N4

Building and Structural Surveying

Hands-On!

Lecturer Guide

Alfred Ramahlape

Additional resource material for this title includes:

- **PowerPoint presentation**
- **Interactive tests**
- **Past exam papers**
- **Electronic Lecturer Guide**

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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.

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

- Surveying
- Building Construction

3. Prerequisites

The student must meet at least one of the following requirements.

3.1 Completed National N3 certificate with Building Science N3 or Building and Civil Technology N3.

3.2 Passed Grade 12 with 50% in Mathematics or Natural Science and relevant Civil subjects.

3.3 Completed NCV Level 4 in any Civil Engineering programme.

3.4 Passed senior certificate for adult learners NQF Level 4 (50% or D symbol) in Mathematics or Physical Science.

4. Duration

Full-time: 7.5 hours per week. This instructional offering may also be offered part-time.

5. Evaluation

5.1 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 (Exam mark)

5.2 The examination in Building and Structural Surveying N4 (Engineering Studies – Report 191) will be conducted as follows:
Modules 1 to 8 **MARKS:** 100
DURATION: 3 HOURS
CLOSED BOOK:

- Formula sheet is attached to the question paper
- Scientific calculators allowed
- No programmable calculators allowed
- No references allowed.
- No external examination papers or memoranda allowed

5.3 Weighting:
The following weights are consequently awarded to each category:

Knowledge and understanding	Applying	Analysing/syntheses and evaluating
30–40	30–40	20–25

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 value of modules

MODULES	WEIGHTING
Module 1: Basic principles of surveying	15
Module 2: Linear measurement	15
Module 3: Height measurement	10
Module 4: Basic concepts	10
Module 5: Angular measurement	10
Module 6: Setting out	10
Module 7: Area and volume	10
Module 8: Plane table surveying	10
Module 9: Compass surveying	10
Total	**100%**

8. Work schedule

Week	Topic	Content	Hours
1–2	**Module 1** Basic principles of surveying	1.1 Surveying 1.2 Methods of fixing a point in surveying 1.3 Types of surveying 1.4 Classification of surveying 1.5 Types of control points 1.6 Surveyor	15 hours
2–3	**Module 2** Linear measurement	2.1 Linear surveying method 2.2 Chain and tape surveying 2.3 Field problems 2.4 Errors and mistakes in survey measurements 2.5 Errors in measurement and corrections	15 hours

Week	Topic	Content	Hours
4	**Module 3** Height measurement	3.1 Definition of levelling 3.2 Levelling terminology 3.3 Open and close traverse levelling 3.4 Errors in levelling 3.5 Levelling equipment 3.6 Hand signals 3.7 Reducing levels 3.8 Collimation error 3.9 Reciprocal levelling	10 hours
5	**Module 4** Basic concepts	4.1 South African coordinates systems 4.2 Map scale 4.3 Angular measurements	10 hours
6	**Module 5** Angular measurement	5.1 Purpose of angular measurement 5.2 Theodolite 5.3 Using a theodolite 5.4 Horizontal angles 5.5 Horizontal collimation and index error	10 hours
7	**Module 6** Setting out	6.1 Definition and purpose of setting out 6.2 Setting out procedures 6.3 Equipment for setting out	10 hours
8	**Module 7** Area and volume	7.1 Area 7.2 Volume	10 hours
9	**Module 8** Plane table surveying	8.1 Plane table surveying	10 hours
10	**Module 9** Compass surveying	9.1 Compass surveying	10 hours
	TOTAL		**100 hours**

9. Lesson plan template

Subject and level	N4 Building and Structural Surveying	**Campus**	
Prescribed textbook (Title and author)	*N4 Building and Structural Surveying* by Alfred Ramahlape	**Lecturer**	

WEEK 1						
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 tasks) to be done this week**
		Lecture		White board/OHP		
		Group work		Models		
		Demonstration		Handouts		
		Simulation		Multimedia		
		Introduction to lessons				
		Recapping/reinforcement				

This page may be photocopied.

Subject and level	N4 Building and Structural Surveying	**Campus**	
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WEEK 2						
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 tasks) to be done this week**
		Lecture		White board/OHP		
		Group work		Models		
		Demonstration		Handouts		
		Simulation		Multimedia		
		Introduction to lessons				
		Recapping/reinforcement				

Subject and level	N4 Building and Structural Surveying	**Campus**	
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WEEK 3

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 tasks) to be done this week
		Lecture		White board/OHP		
		Group work		Models		
		Demonstration		Handouts		
		Simulation		Multimedia		
		Introduction to lessons				
		Recapping/reinforcement				

Subject and level	N4 Building and Structural Surveying	**Campus**	
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WEEK 4

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 tasks) to be done this week
		Lecture		White board/OHP		
		Group work		Models		
		Demonstration		Handouts		
		Simulation		Multimedia		
		Introduction to lessons				
		Recapping/reinforcement				

Subject and level	N4 Building and Structural Surveying	Campus	
Prescribed textbook (Title and author)	*N4 Building and Structural Surveying* by Alfred Ramahlape	Lecturer	

WEEK 5								
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 tasks) to be done this week**
		Lecture			White board/OHP			
		Group work			Models			
		Demonstration			Handouts			
		Simulation			Multimedia			
		Introduction to lessons						
		Recapping/reinforcement						

Subject and level	N4 Building and Structural Surveying	**Campus**	
Prescribed textbook (Title and author)	*N4 Building and Structural Surveying* by Alfred Ramahlape	**Lecturer**	

WEEK 6

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 tasks) to be done this week
		Lecture		White board/OHP		
		Group work		Models		
		Demonstration		Handouts		
		Simulation		Multimedia		
		Introduction to lessons				
		Recapping/reinforcement				

Subject and level	N4 Building and Structural Surveying	**Campus**	
Prescribed textbook (Title and author)	*N4 Building and Structural Surveying* by Alfred Ramahlape	**Lecturer**	

WEEK 7

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 tasks) to be done this week
		Lecture		White board/OHP		
		Group work		Models		
		Demonstration		Handouts		
		Simulation		Multimedia		
		Introduction to lessons				
		Recapping/reinforcement				

Subject and level	N4 Building and Structural Surveying	**Campus**	
Prescribed textbook (Title and author)	*N4 Building and Structural Surveying* by Alfred Ramahlape	**Lecturer**	

