reference to the zero mark of the instrument.

   1.2 The whole circle bearing is the direction measured clockwise from the south direction of the South African coordinate system.

   1.3 The orientation target is a point of known coordinates, such as communication towers, used to calculate the orientation angle or mean orientation angle.

2. The whole circle bearing is the sum of the mean direction and orientation angle.

3. To counter the possibility of errors that may exist due to coordinates of an orientation target being flawed, two or more orientation targets are used to calculate the orientation angle.

4.

Instrument	Target	Mean direction	Orientation angle/Mean orientation angle	WCB	Distance
A	T_1	74:49:08	327:41:08	42:30:16	1 020,15
	T_2	176:20:35	327:41:35	144:02:10	1 836,40
	T_3	254:59:11	327:41:22	222:40:33	1 905,21
	B	302:13:26	327:41:24	269:54:50	1 724,56

$$\text{Weighted average} = \frac{(8'' \times 1) + (35'' \times 1{,}8) + (22'' \times 1{,}9)}{1 + 1{,}8 + 1{,}9} = 24''$$

$\bar{z} = 327:41:00 + 24'' = 327:41:24$

$$\text{Weighted average} = \frac{(8'' \times 1) + (35'' \times 1{,}8) + (22'' \times 1{,}9)}{1 + 1{,}8 + 1{,}9} = 24''$$

$\bar{z} = 327:41:00 + 24'' = 327:41:24$

$Y_B = Y_A + d_{A-B} .\sin(WCB_{A-B})$

$Y_B = -834{,}19 + 1\,020{,}15 \sin 269{:}54{:}50$

$Y_B = -1\,854{,}34$

$X_B = X_A + d_{A-B} .\cos(WCB_{A-B})$

$X_B = +4\,205{,}13 + 1\,020 \cos 269{:}54{:}50$

$X_B = +4\,203{,}60$

5.

Instrument	Target	Mean direction	Orientation angle/Mean orientation angle	WCB	Distance
E	P_1	288:53:55	104:25:50	33:19:45	1 105,14
	P_2	325:09:29	104:28:45	69:38:14	1 314,09
	P_3	48:43:36	104:25:32	153:09:08	1 503,85
	P_4	129:49:54	104:25:26	234:15:20	1 302,60
	F	29:47:13	104:25:35	134:12:48	1 215,58

The orientation target P_1 differs by 3 minutes from other targets. Therefore, it will not be used in calculating the weighted average.

$$\text{Weighted average} = \frac{(50'' \times 1{,}1) + (32'' \times 1{,}5) + (26'' \times 1{,}3)}{1{,}1 + 1{,}5 + 1{,}3} = 35''$$

$\bar{z} = 104{:}25{:}00 + 35'' = 104{:}25{:}35$

$Y_F = Y_E + d_{E-F} .\sin(WCB_{E-F})$

$Y_F = -1\,133{,}46 + 1\,215{,}58 \sin 134{:}12{:}48$

$Y_F = -262{,}20$

$X_F = X_E + d_{E-F} .\cos(WCB_{E-F})$

$X_F = -2\,095{,}17 + 1\,215{,}58 \cos 134{:}12{:}48$

$X_F = -2\,942{,}83$

6.1

Instrument	Target	Mean direction	Orientation angle/Mean orientation angle	WCB	Distance
B	S_1	22:24:18	212:04:13	234:28:31	1 203,98
	S_2	71:03:38	212:04:27	283:08:05	1 820,30
	S_3	94:06:22	212:04:52	306:11:14	2 025,16
	S_4	192:53:47	212:04:39	44:58:26	2 135,20
	D	108:44:50	212:04:35	256:40:15	1 435,17

$$\text{Weighted average} = \frac{(13'' \times 1{,}2) + (27'' \times 1{,}8) + (52'' \times 2{,}0) + (39''\times 2{,}1)}{1{,}2 + 1{,}8 + 2{,}0 + 2{,}1} = 35''$$

$\overline{z} = 212:04:00 + 35'' = 212:04:35$

6.2 $Y_D = Y_B + d_{B\text{-}D} .\sin(WCB_{B\text{-}D})$

$Y_D = 2\,035{,}70 + 1\,435{,}17 \sin 256:40:15$

$Y_D = +639{,}19$

$X_D = X_B + d_{B\text{-}D} .\cos(WCB_{B\text{-}D})$

$X_D = -1\,209{,}35 + 1\,435{,}17 \cos 256:40:15$

$X_D = -1\,540{,}22$

6.3 BD 256:40:15

DBE 36:15:05

BE 292:55:20

EBF 136:49:24

BF 69:44:44

FBG 103:56:15

FG 173:40:59

7.1

Instrument	Target	Mean direction	Orientation angle/Mean orientation angle	WCB	Distance
P	R_1	300:54:38	302:03:58	242:58:36	3 522,10
	R_2	46:12:14	302:03:08	348:15:22	2 725,18
	R_3	120:51:05	302:03:39	62:54:44	1 867,65
	A	184:38:59	302:03:37	126:42:36	2 045,97

$$\text{Weighted average} = \frac{(58'' \times 3{,}5) + (8'' \times 2{,}7) + (39'' \times 1{,}9)}{3{,}5 + 2{,}7 + 1{,}9} = 37''$$

$\bar{z} = 302:03:00 + 37'' = 302:03:35$

7.2 $Y_A = Y_A + d_{P-A} .\sin(WCB_{P-A})$

$Y_A = -3\,077{,}46 + 2\,045{,}97 \sin 126:42:36$

$Y_A = -1\,437{,}26$

$X_A = X_P + d_{P-A} .\cos(WCB_{P-A})$

$X_A = +2\,756{,}02 + 2\,045{,}97 \cos 126:42:36$

$X_A = +1\,533{,}01$

7.3 PA 126:42:36

APB 73:15:45

PB 199:58:21

BPC 92:52:10

PC 292:50:31

CPD 18:23:36

PD 311:14:07

DPE 103:58:24

PE 55:12:31

Summative assessment SB page 61

1. 1.1 E

   1.2 D

   1.3 F

   1.4 B

   1.5 C (5)

2. Any FIVE of the following:

   - Correction for absolute length
   - Correction for pull or tension
   - Correction for temperature
   - Correction for sag
   - Correction for slope
   - Correction for the sea level. (5)

3.
   - Hold the instrument against a ranging rod and aim it at a distant ranging rod, in such a way that the line of sight is parallel to the ground.
   - Turn the bubble by turning the large milled-head knob until the bubble appears in the mirror.
   - When the bubble is centred against the cross wire, the index arm will be pointing to the vertical angle reading for the ground slope.
   - Then take the instrument down from the eye and note the angle reading.
   - A Vernier scale and magnifying glass can be used to achieve a finer reading. (6)

4.1 $C_t = L \times e(t_m - t_s)$

$C_t = 1\,236{,}45 \times 1{,}1 \times 10^{-5} (26 - 20)$

$C_t = +0{,}0816$

$S_c = L(1 - \cos\theta)$

$S_c = 1\ 236{,}45(1 - \cos 3{:}27{:}35)$

$S_c = 2{,}2535$

$$C_p = \frac{(P - Po)L}{AE}$$

$$C_p = \frac{(9{,}5 - 6{,}5)1\ 236{,}45}{5{,}4 \times 2{,}1 \times 10^6}$$

$C_p = 3{,}271$

Correct distance (CD) = $L \pm C_t - S_c - C_p$

Correct distance = 1 236,45 + 0,0816 – 2,2535 – 3,271

= 1 231,01 m (8)

4.2 $$C_H = \frac{L \times H}{R}$$

$$C_H = \frac{1\ 236{,}45 \times 1\ 837{,}84}{6\ 373\ 000}$$

$C_H = 0{,}3566$

Correct baseline distance = 1231,01 – 0,3566

= 1 230,65 (2)

5.

JOIN				
R	+42,98	+189,02		46:10:19
S	+643,58	+765,54		832,52 m
	+600,60	+576,52		
R			+42,98	+189,02
46:10:19	0,721421225	0,692496509	+600,60	+576,52
832,52 m				
S			+643,58	+765,54

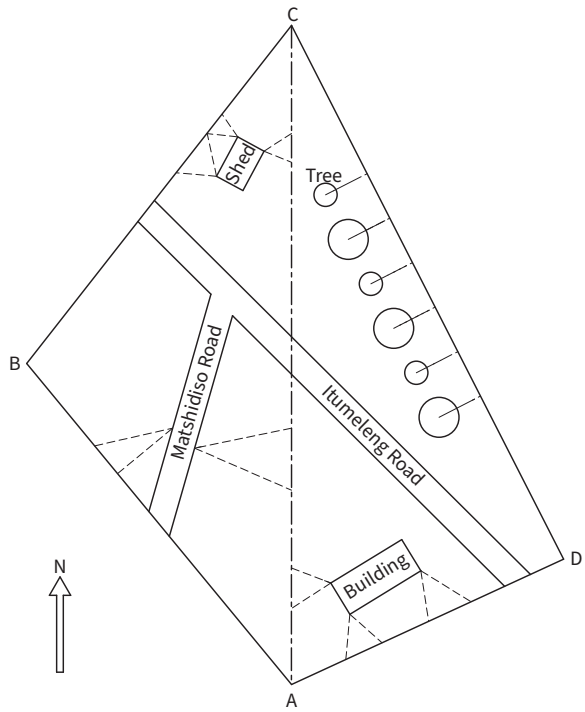
(6)

6.

P1			– 53,45	+126,32
203:14:25			– 60,55	– 141,00
153,45 m				
P2			– 114,00	– 14,68
P1	– 53,45	+126,32		
P2	– 114,00	– 14,68		
	– 60,55	– 141,00		203:14:25
				153,45 m

(6)

7.



(12)

Total: 50 marks

MODULE

3 *Height measurements*

By the end of this module, students should be able to:

- explain the term *levelling* and the purpose of levelling;
- explain the following terminology as used in levelling:
  - mean sea level
  - local heights
  - datum
  - closure error
  - official heights
  - horizontal plane (horizontal line)
  - plane
  - direction of gravity
  - vertical plane
  - incline plane
  - level surface (level line)
  - benchmark
  - foresight
  - intermediate sight
  - back sight
  - collimation line (line of sight)
  - change point;
- explain the different between closed *traverse levelling* and open *traverse* levelling;
- explain the following types of errors in levelling:
  - natural causes
  - instrument errors
  - personal errors;
- calculate the reduced levels by means of the following:
  - rise and fall method
  - collimation method;
- determine collimation error through the two-peg test;
- define *reciprocal levelling;* and
- reduce reciprocal levels.

Introduction

Height, or orthometric height, refers to elevation which is defined as the vertical distance along the plumb line, from a point of interest to a reference surface known as the geoid. The geoid is an imaginary mean sea level surface. The measurement of heights is required to determine height difference between points or the height of a point relative to a datum. The process of measuring height is called levelling. This module will detail the method involved in measuring, recording and reducing the measurement to establish the position of points on the earth's surface.