WEEK 8								
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 tasks) to be done this week**
		Lecture			White board/OHP			
		Group work			Models			
		Demonstration			Handouts			
		Simulation			Multimedia			
		Introduction to lessons						
		Recapping/reinforcement						

Subject and level	N4 Building and Structural Surveying	**Campus**	
Prescribed textbook (Title and author)	*N4 Building and Structural Surveying* by Alfred Ramahlape	**Lecturer**	

WEEK 9

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 tasks) to be done this week
		Lecture		White board/OHP		
		Group work		Models		
		Demonstration		Handouts		
		Simulation		Multimedia		
		Introduction to lessons				
		Recapping/reinforcement				

Subject and level	N4 Building and Structural Surveying	**Campus**	
Prescribed textbook (Title and author)	*N4 Building and Structural Surveying* by Alfred Ramahlape	**Lecturer**	

WEEK 10

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 tasks) to be done this week
		Lecture		White board/OHP		
		Group work		Models		
		Demonstration		Handouts		
		Simulation		Multimedia		
		Introduction to lessons				
		Recapping/reinforcement				

1 *Basic principles of surveying*

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

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

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

- explain the following types of control points:
  - trigonometric beacons
  - minor control points
  - benchmarks
  - GPS control
  - reference marks;
- describe the following functions of a good surveyor:
  - field work
  - office work and administrative functions
  - care and adjustments of instruments;
- describe qualities of a good surveyor;
- explain the purpose of the field book;
- describe and list the following survey field notes:
  - points to observe when taking field notes
  - classification of field notes; and
- list the information to be contained in the field book.

For many centuries, surveying has been one of the essential elements in the development of the human environment. It is an imperative requirement in the planning and execution of nearly every form of construction. Without this service, there would be no railroads, tall buildings or bridges, etc. Understanding the terminology used in surveying is therefore essential to understanding the discipline.

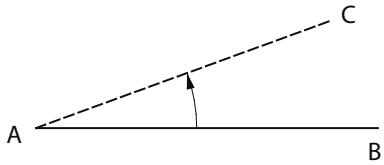
Exercise 1.1

SB page 14

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 measurement of horizontal distances, vertical distances, angle and directions.
2. Any three of the following:
   - Working from a whole to a part.
   - Fixing a point in relation to two other fixed points
   - Accuracy
   - Independent checking
3. Any of the following:
   - To prepare topographical maps showing the hills, valley, rivers, villages, town, etc., of a country.

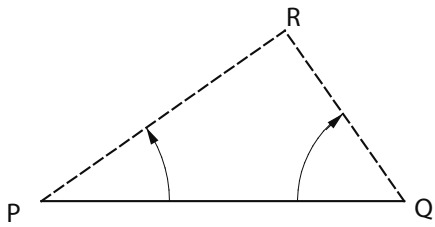
- To prepare cadastral maps showing the boundaries of fields and other properties.
- To prepare contour maps, determine the volume of reservoirs and to find the best possible route for roads, railways, etc.
- To prepare archaeological maps, including places where ancient relics exist.
- To prepare a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

4. 4.1



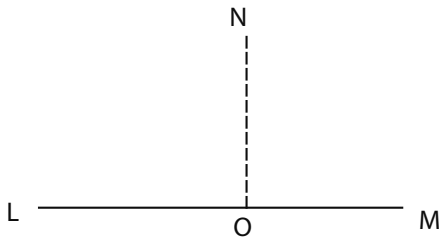
To determine the position of point C, from the known baseline AB, measure Angle BAC and distance AC.

4.2



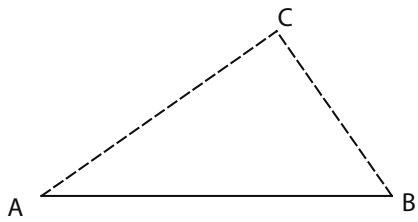
To establish point R, from Baseline PQ measure angle QPR and PQR when the lines meet its point R

4.3



AB being is a known baseline. To establish point L. use an optical square and measure right angle MOL or NOL and distance OL

4.4



To determine the position of point C, from the known baseline AB, measure distance AC and distance BC, where the line meet its point C

Exercise 1.2

SB page 20

1. **Secondary categories**:
   These categories are directed by circumstance, which could be the:
   - nature of the field surveyed
   - purpose of the survey
   - method of survey
   - instrument used.

2. **Geodetic survey** is a survey in which the curvature of the earth is taken into account and where a higher degree of accuracy in linear and angular observations is achieved
   Plane survey is a survey in which the earth curvature in neglected and a low degree of accuracy is achieved

3. Any three of the following:
   - Total station survey
   - Chain survey
   - Theodolite survey
   - Compass survey
   - Plane table survey
   - Photographic and aerial survey

4. Any four of the following:
   - Trigonometric beacons
   - Minor control points
   - Benchmarks
   - GPS control
   - Reference marks

Exercise 1.3 SB page 23

1.
- Reconnaissance
- Measuring distances and angles
- Recording field notes.

2. Any two of the following
- Honest
- Has sound knowledge of the surveying _eld of work
- Is neat when working with _eld books
- Has initiative and a resourceful approach to problems
- Accepts verified information as trustworthy
- Reliable
- Has sound judgement

3. The field book is a small book used by a surveyor in the field to record survey data and notes as surveys are carried out.

4.
- Accuracy
- Integrity
- Legibility
- Arrangement
- Clarity

Summative assessment SB page 24

1. 1.1 D
1.2 E
1.3 B
1.4 F
1.5 C (5)

2. 2.1 GPS is a satellite-based system that can locate positions anywhere on earth. It can be used for any application that requires location coordinates (2)
2.2 Reference marks are survey controls used when marking a boundary for a registered plan. They are place at a location away from the actual boundary corner, with stated direction and distance from the boundary corner (2)

3. Any three of the following:
Topographic survey, used to determine the natural features of the country such as hills, valleys, etc..
Cadastral survey, used to determine details such boundaries of houses, etc.
Hydrographic survey, used for measurement and obtaining description of feature that affect the maritime, navigation
Astronomical survey, used to determine the meridian, azumith, etc. (3)

4. Any three 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 the technology and use them in the field.
   - To solve measurement problems in an optimal way (3)

5. Working from a whole to a part is enclosing the whole survey area with main stations and main lines. The main stations and lines are then used to divide the survey area into a number of divisions by forming well-conditioned triangle. (2)

6. Fixing a point means taking such observations and/or measurements that may be necessary to determine the position of a point relative to other point whose position are known (2)

Total: 19 marks

2 *Linear measurement*

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;
- explain the functions and advantages of electronic distance measurement;
- list the advantages and disadvantages of the following linear measurement equipment:
  - chain
  - steel tape;
- explain the following with the aid of a neatly labelled sketch:
  - measuring around building/pond
  - measuring distance across a river/busy road
  - obstacle to line of sight but to measurement;
- explain types of errors and mistakes in surveying measurements;
- errors and mistakes in survey measurements, such as:
  - accidental errors
  - constant errors
  - systematic errors
  - mistakes; and
- calculate the following error correction that may be occur during taping because of:
  - sag
  - tension
  - slope
  - temperature
  - length
  - altitude at sea level.

The main equipment used in linear measurement is a chain or tape, which is liable to giving erroneous measurements due to expansion, contraction and tension etc. It is for this reason that corrections are made to field work measurements in order to provide precise measurements.

The correction is positive if the incorrect length is to be increased and the correction is negative if the incorrect length must be decreased.

Exercise 2.1

SB page 44

1. 1.1 Accidental errors are human errors not caused by carelessness.
   1.2 Systematic errors are errors that depend, for their magnitude and sign, on external circumstances such as temperature changes, the slope of land, etc., and they tend to produce cumulative effects.
   1.3 Constant errors are those that, in all measures under the same circumstances, have the same magnitude and algebraic sign as a result of incorrect equipment used.

2. MD = 92,500 m
   ATL = 100 + 0,02 = 100,02 m
   $$CD = \frac{MD \times ATL}{GTL}$$
   $$= \frac{92{,}5 \times 100{,}02}{100}$$
   = 92,519 m

3. $S_C = L(1 - \cos\theta)$
   $S_C = 92(1 - \cos 7°25')$
   = 0,77 m

   $CD = L - S_C$
   CD = 92 − 0,77
   = 91,23 m

4. $$C_S = \frac{W^2 L^3}{24 T^2}$$
   $$C_S = \frac{0{,}016^2 \times 92^3}{24\,(6{,}8)^2}$$
   = 0,18 m

   $CD = L - C_S$
   CD = 92 − 0,18
   = 91,82 m

5. MD = 50 m
   ATL = 60 + 0,05 = 60,05 m

   $$CD = \frac{MD \times ATL}{GTL}$$
   $$= \frac{50 \times 60{,}05}{60}$$
   = 50,042 m

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

$C_t = 97{,}121 \times 0{,}0000112(35 - t_s)$

$0{,}0163 = 0{,}0011(35 - t_s)$

$0{,}0163 = 0{,}0385 - 0{,}0011\,t_s$

$0{,}0011\,t_s = 0{,}0385 - 0{,}0163$

$t_s = \frac{0{,}0217}{0{,}0011}$

$t_s = 19{,}7\ °C$

7. $C_H = \frac{L \times H}{R}$

$= \frac{66{,}66 \times 1\,200}{6\,373\,000}$

$= 0{,}013$

$CD = L - C_H$

$CD = 66{,}66 - 0{,}013$

$= 66{,}647\ m$

8. $MD = 98{,}6\ m$

$ATL = 100 - 0{,}03 = 99{,}97\ m$

$CD = \frac{MD \times ATL}{GTL}$

$CD = \frac{98{,}6 \times 99{,}97}{100}$

$= 98{,}56\ m$

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

$C_t = 104 \times 0{,}0000113(15 - 20)$

$C_t = -0{,}006$

$CD = L - C_t$

$CD = 104 - 0{,}006$

$CD = 103{,}994\ m$

10. $C_S = \frac{W^2 L^3}{24\,T^2}$

$C_S = \frac{0{,}015^2 \times \left(\frac{120}{3}\right)^3}{24\,(7)^2} \times 3$

$= 0{,}012 \times 3$

$= 0{,}036\ m$

$CD = L - C_S$

$CD = 120 - 0{,}036$

$= 119{,}964\ m$

11. $S_C = L(1 - \cos\theta)$

$S_C = 56{,}657(1 - \cos 6°35')$

$= 0{,}374$ m

$CD = L - S_C$

$CD = 56{,}657 - 0{,}374$

$= 56{,}283$ m

12. $MD = 78{,}344$ m

$ATL = 100 + 0{,}03 = 100{,}03$ m

$$CD = \frac{MD \times ATL}{GTL}$$

$$= \frac{78{,}344 \times 100{,}03}{100}$$

$= 78{,}368$ m

13. Mass of 100 − m tape = 0,16 kg

Mass of tape per metre $= \frac{0{,}16}{100} = 0{,}0016$ kg/m

$$C_S = \frac{W^2 L^3}{24 T^2}$$

$$C_S = \frac{0{,}0016^2 \times 98{,}5^3}{24(6{,}8)^2}$$

$= 2{,}205$ m

$CD = L - C_S$

$CD = 98{,}5 - 2{,}205$

$= 96{,}295$ m

Summative assessment

SB page 45

1. Constant errors
   Systematic errors
   Accidental errors (3 × 1)

2. $S_C = L(1 - \cos\theta)$
   $= 76{,}5(1 - \cos 6°20'15'')$
   $= 0{,}467$ m

   $CD = L - S_C$
   $= 76{,}5 - 0{,}467$
   $= 76{,}033$ m (5)

3. 3.1 $C_t = L \times e(t_m - t_s)$
   $C_t = 85{,}93 \times 0{,}0000112(33 - 20)$
   $C_t = +0{,}013$ (3)

   3.2 $CD = L \pm C_t$
   $CD = 85{,}93 + 0{,}013$
   $CD = 85{,}943$ m (2)

4. $C_S = \frac{W^2 L^3}{24 T^2}$

   $C_S = \frac{0{,}015^2 \times \left(\frac{80}{2}\right)^3}{24(7)^2} \times 2$
   $= 0{,}171$

   $CD = L - C_S$
   $= 80 - 0{,}171$
   $= 79{,}829$ m (6)

Total: 19 marks

3 Height measurement

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

- explain the terms levelling and purpose of levelling
- explain the following terminology as used in levelling:
  - mean sea level (MSL)
  - local heights
  - datum
  - closure error
  - official heights
  - horizontal plane (horizontal line)
  - plane
  - direction of gravity
  - vertical plane
  - incline plane
  - level surface (level line)
  - benchmark (BM)
  - foresight (FS)
  - intermediate sight (IS)
  - back sight
  - collimation line (line of sight)
  - change point (CP);
- explain the difference between close and open traverse levelling;
- explain the following types of errors in levelling:
  - natural causes
  - instrument errors
  - personal errors;
- identify and label the components of the following levelling equipment by way of a neatly labelled diagram:
  - levelling staff
  - staff bubble
  - change plate
  - traveller or boning rod
  - dumpy level
  - tripod stand
  - bubble tube
  - tilting level
  - automatic level

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

- interpret the communication or hand signals used by a good surveyor and his/her assistant during field operation;
- calculate the reduced levels by means of the following:
  - rise and fall method
  - collimation method
- determine the collimation error by two-peg test;
- define the term reciprocal levelling; and
- reduce reciprocal levels by means of calculations.