Exercise 3.1 SB page 74

1. Methods of levelling

   1.1 Barometric levelling is an indirect method of levelling in which the differences in the elevation of points are determined from differences in atmospheric pressure observed with altimeters or barometers at each point.

   1.2 Trigonometric levelling is a process of levelling in which the elevation of points or the difference in height between points is measured from the observed horizontal distances and vertical angles in the field. The trigonometric relations are then used to find the elevation of a point from the angle and horizontal distance.

   1.3 Differential levelling is a method of levelling that uses a surveyor's level and a levelling staff to determine the difference in elevation between points that are distant from each other.

2. The basic principle of trigonometric levelling is based on the fundamentals principle of trigonometry, in which the horizontal distance and vertical angles are used to determine the difference in height between the instrument point and the surveyed point.

3. $V = D \tan\theta$

   $V = 50 \tan 25{:}15{:}20$

   $V = 23{,}587$ m

$RL_{Pole\ top} = RL_{BM} + r + V$

$RL_{Pole\ top} = 1\ 250 + 3{,}53 + 23{,}587$

$RL_{Pole\ top} = 1\ 277{,}117$ m

4. $\theta = 90 - 60{:}10{:}12 = 29{:}49{:}48$

$V = D \tan\theta$

$V = 450 \tan 29{:}49{:}48$

$V = 258{,}03$ m

$RL_S = RL_R + hi + V - r$

$RL_S = 225{,}25 + 1{,}6 + 258{,}03 - 2{,}15$

$RL_S = 482{,}73$ m

5.1 $C_d = 0{,}0673(0{,}6)^2$

$C_d = 0{,}024$ m

5.2 $V = D \tan\theta$

$V = 600 \tan 06{:}50{:}45$

$V = 72{,}033$ m

$RL_G = RL_F + hi + V - r + C_d$

$RL_G = 105{,}43 + 1{,}65 + 72{,}033 - 1{,}35 + 0{,}024$

$RL_G = 177{,}787$ m

6. $\theta = 9\ 0 - 98{:}07{:}12 = -08{:}07{:}12$

$V = D \tan\theta$

$V = 580 \tan 08:07:12$

$V = 82{,}753 \text{ m}$

$C_d = 0{,}0673(0{,}58)^2$

$C_d = 0{,}023 \text{ m}$

$RL_{\text{Tower bottom}} = RL_R + hi - V + C_d$

$RL_{\text{Tower bottom}} = 880{,}59 + 1{,}15 - 82{,}753 + 0{,}023$

$RL_{\text{Tower bottom}} = 799{,}01 \text{ m}$

$RL_{\text{Tower top}} = RL_{\text{Tower bottom}} + \text{Tower Height}$

$RL_{\text{Tower top}} = 799{,}01 + 136{,}43$

$RL_{\text{Tower top}} = 935{,}44 \text{ m}$

7.1 Let $V_1 = \theta = 11:10:14$ be the angle of elevation and

$V_2 = \alpha = 30:05:09$ be the angle of depression

$V_1 = D \tan\theta$

$V_1 = 190 \tan 11:10:14$

$V_1 = 3{,}882 \text{ m}$

$V_2 = D \tan\theta$

$V_2 = 190 \tan 30:05:09$

$V_2 = 110{,}076 \text{ m}$

Parapet wall height = 3,882 + 110,076

= 113,896

7.2 $RL_{Top\ of\ Parapet} = RL_{BM} + hi + V_2$

$RL_{Top\ of\ Parapet} = 63{,}80 + 0{,}88 + 110{,}076$

$RL_{Top\ of\ Parapet} = 174{,}756$ m

8. $\theta = 90 - 85{:}17{:}35 = 04{:}42{:}25$

$V = D \tan\theta$

$V = 495 \tan 04{:}42{:}25$

$V = 40{,}757$ m

$C_d = 0{,}0673(d)^2$

$C_d = 0{,}0673(0{,}495)^2$

$C_d = 0{,}016$ m

$RL_{Hill\ top} = RL_{Staff\ station} + hi + V + C_d$

$RL_{Hill\ top} = 1\ 358{,}35 + 1{,}38 + 40{,}737 + 0{,}016$

$RL_{Hill\ top} = 1\ 400{,}476$ m

Practical pair activity 3.1

Get students to form a team of two and instruct them to do the following:

Select an area on your campus building or a nearby building and determine its elevation. A theodolite and staff are required.

Use the reduced level of a known point, such as a manhole.

Record the reading. Each team member should have the opportunity to calculate the elevations of the point surveyed.

Practical pair activity 3.2

Get students to form a team of two and instruct them to do the following:

Select SIX points (far apart) on your campus grounds and a point with a known reduced level that can be used as a benchmark.

Observe each point and record the readings.

Calculate the reduced levels of each point using both the rise and fall method and the collimation height method.

Each team member must do their own calculations.

Exercise 3.2 SB page 83

1. 1.1 D

   1.2 C

   1.3 B

2.1 Instrument error:

- The permanent adjustment of the instrument may not be perfect; that is, the line of collimation may not be parallel to the line of sight.
- The internal arrangement of the focusing tube may not be correct.
- Graduation of the levelling staff may not be perfect.

2.2 Personal errors:

- The instrument may not be levelled perfectly.
- The focus of the eye-piece and object glass may not be perfect.
- The parallax may not have been eliminated.
- The position of the staff may be displaced at the change point when taking FS and BS readings.

- Entry and recording in the field book may be incorrect.
- Staff may not have been fully extended, may not have been held vertical.

3. A closed loop traverse is a series of level runs from a known datum or reduced level back to the same point of known reduced level.

   A closed link traverse is a series of level runs from a known datum or reduced level to another datum or reduced level.

Exercise 3.3 SB page 101

1.

POINT	BS	IS	FS	Rise	Fall	RL
A	2,40					150,00
B		2,00		0,40		150,40
C		1,90		0,10		150,50
D	2,80		1,40	0,50		151,00
E		2,00		0,80		151,80
F	1,30		2,60		0,60	151,20
G	0,60		3,00		1,70	149,50
H			1,70		1,10	148,40
	7,10		8,70	1,80	3,40	148,40
	-8,70			-3,40		-150,00
	-1,60			-1,60		-1,60

2.

POINT	BS	IS	FS	Rise	Fall	RL	Cor.	Final RL
BM1	1,23					130,20		130,20
A		2,14			0,91	129,29	+0,21	129,50
B	2,84		2,46		0,32	128,97	+0,21	129,50
C		1,98		0,86		129,83	+0,42	129,50
D		2,34			0,36	129,47	+0,42	129,50
E		3,21			0,87	128,60	+0,42	129,02
F	1,86		2,39	0,82		129,42	+0,63	129,84
G	2,46		1,69	0,17		129,59	+0,84	130,22
H		1,54		0,92		130,51	+0,84	131,35
I		2,06			0,52	129,99	+0,84	130,83
J		1,96		0,10		130,09	+0,84	130,93
BM2			2,32		0,36	129,73	+0,84	130,57
	8,39		8,86	2,87	3,34	129,73		
	-8,86			-3,34		-130,20		
	-0,47			-0,47		-0,47		

3.

POINT	BS	IS	FS	Rise	Fall	RL
BM1	3,141					404,473
A		0,086		3,055		407,528
B	2,111		4,283		4,197	403,331
C		1,406		3,517		406,848
D		2,032		0,626		407,474
E	3,108		3,638		5,670	401,804
F	1,823		2,110	5,218		407,022
G		3,111			4,934	402,088
H	4,123		2,109	5,220		407,308
I		3,281			7,404	399,904
BM2			3,083	0,198		400,102
	2,414		6,785	17,834	22,205	400,102
	-6,785			-22,205		-404,473
	-4,371			-4,371		-4,371

4.

POINT	BS	IS	FS	Rise	Fall	RL
A	6,20					100,00
B		2,40		3,80		103,80
C	4,96		6,22		3,82	99,98
D		5,31			0,35	99,63
E		4,78		0,53		100,16
F	3,73		8,86		4,08	96,08
G	6,32		10,74		7,01	89,07
H		5,03		1,29		90,36
I		7,31			2,28	88,08
J			6,01	1,30		89,38
	21,21		31,83	6,92	17,54	89,38
	-31,83			-17,54		-100,00
	-10,62			-10,62		-10,62

5.

POINT	BS	IS	FS	Rise	Fall	RL
BM3	2,87					1 153,13
A		2,92				1 153,08
B		1,34		1,58		1 154,66
C	3,16		0,98	0,36		1 155,02
D		2,30		0,86		1 155,88
E		0,97			0,67	1 155,21
F	2,42		0,76	2,21		1 157,42
G		1,25		1,17		1 158,59
BM4			2,48		1,23	1 157,36
	8,45		4,22	6,18	1,95	1 157,36
	-4,22			-1,95		1 153,13
	4,23			4,23		4,23

6.

POINT	BS	IS	FS	Rise	Fall	RL	Cor.	Final RL
BM1	2,02					300,00		300,00
B		3,46			5,48	294,52	-0,04	294,48
C	1,60		2,46	1,00		295,52	-0,04	295,48
D		2,39			3,99	291,53	-0,08	291,45
E		3,05			0,66	290,87	-0,08	290,79
F	3,56		1,75	1,30		292,17	-0,08	292,09
G		2,84		0,72		292,89	-0,12	292,77
H	2,44		3,90		1,06	291,83	-0,12	291,71
J		3,24			0,80	291,03	-0,16	290,87
K		5,63			2,39	288,64	-0,16	288,48
L	1,46		3,20	2,43		291,07	-0,16	290,91
M		1,74			0,28	290,79	-0,20	290,59
N	1,90		2,35		0,61	290,18	-0,20	289,98
P		2,40			0,50	289,68	-0,24	289,44
Q	2,44		3,75		1,35	288,33	-0,24	288,09
BM2			0,52			290,25	-0,24	289,97
	8,18		17,93	7,37	17,12	290,25		
	-17,93			-17,12		300,00		
	-9,75			-9,75		-9,75		

Exercise 3.4 SB page 108

1.

POINT	BS	IS	FS	Collimation height	Reduced level
A	1,153			34,863	33,710
B	1,545		1,333	35,075	33,530
C	1,735		1,234	35,576	33,841
D		1,264			34,312
E	1,963		1,344	36,195	34,232
F			1,342		34,853
	6,396		5,253		34,853
	-5,253				-33,710
	1,143				1,143

2.