Levelling deals with the determination of elevations and heights of points using levelling equipment. Its applications are wide-ranging and extend from road construction to calculating the volume of earthworks.

Exercise 3.1

SB page 53

1. 1.1 *Change point* is the position of the previous foresight which is used as the new back-sight reading.
   1.2 *Local heights* are height to which an arbitrary height (value) has been assigned
   1.3 *Incline plane* is a sloping surface at any angle other than a right angle to the horizontal or vertical plane.
   1.4 *Mean sea level* is the average height of the sea between high and low tide.
   1.5 *Intermediate sight* is the reading taken between the back sight and fore sight.

2. Levelling is done for all important engineering works and construction projects, for purpose of establishing the elevations of points on the earth's surface for topographic maps, design of highways, railways, canals, etc. Also for locating grade lines, excavating levels and laying out of construction projects. Levelling is necessary for determination of the drainage characteristics of an area, including volumes of earthwork for road, rails, etc.

3. *Closed level traverse* is a series of level runs from a known datum or reduced level to another known datum or reduced level.
   Open level traverse is a series of level runs from a known datum or reduced level to an unknown.

4.
- The permanent adjustment of the instrument may not be perfect; that is, the line of collimation not parallel to the line of sight.
- The internal arrangement of the focussing tube may not be correct.
- Graduation of the levelling staff may not be perfect.

Exercise 3.2

SB page 64

1.
1.1 A plane is a surface on which any straight line joining two points on it will touch the plane completely.
1.2 A vertical plane is the plane at a right angle to the horizontal line.
1.3 A horizontal plane is a plane at a right angle to the direction of gravity at one point only.
1.4 An inclined plane is a sloping surface at any angle other than a right angle to the horizontal or vertical plane.
1.5 A collimation line is a line joining the intersection of cross hairs and the optical centre of the object glass.
1.6 A change point is a point where the instrument is moved and the position of the previous foresight is used as the new back-sight reading.

2.
2.1 Official heights are bench marks that have been determined by precise levelling, while local heights are heights to which an arbitrary height has been assigned.
2.2 A benchmark is a permanent mark showing the known height of that point above the mean sea level, while a datum is a point on the surface or line from which heights or levels of points are measured.
2.3 A back sight is the first reading taken from a known point after the instrument has been set up and a foresight is the last reading taken before the instrument is moved.

3.
- Object lens
- Object lens focus knob
- Eyepiece
- Levelling screw
- Horizontal motion screw
- Circular bubble

4.
- The telescope of the dumpy level is rigidly fixed, while the tilting level telescope is not rigid.
- The tilting level telescope can move horizontally and to an extent vertically, while that of the dumpy level is restricted to horizontal movement.

- A tilting level bubble has to be centred for every setup, while a dumpy level bubble is set up once.

5.
- Radius of the curvature of the tube
- Size of the diameter of the bubble
- Overall length of the liquid in the tube
- Viscosity of the liquid in the tube
- Finishing texture of the tube's internal surface

6.
- Ethanol
- Alcohol

7.
7.1 1,865
7.2 1,820
7.3 1,790

8.
8.1 Extend your right arm to the right, clench your fist, slightly bend your arm and pump your fist sharply up and down.
8.2 Hold out your right arm horizontally to the right.
8.3 Rapid throwing-out movement to the left-hand side with the left hand
8.4 Raise both hands vertically above your head and keep them there.

Exercise 3.3

SB page 72

1.

Collimation height method	Rise and fall method
It is more rapid and saves a considerable amount of time and labour.	It is laborious as the staff reading of each station must be compared to get a rise or fall.
It is well adopted for reduction levels for construction work.	It is well adopted for determining the difference in the levels of two points.
There is no check on reduction of R.Ls. of intermediate stations.	There is a complete check on the reduction of R.Ls. of intermediate stations.
There are only two arithmetical checks.	There are three arithmetical checks.
Errors, if any in intermediate sights are not detected.	Errors in intermediate sights are noticed as these are used for finding out the rises or falls.

2.
- Instrument errors
- Personal errors
- Errors due to natural causes

3.

Point	BS	IS	FS	Rise	Fall	Reduced level
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			2,60		0,60	151,20
	5,20		4,00	1,80	0,60	151,20
	–4,00			–0,60		–150,00
	1,20			1,20		1,20

4.

Point	BS	IS	FS	Rise	Fall	Reduced level
A	1,30					95,00
B		2,50			1,20	93,80
C		1,10		1,4		95,2
D		1,25			0,15	95,05
E	2,10		1,35		0,10	94,95
F		2,00		0,10		95,05
G		3,10			1,10	93,95
H			2,25	0,85		94,80
	3,40		3.60	2,35	2,55	94,80
	–3,60			–2,55		–95,00
	–0,20			–0,20		–0,20

5.

Point	BS	IS	FS	Rise	Fall	Reduced level
A	1,40					230,00
B		3,00			1,60	228,40
C		2,90		0,10		228,50
D	2,45		1,38	1,52		230,02
E		2,00		0,45		230,47
F	1,55		2,60		0,60	229,87
G	2,30		1,60		0,05	229,82
H		1,80		0,50		230,32
I			2,50		0,70	229,62
	7,70		8,08	2,57	2,95	229,62
	–8,08			– 2,95		–230,00
	–0,38			– 0,38		–0,38

Exercise 3.4

SB page 75

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	Reduced level
0 m	3,63			749,45	745,82
20 m		2,87			746,58
40 m	3,02		2,15	750,32	747,30
60 m	0,83		2,06	749,09	748,26
80 m		0,78			748,31
100 m		1,49			747,60
120 m	0,62		1,63	748,08	747,46
140 m		3,96			744,12
160 m		3,81			744,27
180 m		3,50			744,58
200 m	1,46		1,76	747,78	746,32
220 m			2,05		745,73
	9,56		9,65		745,73
	–9,65				–745,82
	–0,09				–0,09

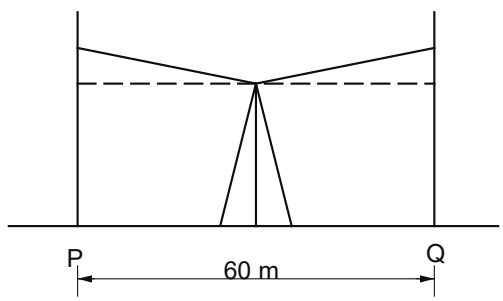
3.