POINT	BS	IS	FS	Collimation height	RL	Cor.	Final RL
0 m	3,63			749,45	745,82		745,82
20 m		2,87			746,58	+0,006	746,586
40 m	3,02		2,15	750,32	747,30	+0,012	747,312
60 m	0,83		2,06		750,32	+0,018	750,338
80 m		0,78			749,54	+0,018	749,558
100 m		1,49			747,96	+0,018	747,978
120 m	0,62		1,63	748,44	747,82	+0,018	747,838
140 m		3,96			744,48	+0,024	744,504
160 m		3,81			744,63	+0,024	744,654
180 m		3,50			744,94	+0,024	744,964
200 m	1,46		1,76	748,14	746,68	+0,024	746,704
220 m			2,05		746,09	+0,03	748,12
	9,56		9,65		746,09		
	-9,65				745,82		
	-0,09				-0,09		

3.

POINT	BS	IS	FS	Collimation height	RL	Cor.	Final RL
BMA	0,13			300,13	300,00		300,00
B	1,73		1,33	300,53	298,80	+0,005	298,805
C		1,26			299,27	+0,010	299,280
D	1,96		1,34	301,15	299,19	+0,010	299,200
E	2,30		1,34	302,11	299,81	+0,015	299,825
F			1,11		301,00	+0,020	301,02
	6,12		5,12		301,00		
	-5,12				300,00		
	+1,00				+1,00		

4.

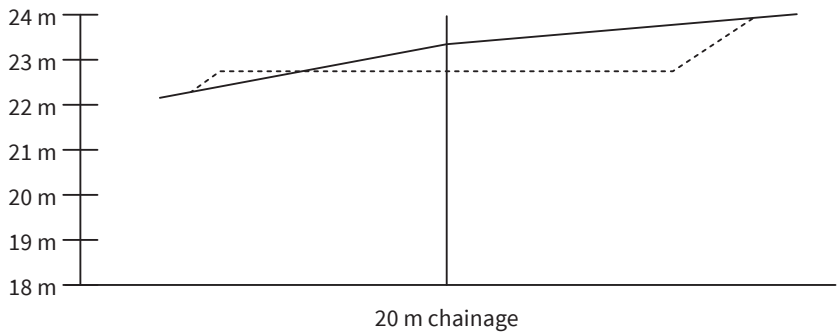
POINT	BS	IS	FS	Collimation height	Reduced Level
A	4,42			148,27	143,85
B		5,50			142,77
C	3,16		1,47	149,96	146,80
D		1,95			148,01
E		4,55			145,41
F	4,65		3,97	150,64	145,99
G		3,90			146,74
H		6,32			144,32
I	4,16		1,62	153,18	149,02
J		1,62			151,56
K			5,20		147,98
	16,39		12,26		147,98
	-12,26				-148,85
	4,13				4,13

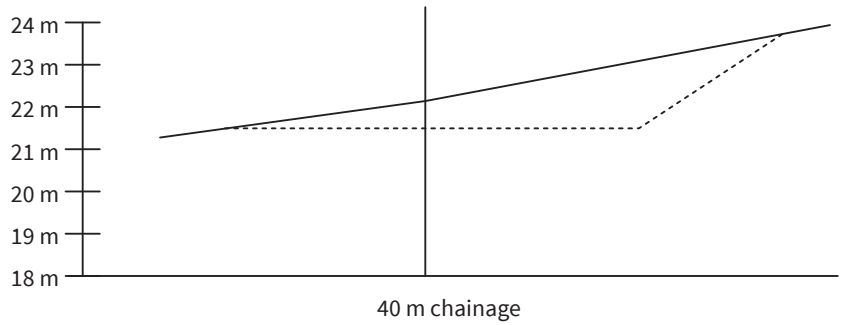
5.

POINT	BS	IS	FS	Collimation height	Reduced Level
BM 5	4,61			889,47	884,86
P1		3,54			885,93
P2		1,69			884,24
P3	1,80		3,21	890,88	892,68
P4		2,40			893,28
P5	2,89		3,62	890,15	887,26
P6		1,20			891,35
P7		2,20			892,35
P8		1,46			888,69
P9			1,20		888,95
	5,70		1,61		888,95
	-1,61				884,86
	4,09				4,09

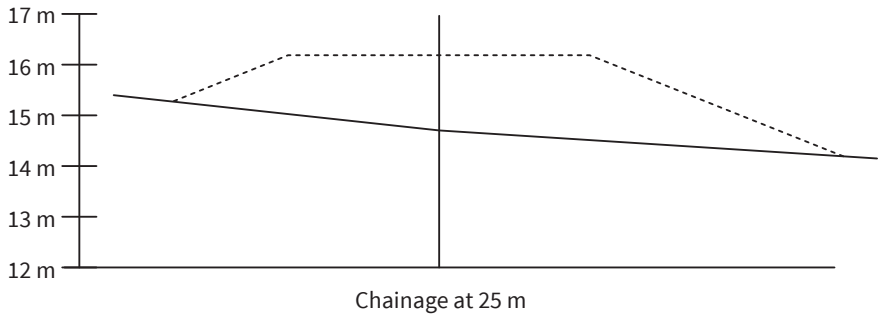
Exercise 3.5 SB page 115

1.

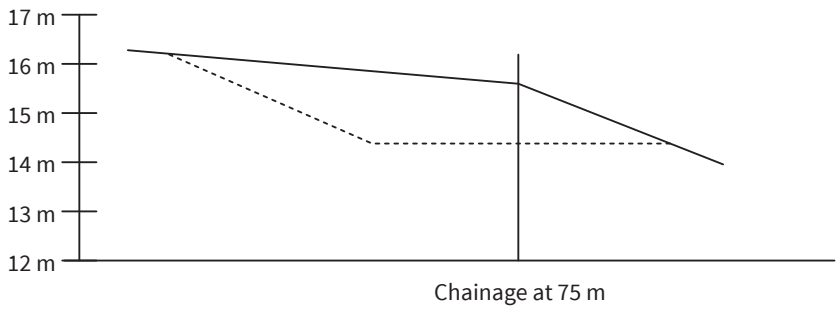



24 m
23 m
22 m
21 m
20 m
19 m
18 m
40 m chainage

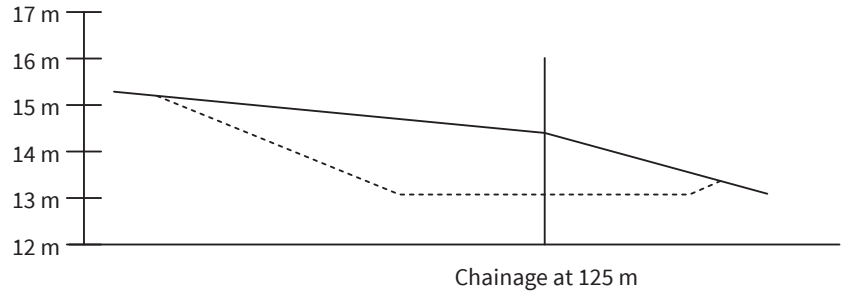
2.1


17 m
16 m
15 m
14 m
13 m
12 m
Chainage at 25 m

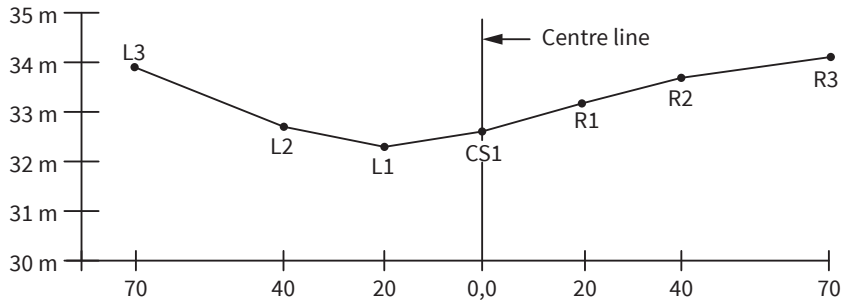
2.2


17 m
16 m
15 m
14 m
13 m
12 m
Chainage at 75 m

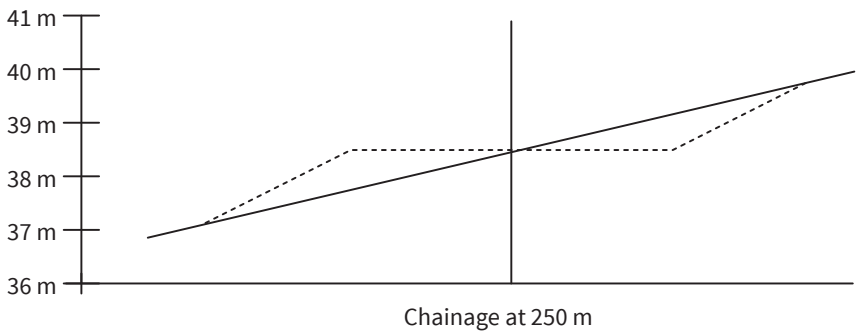
2.3


17 m
16 m
15 m
14 m
13 m
12 m
Chainage at 125 m

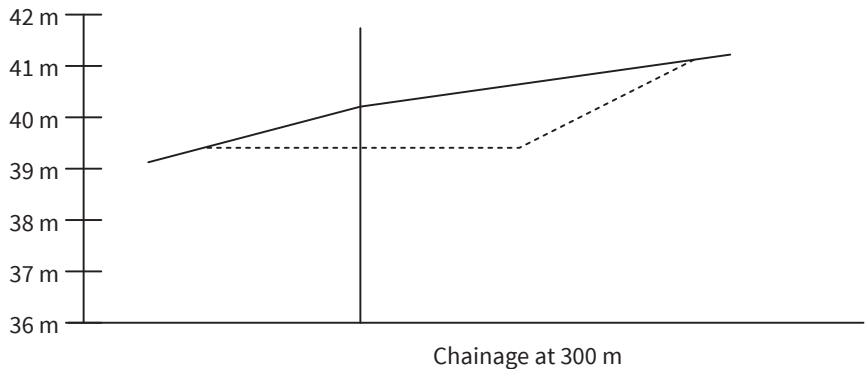
3.