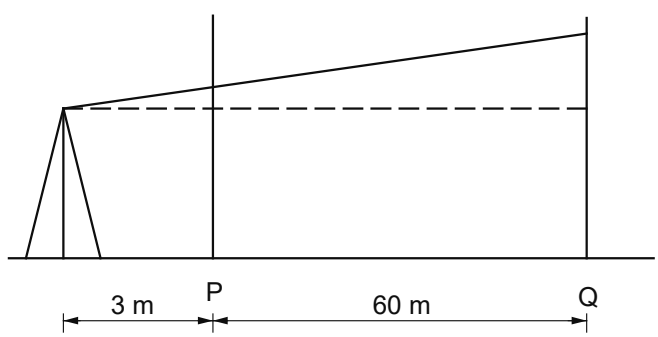
Point	BS	IS	FS	Collimation height	Reduced level
BM 5	4,61			889,47	**884,86**
P1		3,54			885,93
P2		1,69			884,24
P3	1,80		3,21	890,88	892,68
P4		2,40			893,28
P5	2,89		3,62	890,15	887,26
P6		1,20			891,35
P7		2,20			892,35
P8		1,46			888,69
P9			1,20		888,95
	5,70		1,61		888,95
	–1,61				884,86
	4,09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

Exercise 3.5

SB page 82

1. 1.1





1.2 True difference = 1,909 − 1,824 = 0,085
Apparent difference = 2,520 − 1,387 = 1,133
Collimation error = 1,133 − 0,085 = 1,048
e = 1,387 + 0,085 = 1,472
$C_P = \frac{3}{60}(2{,}520 - 1{,}472) = 0{,}053$
$C_Q = \frac{60 + 3}{60}(2{,}520 - 1{,}472) = 1{,}101$

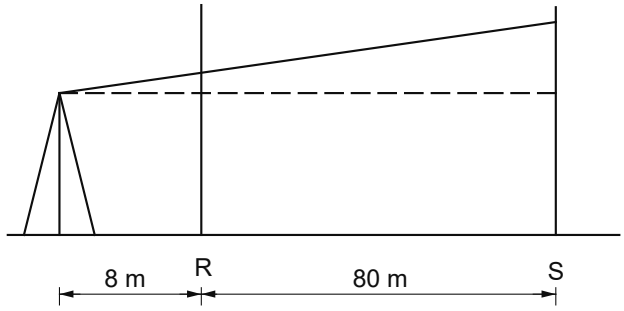
1.3 Correct reading at peg P = 1,387 − 0,053 = 1,334
Correct reading at peg Q = 2,520 − 1,101 = 1,419

1.4 Apparent difference = 1,419 − 1,334 = 0,085
Collimation error = 0,085 − 0,085 = 0

2 2.1 True difference = 1,335 − 1,151 = 0,184
Apparent difference = 1,649 − 0,767 = 0,852
Collimation error = 0,852 − 0,184 = 0,668

Note

Sketch the second test so as to know which point is near the level, because the reading of the point near the level is the one used when calculating 'e'.

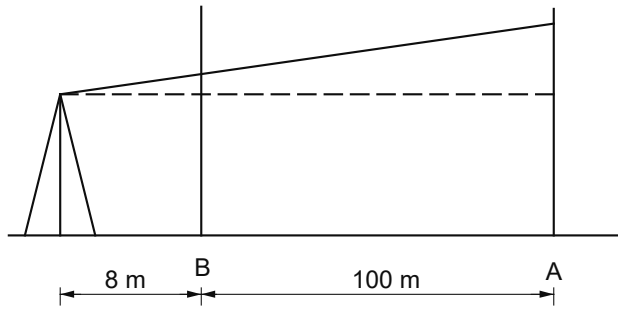


2.2 e = 1,649 + 0,184 = 1,833
$C_P = \frac{8}{80}(0{,}767 - 1{,}833) = -0{,}107$
$C_Q = \frac{80 + 8}{80}(0{,}767 - 1{,}833) = -1{,}173$

2.3 Correct reading at peg P = 1,649 + 0,107 = 1,756
Correct reading at peg Q = 0,767 + 1,173 = 1,940
Apparent difference = 1,940 − 1,756 = 0,184
Collimation error = 0,184 − 0,184 = 0

3. True difference = 1,709 − 1,549 = 0,16
Apparent difference = 2,102 − 1,942 = 0,16
Collimation error = 0,16 − 0,16 = 0

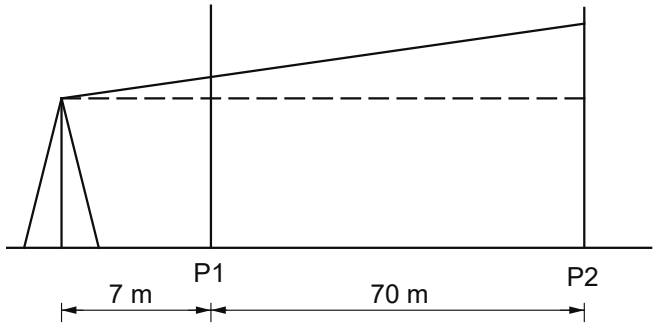
4. 4.1 True difference = 1,156 − 1,062 = 0,094
Apparent difference = 1,325 − 0,546 = 0,779
Collimation error = 0,779 − 0,094 = 0,685



4.2 e = 1325 + 0,094 = 1,419
$C_B = \frac{8}{100}(0{,}546 - 1{,}419) = -0{,}07$
$C_A = \frac{100 + 8}{100}(0{,}546 - 1{,}419) = -0{,}943$

4.3 Correct reading at peg A = 0,546 + 0,943 = 1,489
Correct reading at peg B = 1,325 + 0,07 = 1,395
Apparent difference = 1,489 − 1,395 = 0,094
Collimation error = 0,094 − 0,094 = 0