35 m
34 m
33 m
32 m
31 m
30 m
L3
L2
L1
CS1
R1
R2
R3
Centre line
70
40
20
0,0
20
40
70

4.1

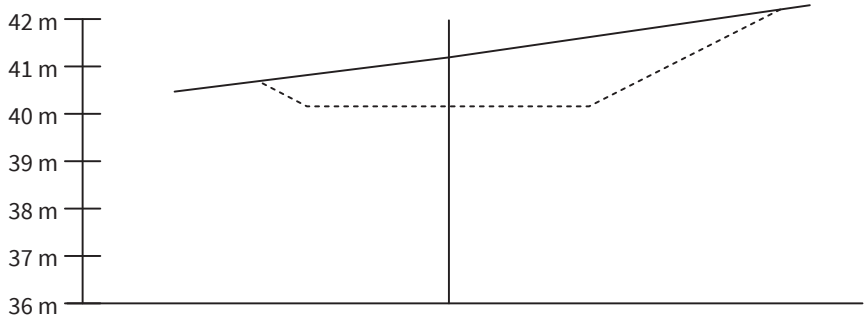

41 m
40 m
39 m
38 m
37 m
36 m
Chainage at 250 m

4.2



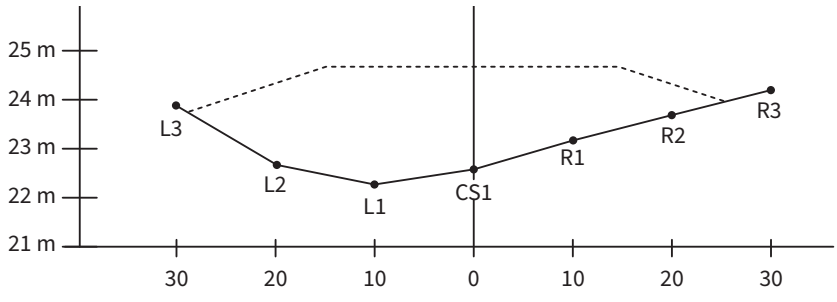
Chainage at 300 m

4.3

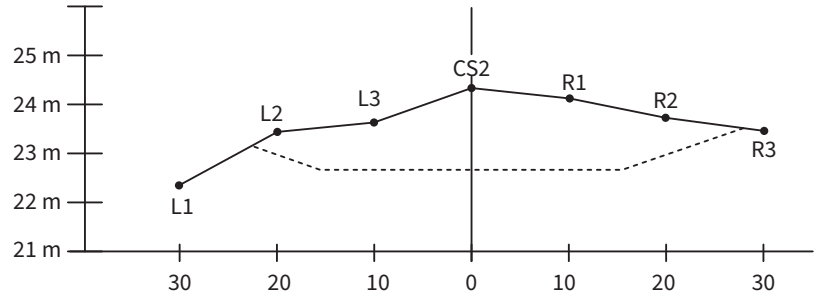


Chainage at 350 m

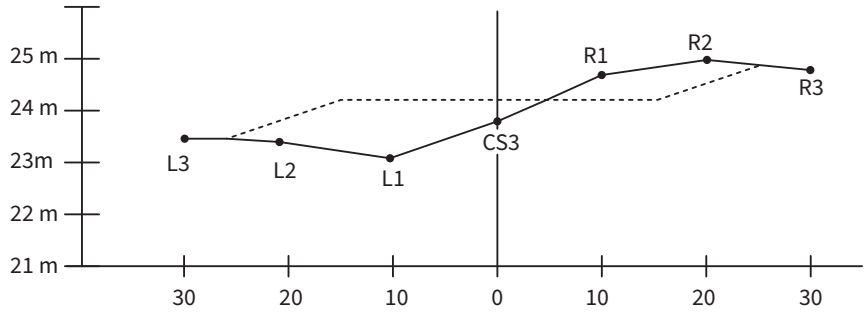
5.



Cross section 1 at 0 m



Cross section 2 at 50 m



Cross section 3 at 100 m

Summative assessment SB page 120

1. 1.1 Barometric levelling

   1.2 Cooke's level

   1.3 Trigonometric levelling

   1.4 Closed link traverse

   1.5 Differential levelling (2 x 5) (10)

2. Any FOUR of the following:

   - To find the elevations of points on the earth's surface for topographic maps

- For the design of highways, railways, canals, etc.
- For locating grade lines
- For laying out of construction projects
- For locating excavating levels
- To determine the drainage characteristics of an area
- Determination of volumes of earthwork for roads, railways. (4)

3. $V = D \tan\theta$

$V = 730 \tan 07{:}13{:}15$

$V = 92{,}49$ m

$C_d = 0{,}0673(d)^2$

$C_d = 0{,}0673(0{,}73)^2$

$C_d = 0{,}036$ m

$RL_{Building\ top} = RL_{BM} + hi + V + C_d$

$RL_{Building\ top} = 250 + 1{,}65 + 92{,}49 + 0{,}036$

$RL_{Hill\ top} = 344{,}176$ m (7)

4.

BS	IS	FS	Rise	Fall	RL	Remarks
1,67					334,34	SV20
	1,44		0,23		334,57	SV40
	1,57		3.01		337,58	SV60
	1,36			2,93	**334,65**	SV80
1,33		1,28	0,08		334,73	SV100
	1,40			0,07	334,66	SV120
1,66		1,98	3,38		338,04	SV140
		1,40		3,06	334,98	SV160
1,34		0,70	6,70	6,06	334,98	
=0,70			-6,06		334,34	
0,64			0,64		0,64	

(11)

5. Any FIVE of the following:

- The instrument may not be levelled perfectly.
- The focus of the eye-piece and object glass may not be perfect.
- The parallax may not be eliminated.
- The position of the staff may be displaced at the change point when taking FS and BS readings.
- Entry and recording in the field book may not be correct.
- Staff may not be fully extended, or may not be held vertical. (5)

6. Inverted level staff readings are readings taken with the staff being held upside-down with the bottom of the staff placed against the point to which the level is required. Inverted staff readings are booked as negative quantities. (3)

Total: 40 marks

MODULE

4 Angular measurement

By the end of this module, students should be able to:

- define *tacheometric surveying;*
- explain the fundamental principles, purpose and advantages of tacheometry; and
- ddetermine the horizontal and vertical distances of points and the difference in elevations between points.

Introduction

Measurement of angles is an integral part of surveying. Initially, surveyors used the compasses to define direction, by putting the survey on a magnetic meridian. Theodolites were developed to allow more accurate measurement of angles, both vertical and horizontal. This module will detail the instrument and method involved in taking and reducing these measurements.

Exercise 4.1 SB page 130

1.

	Degrees	Minutes	Seconds
Main scale	112	40	
Vernier scale		18	20
Total reading	112	58	20

2.

	Degrees	Minutes	Seconds
Main scale	140	20	
Vernier scale		12	20
Total reading	140	32	20

3.	Degrees	Minutes	Seconds
Main scale	68	10	
Vernier scale		05	00
Total reading	68	15	00

4.	Degrees	Minutes	Seconds
Main scale	356	40	
Vernier scale		03	00
Total reading	356	43	00

5.	Degrees	Minutes	Seconds
Main scale	270	00	
Vernier scale		00	00
Total reading	270	00	00

6.	Degrees	Minutes	Seconds
Main scale	358	50	
Vernier scale		14	40
Total reading	359	04	40

Group activity 4.1

Get students to form a team of three and instruct them to do the following:

One person will operate the instrument, one will hold the staff and one will record the readings.

Observe horizontal angles of SIX points and record the Vernier scale readings and reduce, exchanging positions after each two points are surveyed.

Group activity 4.2

Get students to form a team of three and instruct them to do the following:

One person will operate the instrument, one will hold the staff and one will record the readings.

Observe vertical angles of THREE points and record the Vernier scale readings (using face left and face right) and reduce. Exchange positions after each two points are surveyed.

Exercise 4.2 SB page 136

1.

Target	Circle left	Circle right	Mean angle
Q	168:11:42	348:11:42	
R	17:11:50	197:11:56	
	209:00:08	209:00:14	209:00:11
R	17:11:50	197:11:56	
S	104:03:42	284:03:42	
	86:51:52	86:51:46	86:51:49
S	104:03:42	284:03:42	
T	105:04:44	285:04:40	
	1,143		
T	105:04:44	285:04:40	
Q	168:11:41	348:11:43	
	63:06:57	63:07:03	63:07:00
			360:00:00

2.

To	Circle left	Circle right	Mean angle
T1	96:43:20	276:43:00	
	96:43:20	96:43:00	96:43:10

3.

Target	Circle left	Circle right	Mean angle
R	315:24:44	135:26:00	
S	120:54:26	300:56:42	
	165:29:42	165:30:42	165:30:12
S	120: 54: 26	300:56:42	
T	192:42:34	12:43:30	
	71:48:08	71:46:48	71:47:28
T	192:42:34	12:43:30	
R	315:24:34	135:26:10	
	122:42:00	122:42:40	122:42:20
			360:00:00

4.

To	Circle left	Circle right	Mean angle
B	54:36:21	234:36:23	
	54:36:21	54:36:23	54:36:22

5.

To	Circle left	Circle right	Mean angle
H	07: 01:00	187:00:40	
	07: 01:00	07:00:40	07:00:50

6. E = 90 – (–6:28:37) = 96:28:37

F = 90 – (+9:56:45) = 80:03:15

7.

Target	Circle left	Circle right	Mean angle	Correction	Corrected mean angle
B	07:00:40	187:01:00			
C	96:43:20	276:43:00			
	89:42:40	89:42:00	89:42:20	+ 00:00:02	89:42:22
C	96:43:20	276:43:00			
D	187: 22:10	07:21:50			
	90:38:40	90:38:50	90:38:45	+ 00:00:02	90:38:47
D	187:22:10	07:21:50			
E	204:15:15	24:15:39			
	16:53:05	16:53:49	16:53:27	+ 00:00:02	16:53:29
E	204:15:15	24:15:39			
F	276:35:10	96:35:50			
	72:19:55	72:20:11	72:20:03	+ 00:00:02	72:20:05
F	276:35:10	96:35:50			
G	342:20:05	162:20:01			
	65:44:55	65:44:11	65:44:33	+ 00:00:02	65:44:35
G	342:20:05	162:20:01			
B	07:01:00	187:00:26			
	24:40:55	24:40:25	24:40:40	+ 00:00:02	24:40:42
			359:59:48		360:00:00

8.

To	Circle left	Circle right	Mean angle
C	177:52:38	357:52:26	
	177:52:38	177:52:26	177:52:32

9.

Target	Circle left	Circle right	Mean angle	Correction	Corrected mean angle
P	120:32:41	300:32:44			
Q	154:46:49	334:46:48			
	34:14:08	34:14:04	34:14:06	– 00:00:03	34:14:03
Q	154:46:49	334:46:48			
R	175:54:55	355:55:10			
	21:08:06	21:08:22	21:08:14	– 00:00:03	21:08:11
R	175:54:55	355:55:10			
S	207:44:05	27:43:56			
	31:49:10	31:49:10	31:48:58	– 00:00:03	31:48:55
S	207:44:05	27:43:56			
T	234:36:21	54:37:20			
	26:52:16	26:53:24	26:52:50	– 00:00:03	26:52:47
T	234:36:21	54:37:20			
P	120:32:22	300:32:33			
	245:57:01	245:55:13	245:56:07	– 00:00:03	245:56:04
			360:00:15		360:00:00

Exercise 4.3 SB page 140

1.

Circle	Circle reading	Vertical angle	Mean angle
CL	93:56:10	– 03:56:10	– 03:56:45
CR	266:04:40	– 03:55:20	

2.

From	To	Zenith distance	Vertical angle
M	N	95:10:16	– 05:10:16
	L	83:30:00	+ 6:30:00

3.