5. True difference = 1,375 − 1,191 = 0,184
Apparent difference = 1,589 − 0,807 = 0,782
Collimation error = 0,782 − 0,184 = 0,598



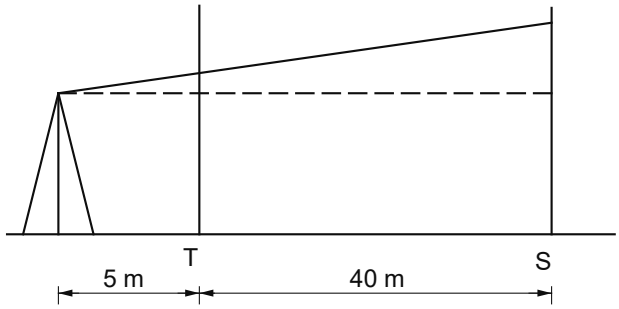
e = 0,807 + 0,184 = 0,991

$C_{P1} = \frac{7}{70}(1,589 - 0,991) = 0,06$

$C_{P2} = \frac{70 + 7}{70}(1,589 - 0,991) = 0,658$

Correct reading at peg P1 = 0,807 − 0,06 = 0,747
Correct reading at peg P2 = 1,589 − 0,658 = 0,931
Apparent difference = 0,931 − 0,747 = 0,184
Collimation error = 0,184 − 0,184 = 0

6. True difference = 1,582 − 1,447 = 0,135
Apparent difference = 1,800 − 0,967 = 0,833
Collimation error = 0,833 − 0,135 = 0,698



e = 1 800 + 0,135 = 1,935

$C_T = \frac{5}{40}(0,967 - 1,935) = -0,121$

$C_S = \frac{40 + 5}{40}(0,967 - 1,935) = -1,089$

Correct reading at peg T = 1,800 − 0,121 = 1,921
Correct reading at peg S = 0,967 − 1,089 = 2,056
Apparent difference = 2,056 − 1,921 = 0,135
Collimation error = 0,135 − 0,135 = 0

Exercise 3.6

SB page 86

1. Difference between readings taken 3m from A = 3,80 − 3,42 = 0,38
   Difference between readings taken 3m from B = 2,68 − 2,29 = 0,39

   Mean difference = $\frac{0,38 + 0,39}{2}$ = 0,385

   RL_B = 100 − 0,385 = 99,615 m

2. Difference between readings taken 3m from A = 3,35 − 1,95 = 1,40
   Difference between readings taken 3m from B = 2,85 − 1,55 = 1,30

   Mean difference = $\frac{1,40 + 1,30}{2}$ = 1,35

   RL_A = 139,50 + 1,35 = 140,85 m

3. Reading at P taken 3 m from P = $\frac{4,91 + 4,85}{2}$ = 4,88
   Reading at Q taken 3 m from P = $\frac{2,50 + 2,42}{2}$ = 2,46

   Difference between readings taken 3m from P = 4,88 − 2,46 = 2,42

   Reading at Q taken 3 m from Q = $\frac{1,31 + 1,25}{2}$ = 1,28

   Reading at P taken 3 m from Q = $\frac{3,70 + 3,66}{2}$ = 3,68

   Difference between readings taken 3m from Q = 3,68 − 1,28 = 2,40

   Mean difference = $\frac{2,42 + 2,40}{2}$ = 2,41

   RL_P = 50,428 − 2,41 = 48,018 m

4. Difference between readings taken 3m from A = 2,59 − 1,49 = 1,10
   Difference between readings taken 3m from B = 3,03 − 1,82 = 1,21

   Mean difference = $\frac{1,10 + 1,21}{2}$ = 1,155

   RL_B = 152,38 + 1,155 = 153,535 m

5. Difference between readings taken 3m from P5 = 2,59 − 2,31 = 0,28
   Difference between readings taken 3m from P6 = 2,78 − 2,61 = 0,17

   Mean difference = $\frac{0,28 + 0,17}{2}$ = 0,225

   RL_{P6} = 534,20 + 0,225 = 534,425 m

Summative assessment

SB page 88

1. 1.1 J
   1.2 I
   1.3 H
   1.4 G
   1.5 F
   1.6 E
   1.7 D
   1.8 C
   1.9 B
   1.10 A (10 × 1)

2. 2.1 The traveller is used to ensure that an excavation has a uniform depth. (1)
   2.2 The change plate is used to mark the change point position of the staff. (1)

3. • Differential levelling
   • Trigonometric levelling
   • Barometric levelling (3 × 1)

4. Parallax is the apparent movement of the cross hairs relative to the object onto which the instrument is being sighted when looking through the telescope. (2)

5. • Measuring horizontal and vertical angles
   • Setting out lines and angles
   • Levelling
   • Optical distance measurement
   • Plumbing tall buildings
   • Plumbing deep shafts
   • Geographical position fixing from observations of the sun and stars
   • Checking lines and heights (5 × 1)

6. 6.1 Move well to the left (2)
   6.2 Small movement to the right (2)
   6.3 Mark or rod is on line (2)

7. 7.1 HC = 128,65 + 1,98
   = 130,63 (2)
   7.2 RL_P = 130,63 − 1,03
   = 129,60 (2)

Total: 32 marks

4 Basic concepts

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

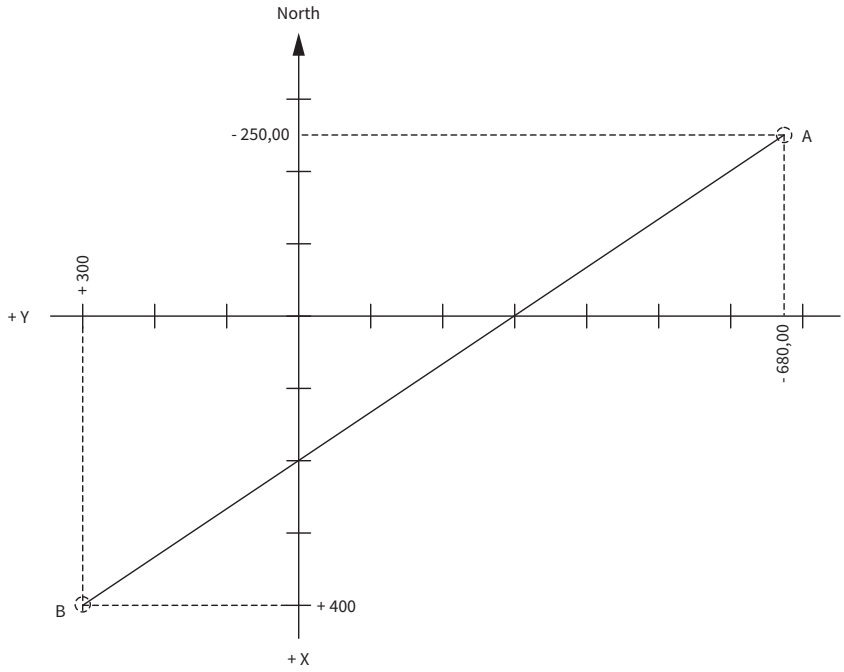
- describe the main South African coordinate system;
- to plot the position of points using the South African system by means of a scale;
- calculate the distance and direction of coordinates between two or more known points;
- explain the following types of scale:
  - engineering scale natural scale
  - divided scale
  - scale of map symbol
- transformation;
- apply the correct formula to calculate transformation scale; and
- calculate and convert the following angular measurements:
  - sexagesimal measurement
  - centesimal measurement
  - radian measurement.