From	To	Circle	Circle reading	Vertical angle	Mean angle	Rise/fall
t	T1	CL	68:34:25	+ 21:25:35	+ 21:25:26	Rise
		CR	291:25:17	+ 21:25:17		
	T2	CL	94:11:46	– 04:11:46	– 04:11:39	Fall
		CR	265:48:28	– 04:11:46		
	T3	CL	98:56:12	– 08:56:12	– 08:56:18	Fall
		CR	261:03:36	– 08:56:24		
	T4	CL	76:22:10	+ 13:37:50	+ 13:37:49	Rise
		CR	283:37:48	+ 13:37:48		

4.1

To	Circle	Circle reading	Vertical angle	Mean angle
B	CL	86 : 36 : 21	+ 3:23:39	+ 3:23:35
	CR	273 : 23 : 31	+ 3:23:31	

4.2

To	Circle left	Circle right	Mean angle
B	168 : 11 : 49	348 : 11 : 43	
	168 : 11 : 49	168 : 11 : 43	168 : 11 : 46

4.3 $HD = KI\cos^2 \theta$

$= 100(3{,}24 - 0{,}43)(\cos 3{:}23{:}35)^2$

$= 280{,}016$

4.4 $MH = \dfrac{TH + BH}{2}$

$MH = \dfrac{3{,}26 + 0{,}43}{2} = 1{,}845$

$VD = 50I\sin\theta$

$VD = 50(3{,}26 - 0{,}43) \times \sin(2 \times 3{:}23{:}35)$

$VD = 16{,}720$ m

$RL_B = RL_A + HI + VD - MH$

$RL_B = 2\,475{,}58 + 1{,}44 + 16{,}72 - 1{,}845$

$RL_B = 2\,491{,}895$ m

Exercise 4.4 SB page 148

1.1 $MH = \frac{2{,}31 + 1{,}63}{2} = 1{,}97$

$\theta = 90 - 96{:}30{:}10 = -6{:}30{:}10$

$VD = 50I\sin\theta$

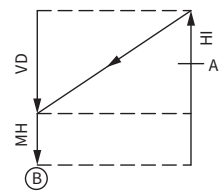
$VD = 50(2{,}31 - 1{,}63)\ \sin(2 \times 6{:}30{:}10)$

$VD = 7{,}652$ m

$RL_B = RL_A + HI - VD - MH$

$RL_B = 900 + 1{,}16 - 7{,}652 - 1{,}97$

$RL_B = 891{,}538$ m



1.2 $HD = KI\cos^2\theta$

$HD = 100(2{,}31 - 1{,}63)\ (\cos 6{:}30{:}10)^2$

$HD = 67{,}128$ m

2.1 $\theta = 90 - 82{:}10{:}40 = 7{:}49{:}20$

$HD = KI\cos^2\theta$

$HD = 100(1{,}89 - 0{,}97)\ (\cos 7{:}49{:}20)^2$

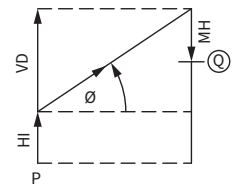
$HD = 90{,}296$ m

2.2 $MH = \frac{1{,}89 + 0{,}97}{2} = 1{,}43$

$VD = 50I\sin\theta$

$VD = 50(1{,}89 - 0{,}97)\ \sin(7{:}49{:}20)$

$VD = 12{,}405$ m



$RL_Q = RL_P + HI + VD - MH$

$RL_Q = 626{,}89 + 1{,}56 + 12{,}296 - 1{,}43$

$RL_Q = 891{,}538$ m

3.1 $MH = \frac{TH + BH}{2}$

$TH + BH = 2MH$

$2{,}14 + BH = 2(2{,}55)$

$BH = 3{,}1 - 2{,}14$

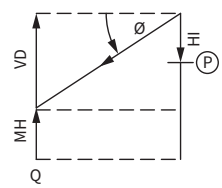
$BH = 0{,}96$

3.2 $\theta = 90 - 96{:}10{:}00 = -6{:}10{:}00$

$VD = 50I\sin\theta$

$VD = 50(1{,}24 - 0{,}96)\ \sin(2 \times 6{:}10{:}00)$

$VD = 12{,}602$ m



$RL_P = RL_Q + MH + VD - HI$

$RL_P = 1\ 718{,}44 + 1{,}55 + 12{,}602 - 1{,}61$

$RL_P = 1\ 730{,}982$ m

4. $MH = \frac{2{,}00 + 0{,}80}{2} = 1{,}40$

$VD = 50I\sin\theta$

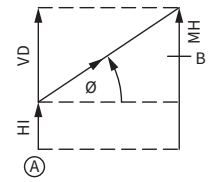
$VD = 50(2 - 0{,}8) \times \sin(2 \times 6{:}20{:}00)$

$VD = 21{,}051$ m

$RL_A = RL_B + MH - VD - HI$

$RL_A = 104{,}68 + 1{,}4 - 21{,}051 - 1{,}2$

$RL_A = 83{,}829$ m



5.1 $\theta = 90 - 98{:}16{:}00 = -8{:}16{:}00$

5.2 $VD = 50I\sin\theta$

$VD = 50(2{,}55 - 0{,}65) \times \sin(2 \times 8{:}16{:}00)$

$VD = 27{,}034$ m

5.3 $HD = KI\cos^2\theta$

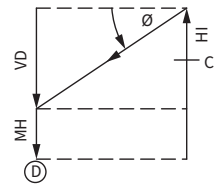
$HD = 100(2{,}55 - 0{,}65)(\cos 8{:}16{:}00)^2$

$HD = 186{,}072$ m

5.4 $RL_D = RL_C + HI - VD - MH$

$RL_D = 2\ 015{,}67 + 1{,}4 - 21{,}051 - 1{,}2$

$RL_D = 83{,}829$ m



5.5 Slope distance $CD = \sqrt{(VD)^2 + (HD)^2}$

$= \sqrt{(27{,}034)^2 + (186{,}072)^2}$

$= 188\ 026$ m

5.6 Gradient of slope $CD = \dfrac{VD}{HD}$

$= \dfrac{27{,}034}{186{,}072}$

$= 1{:}6{,}88$

6.1 Height difference $= 12{,}483 - 9{,}233 = 3{,}25$

$HD = \sqrt{500^2 + 3{,}25^2} = 499{,}986$ m

6.2 Zenith distance $= 90 - 5{:}22{:}30$

$= 84{:}37{:}30$

7. Zenith distance = 90 – (–6:22:30) = 96:22:30

8. $\theta = 90 - 97:30:35 = -7:30:35$ (angle of depression)

9. $\theta = 90 - 93:50:40 = -3:50:40$

$$MH = \frac{4{,}81 + 2{,}51}{2} = 3{,}66$$

$VD = 50I\sin\theta$

$VD = 50(4{,}81 - 2{,}51) \times \sin(2 \times 3:50:40)$

$VD = 15{,}386$ m

$RL_N = RL_M + HI - VD - MH$

$RL_N = 721{,}85 + 1{,}53 - 15{,}386 - 3{,}66$

$RL_N = 704{,}384$ m

$HD = KI\cos^2\theta$

$HD = 100(4{,}81 - 2{,}51)(\cos 3:50:40)^2$

$HD = 228{,}966$ m

Summative assessment SB page 151

1. The vertical angle is used to obtain the elevation of points. The horizontal angle is used primarily to obtain bearing and direction to a survey control point, (2)

2. Process:
   - Mark the point at which the theodolite will be set up with a nail on a wooden peg or a stake. This point is the base for measurement, angles or distances.
   - Set up the tripod. Make sure the instrument is at eye-level. The centre hole of the mounting plate should be over the nail or stake.
   - Anchor the tripod into the ground using the brackets on the sides of each leg.

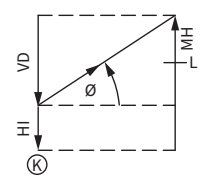
- Mount the theodolite by placing it on top of the tripod, and screw it in place with the mounting knob.
- Measure the height between the ground level and the line of sight, as it be a useful reference to other stations.
- Level the theodolite by adjusting the tripod legs and using the naked-eye level. Slight tuning can be made with the levelling screws to get it right.
- Adjust the vertical plummet using the adjusting screws at the bottom, which allows you to ensure that the instrument remains over the nail or stake.
- Aim the crosshairs at the point to be measured. Lock the theodolite to keep it aimed on the point.
- Take the horizontal and vertical angle readings using the viewing scope for circle readings. (9)

3. Five purposes:
   - For preparation of topographic maps or plans where both horizontal and vertical distances are required
   - To determine differences in elevation between points
   - Measuring the lengths of traverse lines
   - Locating details for a hydrographic survey
   - To complete a field survey for photographic maps. (5)

4. The principle of tacheometry is based on the property of isosceles triangles, where the ratio of the distance of the base from the apex and the length of the base is always constant. (3)

5.1 $\theta = 90 - 87{:}15{:}25 = 2{:}44{:}35$

$$MH = \frac{3{,}15 + 2{,}25}{2} = 2{,}70$$



$VD = 50I\sin\theta$

$VD = 50(3{,}15 - 2{,}25) \times \sin(2 \times 2{:}44{:}35)$

$VD = 4{,}302$ m (6)

5.2 $HD = KI \cos^2\theta$

$HD = 100(3{,}15 - 2{,}25)(\cos 2{:}44{:}35)^2$

$HD = 89{,}794$ m (3)

6. $\theta = 90 - 97{:}04{:}15 = -7{:}04{:}15$ (Fall) (3)

Total: 31 marks

MODULE

5 *Building surveys*

By the end of this module, students should be able to:

- use the simple bending equation;
- explain how horizontal and vertical angular measurements are related to points on the ground;
- explain the types and uses of theodolites and the terms used when measuring with a theodolite, such as:
  - vertical axis
  - horizontal axis
  - circle left
  - circle right
  - changing face
  - swinging the telescope
  - transiting the telescope
  - axis of telescope
  - axis of bubble tube
  - bisecting a point or station;
- explain the correct procedures when setting up a theodolite when taking readings;
- explain the procedure in the following methods of horizontal angle measurement:
  - repetition method
  - reiteration method;
- calculate the horizontal angle by means of circle left and circle right observations;
- determine the following:
  - collimation error of the horizontal axis
  - index error;
- calculate distance and direction between two or more points by means of coordinates; and
- plot coordinates of points by means of the South African coordinate system.

Introduction

A building survey involves examining the building, grounds and any outbuilding on the property. The survey report highlight any defects, both major and minor, and indicates what the defects could mean in the long run. It also provides guidance on any maintenance needed on the building. This module will detail what is involved in building surveying.

Exercise 5.1 SB page 161

1. Running measurement means measurement from a corner to a door, then from the same corner to the other side of the door, then from the same corner to the far corner.

2.1 

2.2 

3. Production drawings are complete sets of drawings that detail the construction of a proposed structure, providing information about dimensions, type of materials, finishes, tools required, and methods of assembly.