Surveying involves collecting field work data and representing the results on a map or plan to a suitable scale. In order to draw maps or plans, one of the most important considerations for the mapping process is the selection of scale, based on the purpose of the map or plan. Understanding the South African coordinate system is of importance when plotting maps.

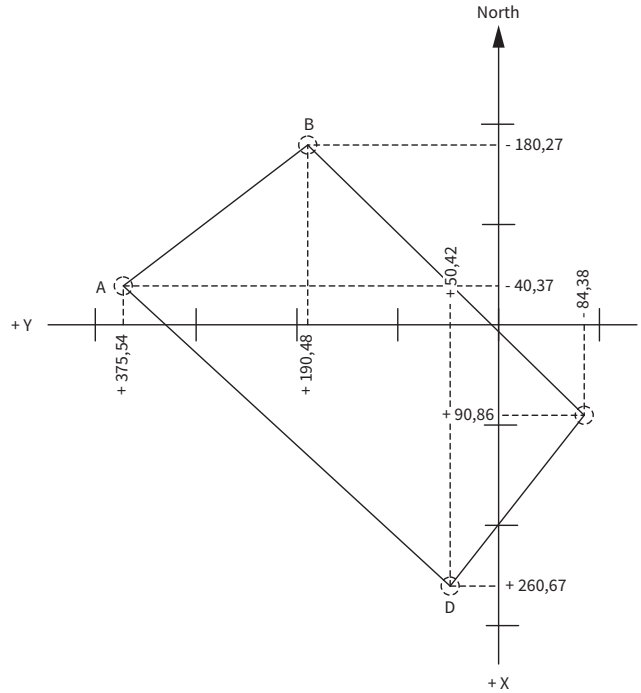
Exercise 4.1

SB page 97

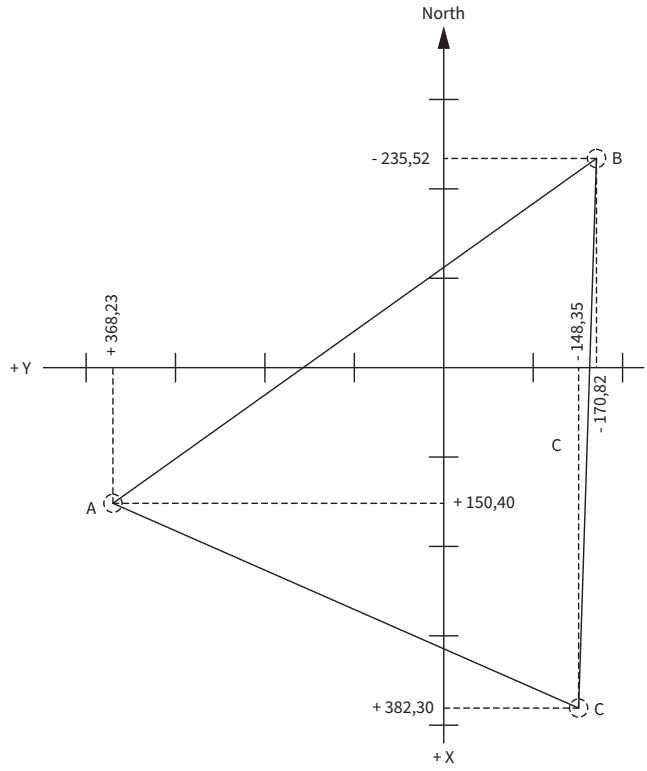
1.



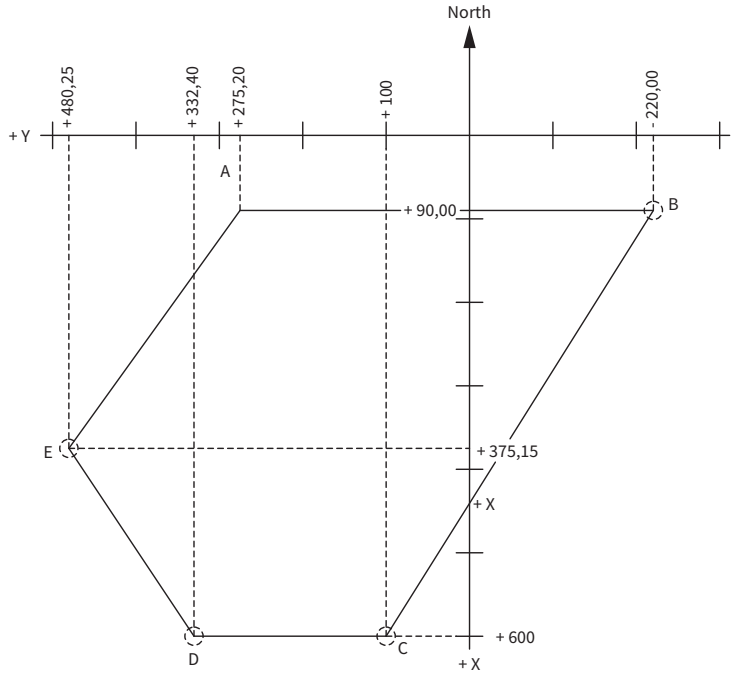
2.



3.


North
- 235,52
B
+ 368,23
- 148,35
+ Y
- 170,82
C
A
+ 150,40
+ 382,30
C
+ X

4.