4. Building codes are regulations governing the design, construction, alterations, and maintenance of structures. They specify the minimum requirements to safeguard the health, safety, and welfare of the building's occupants.

5. Procedure:
   - A walk about the entire building, before commencing measurement, is necessary for better understanding of the layout.
   - Divide the building into sections and roughly draw each section to a scale large enough to add dimensions comfortably. Draw more complex details separately.
   - When drawings are done, measure the building, one section at a time, or all in one go.
   - Start measuring from one corner of the room and proceed around in either clockwise or anticlockwise direction.
   - Measure diagonally across the room to verify if the walls are parallel and corners are 90 degrees.
   - Take running measurements instead of a series of measurements (running measurement means, measurement from a corner to a door,

then from the same corner to the other side of the door, then from the same corner to the far corner). This prevents cumulative errors building up if a series of single measurements are taken then added together.

- Measure a point from a corner on one wall, then on the adjoining wall measure another point from the same corner. Then measure the distance from one point to the other. The three dimensions forming a triangle will be used to calculate the angle between the adjoining wall.
- To measure thickness of the floor above, the distance from the window head to the ceiling height on the ground floor is measured. On the floor above, measure the distance from the window sill to the floor. Outside the building, measure the distance from the ground floor window head to the first floor window sill. Subtract the internal measurements from the external measurement to find the first floor thickness.
- For variations in ground level, identify a constant feature on the elevation of the building (e.g. DPC), and measure the ground variation around the building from the ground to the feature.
- Standard symbols are use to speed up the surveying process.

Practical group activity 5.1

Get students to form a team of three and instruct them to perform the steps that follow.

They will need a tape and camera.

Measure THREE classrooms and record the conditions of each room, which must include the floor(s), walls and windows that are not in good condition (in need of fixing).

Take photos of what needs to be fixed and write a detailed report.

Exercise 5.2 SB page 164

1. Gradient = $\frac{1}{70}$ = 0,0143

   Invert level at S = 250,15 – 1,58 = 248,57

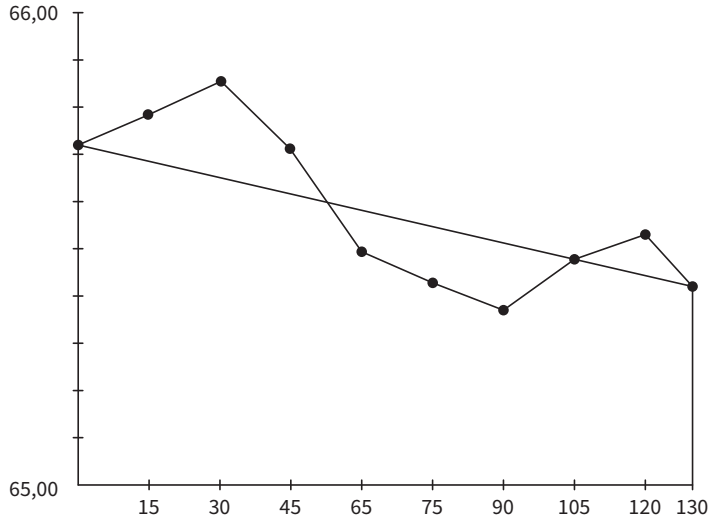
Chainage		Ground level	Invert level	Cut	Fill
S	0	250,15	248,570	1,58	
	20	251,26	248,274	2,986	
	40	247,99	247,980	0,01	
	60	252,56	247,120	5,44	
	65	253,01	247,641	5,369	
	80	247,32	247,356		0,036
	100	250,08	247,140	2,94	
T	115	249,67	246,926	2,744	

2.1 Gradient = $\frac{65{,}72 - 65{,}42}{130} = \frac{0{,}3}{130} = 0{,}0023$

2.2

Chainage		Ground level	Invert level	Cut	Fill
R	0	65,720	65,720	0	0
	15	65,782	65,686	0,096	
	30	65,853	65,651	0,202	
	45	65,711	65,617	0,094	
	60	65,501	65,582		0,081
	75	65,423	65,547		0,124
	90	65,372	65,513		0,141
	105	65,479	65,479	0	0
	120	65,526	65,444	0,082	
S	130	65,421	65,421	0	0

2.3



3. Invert level at M = 322,80 – 1,37 = 321,43

$$\text{Gradient} = \frac{0,7}{100} = 0,007$$

Chainage		Ground level	Invert level	Cut	Fill
M	0	322,80	321,43	1,370	
	25	326,42	321,255	5,165	
	40	327,42	321,150	6,270	
	60	320,42	321,010		0,590
	75	319,46	320,905		1,445
	80	318,23	320,870		2,640
	100	320,44	320,730		0,290
	105	326,47	320,695	5,775	
N	120	322,10	320,590	1,510	

4. $\text{Gradient} = \frac{21}{100} = 0,21$

Chainage		Ground level	Invert level	Cut	Fill
M	0	135,25	135,25	0	0
	10	135,27	137,35		2,08
	20	138,25	139,45		1,20
	30	140,31	141,55		1,24
	40	143,65	143,65	0	0
	50	147,79	145,75	2,04	
	60	150,03	147,85	2,18	
	70	150,89	149,95	0,94	
	80	152,05	152,05	0	0
	90	150,59	154,15		3,56
	100	152,14	156,25		4,11
N	109	150,14	150,14	0	0

Summative assessment SB page 168

1. Building regulations exist to ensure that buildings are designed and constructed in accordance with the set rule(s). The regulations set out national standards for building work, whether it is a major new development, or an extension, or alterations to a house. Construction companies carrying out building work are responsible for complying with the building regulations. (4)

2. A building survey is the inspection and investigation of a building and the services of a property by a professional surveyor to ensure that a building complies with the building regulations. The surveyor will then also be able to advise on the condition of the building. (2)

3. Any FIVE of the following:
   - Clipboard
   - Paper
   - Pens and pencils

- Tape measure
- Laser measure
- Camera
- Voice recorder
- Digital recording device, such as a tablet
- Personal protective equipment. (5)

4.1 Cill height (1)

4.2 Window head height (1)

5. To measure the thickness of the floor above, the distance from the window head to the ceiling height on the ground floor is measured. On the floor above, measure the distance from the window sill to the floor. Outside the building, measure the distance from the ground floor window head to the first floor window sill. Subtract the internal measurements from the external measurement to find the first floor thickness. (2)

Chainage		Ground level	Invert level	Cut	Fill
P	0	216,80	215,540	1,260	
	25	220,41	214,815	5,595	
	40	221,40	214,380	7,020	
	60	214,40	213,800	0,600	
	75	213,40	213,365	0,075	
	80	212,23	213,22		0,990
	100	214,44	212	1,800	
Q	105	222,36	212,495	9,965	

(10)

Total: 25 marks

MODULE

6 *Setting out*

By the end of this module, students should be able to:

- define *setting out;*
- explain the purpose of setting out;
- explain the following terms that are used in setting out:
  - traveller
  - sight rail
  - ranging rod
  - gradient
  - invert level;
- explain the procedure of setting out the following:
  - two points, A and B, stationed on the third point of known coordinates
  - a building from a baseline
  - a rectangular site for excavation and levelling
  - a rectangular site along a road using the road as reference;
- calculate the staff readings necessary to locate sight rails for a drainage layout;
- determine reduced levels by the rise and fall method;
- determine invert levels;
- draw longitudinal sections;
- define *cut and fill*
- calculate slope gradient;
- calculate cut and fill;
- interpret readings from pipeline drawings; and
- determine the slope ratio of pipelines and pipe lengths from longitudinal sections.

Introduction

Setting out is perhaps the most important aspect of the early stages of the construction process. It establishes, on the proposed land, controlling dimensions and references from the architect's plans that will determine the positioning of the building, and in particular, the foundations. It ensures that the construction remains within the legal boundary, meaning there will be no legal dispute later on, such as those regarding property boundaries and right to access.

Exercise 6.1 SB page 181

1.1 A gradient is the rate of rise or fall along the ground or trench length.

1.2 An invert level is the level of the inside bottom surface of a pipe.

2. Setting out slope stakes:
   - Set up the instrument and calculate the direction between the point on which the instrument is set up (instrument station) and point M and calculate the distance between the two points.
   - Then calculate the direction between the instrument station and point N, and the distance between the two points.
   - Orientate direction from the instrument to point M, using the calculated direction of point M, and measure the distance between the instrument station and point M and drive a peg.
   - Swing the instrument to point N using the calculated direction of point N, and measure the distance between the instrument station and point N and drive a peg.

3. Collimation height = 1,50 + 230,31 = 231,81 m

$$\Delta h = \frac{0,8}{100} \times 200 = 1,60 \text{ m}$$

Invert level at P = 229,38 – 0,9 = 228,48 m
Invert level at Q = 228,48 – 1,6 = 226,88
Staff reading at P = 231,81 – (228,48 + 1,9) = 1,45 m
Staff reading at Q = 231,81 – (226,88 + 1,9) = 3,03 m

4.1 $\text{Gradient} = \frac{0,75}{100} = 0,0075$

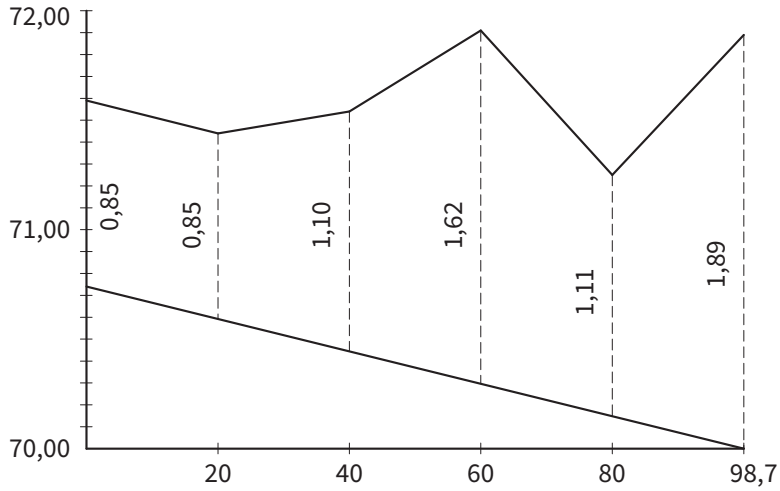
Invert level at 0 m = 71,59 – 0,85 = 70,74

Invert level at 20 m = 70,74 – 0,0075(20) = 70,59
Invert level at 40 m = 70,74 – 0,0075(40) = 70,44
Invert level at 60 m = 70,74 – 0,0075(60) = 70,29
Invert level at 80 m = 70,74 – 0,0075(80) = 70,14
Invert level at 98,7 m = 70,74 – 0,0075(98,7) = 70,00

4.2

Point	BS	IS	FS	Rise	Fall	RL	IL	Excav. depth	Dist. (m)
P	3,70					71,59	70,74	0,85	0
		3,85			0,15	71,44	70,59	0,85	20
		3,75		0,10		71,54	70,44	1,10	40
		4,38			0,63	71,91	70,29	1,62	60
		4,04		0,34		71,25	70,14	1,11	80
Q			3,40	0,64		71,89	70,00	1,89	98,7
	3,70 –3,40 0,30		3,40	01,08 –0,78 0,30	0,78	71,89 –71,59 0,30			

4.3



5. Collimation height = 344,33 + 1,6 = 345,93 m

$$\Delta h = \frac{0{,}7}{100} \times 165 = 1{,}155 \text{ m}$$

Invert level at M1 = 343,35 – 0,80 = 342,55 m

Invert level at M2 = 342,55 – 1,155 = 341,395 m

Staff reading at M1 = 345,93 – (342,55 + 1,8) = 1,586 m

Staff reading at M2 = 345,93 – (341,395 + 1,8) = 2,735 m

6.1 Gradient = $\frac{1}{25} = 0{,}04$

Invert level at 0 m = 71,59 – 1,2 = 70,39

Invert level at 40 m = 70,39 – 0,04(40) = 68,79

Invert level at 60 m = 70,39 – 0,045(60) = 67,99

Invert level at 80 m = 70,39 – 0,04(80) = 67,19

Invert level at 120 m = 70,39 – 0,04(120) = 65,59

Invert level at 130 m = 70,39 – 0,04(130) = 65,19

Invert level at 150 m = 70,39 – 0,04(150) = 64,39

Invert level at 165,70 m = 70,39 – 0,04(165,70) = 63,762

6.2

Point	BS	IS	FS	Rise	Fall	RL	IL	Excav. Depth	Dist. (m)
G	3,38					71,59	70,39	1,2	0
		2,23		1,15		72,74	68,79	3,95	40
		1,35		0,88		73,62	67,99	5,63	60
	1,65		2,27		0,92	72,70	67,19	5,51	80
		1,68			0,03	72,67	65,59	7,08	120
		0,64		1,04		73,71	65,19	8,52	130
	0,04		2,64		2,00	71,71	64,39	7,32	150
F			2,24		2,20	69,51	63,762	5,748	165,7
	5,07 –7,15 –2,08		7,15	3,07 –5,15 –2,08	5,15	69,51 –71,59 –2,08			

7. Collimation height = 104,22 + 1,6 = 105,82 m

$$\Delta h = \frac{1}{160} \times 185{,}6 = 1{,}16 \text{ m}$$

Invert level at R = 100,40 + 1,16 = 101,56 m

Staff reading at R = 105,82 – (101,56 + 1,8) = 2,46 m

Staff reading at S = 105,82 – (100,4 + 1,8) = 3,62 m

8. Collimation height = 282 + 2,6 = 284,60 m

$$\Delta h = \frac{1}{100} \times 165 = 1{,}65 \text{ m}$$

Invert level at F = 280,4 – 1,5 = 278,90 m

Invert level at E = 278,90 + 1,65 = 280,55 m

Staff reading at E = 284,60 – (280,55 + 2) = 2,05 m

Staff reading at F = 284,60 – (278,90 + 2) = 3,70 m

Practical group activity 6.1

Get students to form a team of three and instruct them to do the following:

Find an area in which to place two pegs to represent the road side. Use the pegs to set out a rectangular site along it.

Advise your students and/or provide further details.

Exercise 6.2 SB page 186

1.1 $AB = \sqrt{(209{,}7 - 209{,}48)^2 + (3\,860 - 3\,800)^2} = 60{,}00$ m

$BC = \sqrt{(209{,}48 - 208{,}8)^2 + (3\,923 - 3\,860)^2} = 63{,}00$ m

$CD = \sqrt{(208{,}8 - 207{,}7)^2 + (3\,947 - 3\,923)^2} = 24{,}03$ m

1.2 $\text{AB Gradient} = \frac{209{,}70 - 209{,}48}{60} \times 100 = 0{,}4\ \%$

$\text{BC Gradient} = \frac{209{,}48 - 208{,}80}{63} \times 100 = 1{,}1\ \%$

$\text{AB Gradient} = \frac{208{,}8 - 207{,}7}{24} \times 100 = 4{,}6\ \%$

1.3 $\text{AB Gradient} = \frac{209{,}70 - 209{,}4860}{60} = \frac{0{,}22}{60} = 1{:}272{,}3$

$\text{BC Gradient} = \frac{209{,}48 - 208{,}80}{63} = \frac{0{,}68}{63} = 1{:}92{,}6$

2. $\Delta h = \frac{1}{25} \times 68{,}35 = 2{,}734$

Invert level at P1 = 35,782 + 2,734 = 38,516

3. $\Delta y_{C2\text{-}C1} = \text{-}86\ 243{,}18 - (-86\ 263{,}37) = -20{,}19$

$\Delta x_{C2\text{-}C1} = 385\ 011 - 384\ 934{,}32 = +76{,}68$

$HD_{C2\text{-}C1} = \sqrt{(20{,}19)^2 + (76{,}68)^2} = 79{,}293\ \text{m}$

C2-C1 pipe length $= \sqrt{(79{,}293)^2 + (198{,}643 - 194{,}45)^2} = 79{,}406\ \text{m}$

$\Delta y_{C1\text{-}C3} = -86\ 292{,}89 - (-86\ 243{,}18) = -49{,}71$

$\Delta x_{C1\text{-}C3} = 385\ 010{,}66 - 385\ 011 = +0{,}34$

$HD_{C1\text{-}C3} = \sqrt{(49{,}7)^2 + (0{,}34)^2} = 49{,}711\ \text{m}$

C1-C3 pipe length $= \sqrt{(49{,}711)^2 + (194{,}415 - 188{,}341)^2} = 50{,}081\ \text{m}$

$\Delta y_{C4\text{-}C3} = -86\ 292{,}89 - (\text{-}86\ 309{,}79) = +16{,}9$

$\Delta x_{C4\text{-}C3} = 385\ 010{,}66 - 384\ 946{,}55 = +64{,}11$

$HD_{C4\text{-}C3} = \sqrt{(16{,}9)^2 + (64{,}11)^2} = 66{,}30\ \text{m}$

C4-C3 pipe length $= \sqrt{(66{,}30)^2 + (193{,}192\text{-}188{,}341)^2} = 66{,}477\ \text{m}$

$\Delta y_{C3\text{-}C5} = -86\,316{,}13 - (-86\,292{,}89) = -23{,}24$

$\Delta x_{C3\text{-}C5} = 385\,016 - 385\,010{,}66 = +6{,}13$

$HD_{C3\text{-}C5} = \sqrt{(23{,}24)^2 + (6{,}13)^2} = 24{,}035$ m

C3-C5 pipe length $= \sqrt{(24{,}035)^2 + (188{,}341 - 183{,}434)^2} = 24{,}530$ m

Total pipe length = 79,406 + 50,081 + 66,477 + 24,530 = 220,494 m

4. Gradient × HD = Δh

$\frac{1}{40} \times HD = 48{,}239 - 45{,}367$

$0{,}025 \times HD = 2{,}872$

$HD = 114{,}88$

5. $\Delta h = (80 - 60) \times \frac{20}{1\,000} = 4$ m

$HD = 160 \times \frac{100}{1\,000} = 16$ m

Slope as ratio $= \frac{4}{16} = 1{:}4$

Slope as percentage $= \frac{4}{16} \times 100 = 25\%$

6.1 MH23 – MH24 $= \sqrt{(62{,}337 - 60{,}153)^2 + (208{,}912 - 150{,}912)^2}$
$= 58{,}041$ m

MH24 – MH25 $= \sqrt{(60{,}395 = 60{,}153)^2 + (226{,}912 = 208{,}912)^2}$
$= 18$ m

Total pipe length MH23 – MH25 = 58,041 + 18 = 76,041

6.2 Slope ratio MH24 – MH25 $= \frac{0{,}242}{18} = 1{:}74{,}38$

Summative assessment SB page 189

1.1 C

1.2 A

1.3 E

1.4 B (4)

2. Setting out is done to ensure that the various parts of the structure are correct in all three dimensions, i.e. it is the correct size, in the correct position and has the correct reduced level. It also ensures the work is not delayed, thereby minimising cost. (2)

3. Setting out a sloping rectangular site:

   - The overall outline of the reduced level area is set out from a baseline, using a theodolite, ranging rod, tape and pegs.
   - Pegs are driven at each corner.
   - To control the depth of the excavation, sight rails or profiles are placed opposite each other at the end of the excavation.
   - The depth of the excavation is then controlled by dipping the traveller so that the line of sight between the sight rails is in line with that of the traveller. (4)

4. Collimation height = 166,07 + 1,6 = 167,67

   $\Delta h = \frac{1}{40} \times 250 = 6{,}25$

   Invert level at M1 = 165,35 – 0,98 = 164,37 m

   Invert level at M2 = 164,37 – 6,25 = 158,12 m

   Staff reading at M1 = 167,67 – (164,37 + 1,8)= 1,5 m

Staff reading at M2 = 167,67 – (158,12 + 1,8) = 7,67 m (6)

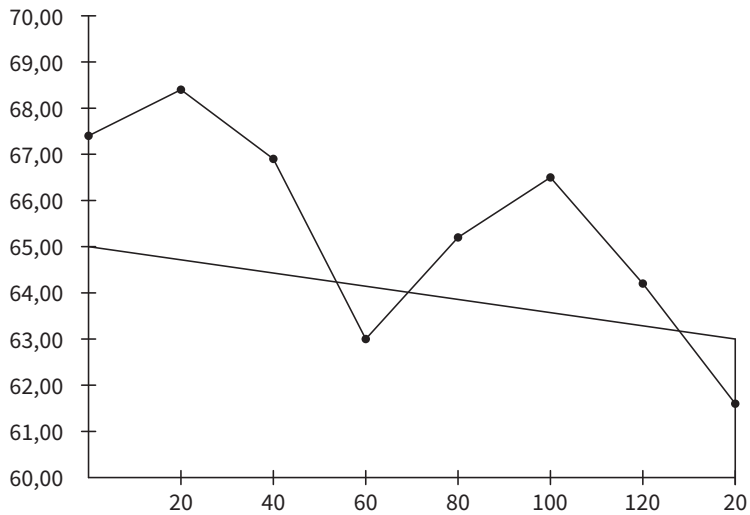
5.1 Gradient = $\frac{21}{100}$ = 0,21 (3)

5.2

Chainage		Ground level	5.1	5.2	
			Invert level	Cut	Fill
B	0	67,40	65,00	2,40	
	20	68,35	64,71	3,64	
	40	66,90	64,43	2,47	
	60	63,00	64,14		1,14
	80	65,21	63,86	1,35	
	100	66,52	63,57	2,95	
	120	64,24	63,29	0,95	
C	140	61,60	63,00		1,40

(3)

5.3



(10)

Total: 32 marks

Exemplar examination paper memorandum

QUESTION 1

1.1 Surveying instrument on a tripod
1.2 Control an excavation
1.3 Adjust the circular bubble to be in its centre
1.4 All three
1.5 All three (5 x 2) (10)

[10]

QUESTION 2

2.1 All of the following:

- To determine the relative position of any objects or points of the earth
- To determine the distance and angle between different objects
- To prepare a map or plan to represent an area on a horizontal plan
- To develop methods through the knowledge of modern science and technology, and to use them in the field
- To solve measurement problems in an optimal way. (5)

2.2 The three stages are:

- Reconnaissance
- Field work and measurement
- Office work. (3)

2.3 Working from the whole to the parts means first establishing a system of control points covering the whole area, with very high degree of precision. Then minor details are located by less precise methods. (5)

2.4 *Accuracy* refers to how closely a measurement or observation is to measuring a true value, since measurements and observations are always subject to error.

Precision refers to how closely repeated measurements or observations come to duplicating measured or observed values. (6)

[19]

QUESTION 3

3.1 $C_t = L \times e(t_m - t_s)$

$C_t = 548 \times 0{,}000012(20 - 14)$

$C_t = -0{,}0395$

$S_c = L(1 - \cos \theta)$

$S_c = 548(1 - \cos 5{:}35{:}25)$

$S_c = 2{,}6063$

Correct distance = 548 + 0,0395 – 2,6063 = 545,354 m (5)

3.2 Any FIVE of the following:

- Tape must be held horizontal.
- Tape must be held on its correct zero mark.
- The correct tension must be applied to the tape.
- Remove all kinks before taping.
- Tape must be held on the correct peg.
- View tape vertically over the peg.
- Measure from and to the centre of the ranging rod. (5)

3.3 $\Delta y_{AB} = -9\,667{,}84 - (-1\,096{,}38) = -8\,571{,}46$

$\Delta x_{AB} = 369{,}64 - 310\,869{,}16 = +58\,773{,}51$

$AB = \sqrt{(-8{,}571{,}46)^2 + (58\,773{,}51)^2} = 59\,395{,}247$ m

Direction AB $= \tan^{-1}\left(\frac{\Delta y}{\Delta x}\right) + 270$

$= \tan^{-1}\left(\frac{58\,773{,}51}{8\,571{,}46}\right) + 270$

= 81:42:09 + 270

= 351:42:09 (6)

[16]

QUESTION 4

4.1 Any FIVE of the following:

- To find the elevations of points on the Earth's surface for topographic maps
- For design of highways, railways, canals, etc.
- For locating grade lines
- For laying out of construction projects
- For locating excavating levels
- To determine the drainage characteristics of an area
- To determine volumes of earthwork. (5)

4.2 $V = D \tan\theta$

$V = 615 \tan 09:18:45$

$V = 100{,}848$ m

$C_d = 0{,}0673D^2$

$C_d = 0{,}0673(0{,}615)^2$

$C_d = 0{,}025$ m

$RL_{Top\ of\ building} = RL_{BM} + Bs + V + C_d$

$RL_{Top\ of\ building} = 1\ 355 + 1{,}73 + 100{,}848 + 0{,}025$

$RL_{Top\ of\ building} = 1\ 457{,}603$ m (6)

4.3

POINT	BS	IS	FS	Rise	Fall	RL
A	1,153					33,71
B	1,545		1,333		0,18	33,53
C	1,730		1,234	0,311		33,841
D		1,264		0,466		34,307
E	1,963		1,344		0,08	34,227
F			1,342	0,621		34,848
	6,391		5,253	1,398	0,26	34,848
	-5,253			-0,260		-33,710
	1,138			1,138		1,138

(10)
[21]

QUESTION 5

5.1

Target	Circle left	Circle right	Mean angle	Correction	Corrected angle
R	98:42:21	278:41:45			
M	184:18:15	04:18:35			
	85:35:54	85:37:10	85:36:32	– 00:00:09	85:36:23
M	184:18:15	04:18:35			
N	281:25:10	101:25:50			
	97:06:55	97:06:55	97:06:55	– 00:00:09	97:06:46
N	281:25:10	101:25:50			
L	358:22:14	178:22:56			
	76:57:04	76:57:06	76:57:05	– 00:00:09	76:56:56
L	358:22:14	178:22:56			
P	06:31:40	186:32:06			
	08:09:26	08:09:10	08:09:18	– 00:00:09	08:09:09
P	06:31:40	186:32:06			
R	98:42:30	278:43:06			
	92:10:50	92:11:00	92:10:55	– 00:00:09	92:10:46
			360:00:45		360:00:00

(10)

5.2 $HD = KI\cos^2 \theta$

$HD = 100(1{,}98 - 0{,}65)(\cos 22{:}15{:}26)^2$

$HD = 113{,}919$ m

$VD = 50I\sin \theta$

$VD = 50(1{,}98 - 0{,}65) \times \sin(2 \times 22{:}15{:}26)$

$VD = 46{,}622$ (6)

[16]

QUESTION 6

6.1 Building regulations are set national standards for building work, whether it is a new build or an extension of an existing building. Building construction practices follow the rules for new builds, or extensions or alterations to a house or building. The rules and regulations cover all aspects of construction, including foundations, damp-proofing, overall stability of the building, insulation, ventilation, heating, fire protection, fire and disabled facilities in certain types of building. Construction companies carrying out building work are responsible for complying with the building regulations. (6)

6.2 $PQ = \sqrt{(11{,}29 - 9{,}32)^2 + (620 - 550)^2}$

$PQ = \sqrt{1{,}97^2 + 70^2}$

$PQ = 70{,}028$ m

$$\text{Slope ratio} = \frac{11{,}29 - 9{,}32}{620 - 550}$$

$= 2{,}814\%$ (6)

6.3 Collimation height = 108,21 + 1,5 = 109,71 m

$$\Delta h = \frac{0{,}8}{100} \times 190 = 1{,}52 \text{ m}$$

Invert level at A = 107,49 – 1,1 = 106,39 m

Invert level at B = 106,39 – 1,52 = 104,87 m

Staff reading at A = 109,71 – (106,39 + 1,45) = 1,26 m

Staff reading at B = 109,71 – (104,37 + 1,45) = 3,89 m (6)

[18]

Total: 100 marks

Glossary

A

Angular measurement – measurement of an angle formed by two rays at a common vertex; the angle can either be vertical or horizontal

Angle of depression – an angle below the line of sight

Angle of elevation – an angle below the horizontal line

Axis of a telescope – an imaginary line passing through the optical centre of the object glass and the optical centre of the eyepiece

Axis of the bubble tube – an imaginary line tangential to the longitudinal curve of the bubble tube, at its midpoint

B

Barometric – refers to levelling determined by differences in atmospheric pressure at various points

Bisecting a point or station – when the vertical hair of the telescope lies in the middle of the ranging rod placed at the survey station being observed

Building survey – the inspection and investigation of a building, as well as the services, done by a professional surveyor to ensure building regulation compliance

C

Cill – a shelf or slab of stone, wood, or metal at the foot of a window opening or doorway

Camber board – to regulate the slope of the excavation

Centring – the process of setting up a theodolite on a ground station

Chaining – the process of measuring the distance with a chain or tape

Changing face – the operation of bringing the vertical circle from one side of the observer to the other side of the observer

Circle left (CL) – also known as *face left;* refers to the situation when the vertical circle of the instrument is on the left of the observer when the reading is taken

Circle right (CR) – also known as *face right;* refers to the situation when the vertical circle of the instrument is on the right of the observer when the reading is taken

Clinometer – a tool used to measure the heights of tall trees, poles or building structures

Collimation line – the line joining the intersection of cross hairs and the optical centre of the object glass

Computation – calculation; the act of calculating

Cross staff – to set out building lines perpendicular to each other when a survey instrument is not required

D

Differential – refers to levelling determined by elevation differences between distant

points using a level and staff

F

Fly levelling – used for transferring levels using the backsight and foresight readings

G

Geodetic – the science of accurate measurement of the earth's shape and geophysical properties

Geoid – the shape that the ocean surface would take under the influence of the earth's gravity

Gradient – the slope of the ground or trench; given as a ratio or a percentage; e.g. a slope of 5 is actually 1:5 as a ratio, with 1 representing the vertical measurement and 5 the horizontal measurement

H

Height measurement – the determination of differentially deduced changes in elevation

Horizontal axis – the axis of rotation of the telescope in the vertical plane, also known as the *trunnion axis*

Horizontal plane – a line at a right angle to the direction of gravity at one point only

Hydrographic survey – a science which deals with the measurement and description of the physical features of bodies of water, coastal areas, and the effects of maritime and offshore activities on these environments

I

Invert level – the level of the inside bottom surface of a drainage/sewer pipe; abbreviated as *IL*

J

Join – the calculation of the distance and direction between two known points using the coordinates of the point

L

Level plane – a line at which every point is of equal elevation and is perpendicular to the direction of gravity at every point

Levelling – determination of the relative elevations or heights of points using a dumpy level or automatic level

Lime powder – to mark the foundation width and column base positions to prepare for excavation

Linear measurement – the measurement of a distance between points or objects

M

Mean direction – the direction measured directly using a theodolite or

total station

Measuring tape – used to set out the dimensions of the building

N

Nylon string – to demarcate the wall thickness, foundation width and building extent

O

Offsetting – the process of measuring the lateral distance of the object from the survey line to the left or right according to the object's position

Orthometric height – the vertical distance along the plumb line

R

Ranging – the process of locating intermediate points on a straight line between two end points in a straight line

Ranging rod – to establish straight lines between corner pegs

S

Series levelling – to determine the difference in level between points on the surface of the ground

Setting out – the transference of surveying details about a site or area from a drawing to the ground

Spirit level – to level profile boards

Stadia rod – a levelling staff used for longer distances

Stadia wires – horizontal cross hairs for theodolites

Swinging the telescope – the process of rotating the telescope about the vertical axis in the horizontal pane; called *right swing* when the telescope is turned clockwise and *left swing* when the telescope is turned anticlockwise

T

Tacheometry – a method of angular surveying to determine the horizontal and vertical distance between two points; based on the properties of the isosceles triangle

Theodolite – to set out the corner pegs of the building

Topographical survey – a survey used to locate all surface features of a property and to depict all natural features and elevations

Transiting the telescope – the process of turning the telescope through 180° in the vertical plane about its horizontal axis

Trigonometric – refers to levelling determined by differences in height between points and their angles or trigonometric relations

V

Vernier scale – a short auxiliary graduated scale

Vertical angle – an angle between the horizontal line and the inclined line of sight

Vertical axis – the axis about which the instrument rotates in a horizontal plane

W

Whole circle bearing – the angle measured from the south direction, which is +X and clockwise, according to the South African coordinate system

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