North
+ 480,25
+ 332,40
+ 275,20
+ 100
220,00
+ Y
A
+ 90,00
B
E
+ 375,15
+ X
+ 600
D
C
+ X

Exercise 4.2

SB page 102

1. $\Delta y_{PQ} = 3\,092{,}95 - 3\,102{,}48 = -9{,}53$
$\Delta x_{PQ} = -1\,688{,}04 - \left(-1058{,}47\right) = -629{,}57$

Distance PQ $= \sqrt{(-9{,}53)^2 + (-629{,}57)^2}$
$= 629{,}64$ m

Direction PQ $= \tan^{-1}\left(\frac{\Delta y}{\Delta x}\right) + 180$
$= \tan^{-1}\left(\frac{9{,}53}{629{,}57}\right) + 180$
$= 00{:}52{:}21 + 180$
$= 180{:}52{:}21$

2. $\Delta y_{MN} = -120{,}45 - (-467{,}89) = +347{,}44$
$\Delta x_{MN} = 467{,}87 - 120{,}45 = +347{,}44$

Distance MN $= \sqrt{(347{,}44)^2 + (347{,}44)^2}$
$= 491{,}354$ m

Direction MN $= \tan^{-1}\left(\frac{\Delta y}{\Delta x}\right)$
$= \tan^{-1}\left(\frac{347{,}44}{347{,}44}\right)$
$= 45°$

3. $\Delta y_{RS} = -233{,}02 - \left(-116{,}33\right) = -116{,}19$
$\Delta x_{RS} = 107{,}80 - 174{,}20 = -66{,}40$

Direction RS $= \tan^{-1}\left(\frac{\Delta y}{\Delta x}\right) + 180$
$= \tan^{-1}\left(\frac{116{,}19}{66{,}40}\right) + 180$
$= 60{:}15{:}11 + 180$
$= 240{:}15{:}11$

$\Delta y_{RT} = -479{,}22 - \left(-116{,}33\right) = -362{,}39$
$\Delta x_{RT} = 242{,}74 - 174{,}20 = +68{,}54$

Direction RT $= \mathrm{t}\left(\frac{\Delta y}{\Delta x}\right) + 90$
$= \tan^{-1}\left(\frac{68{,}54}{362{,}39}\right) + 90$
$= 10{:}42{:}36 + 90$
$= 100{:}42{:}36$

Exercise 4.3

SB page 105

1. 1.1 A natural scale is one where the numerator of the representative fraction is always a unit and the denominator denotes the number of times the map is smaller compared to the area it represents.
   1.2 An engineering scale is a statement of the relation between two different units of measurement. One measurement refers to the map and the other to the ground.
   1.3 A divider scale line is an expression of the scale given graphically in the form of a divided scale line.

2. 1 cm = 2 km
   10 mm = 2 000 000 mm (convert all to millimetres)
   $\frac{10}{10} = \frac{2\,000\,000}{10}$
   1 mm = 200 000 mm
   RF = 1:200 000

3. Map distance = $\frac{\text{ground distance in mm}}{\text{scale}}$
   $= \frac{1\,250 \times 1\,000}{10\,000}$
   = 125 mm

4. True distance = map distance × scale (Note: The answer will be in mm.)
   True distance = 92 × 5 000
   = 460 000 mm
   = 460 m

5. 2 cm = 1 km
   20 mm = 1 000 000 mm (convert all to millimetres)
   $\frac{20}{20} = \frac{1\,000\,000}{20}$
   1 mm = 50 000 mm
   RF = 1:50 000

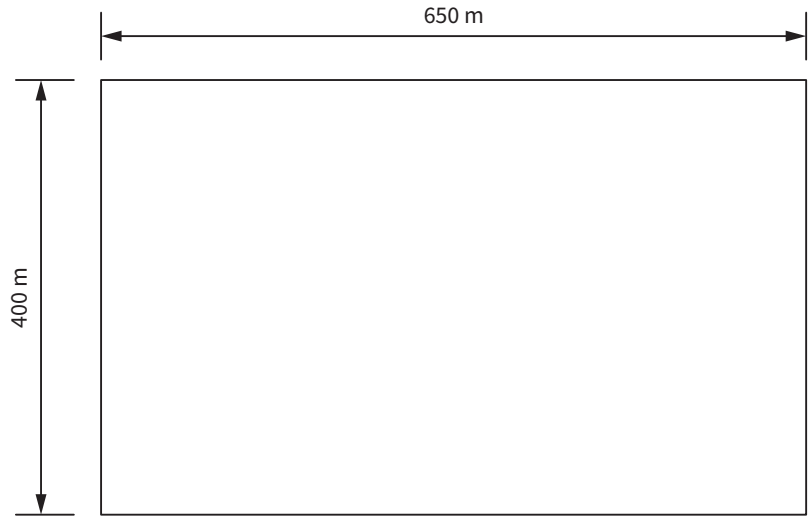
6. True distance = map distance × scale
   True distance = 30 × 250 000
   = 7 500 000 mm
   = 7 500 m

7. Map distance = $\frac{\text{ground distance in mm}}{\text{scale}}$
   $= \frac{1\,500 \times 1\,000}{10\,000}$
   = 150 mm

8. 8.1 Map length $= \frac{650 \times 1\,000}{5\,000}$
$= 130$ mm

Map width $= \frac{400 \times 1\,000}{5\,000}$
$= 80$ mm

8.2 Use the calculated measurements to draw the plot, but insert the actual measurement when dimensioning, as shown below.



9. Area $= \frac{1}{2}$ base × perpendicular height

Ground area $= \frac{1}{2} \times \frac{325 \times 2\,500}{1\,000} \times \frac{170 \times 2\,500}{1\,000}$
$= 0{,}5 \times 812{,}5 \times 425$
$= 172\,656{,}25$ m^2 (Note: Divide this answer by 10 000 to get ha.)
$= 17{,}27$ ha

Exercise 4.4

SB page 108

1. 1.1 $50° = \frac{50 \times 100}{90}$
$= 55{,}6^g$

1.2 $50° = \frac{50}{57{,}3}$
$= 0{,}873$ radians

2. 2.1 $6{,}283$ rad $= 6{,}283 \times 57{,}3$
$= 360°$

2.2 $6{,}283 \text{ rad} = \frac{6{,}283 \times 57{,}3 \times 100}{90}$

$= 400^{g}$

3. $46°25'36'' = 46 + \frac{25}{60} + \frac{36}{3\,600} = 46{,}427$

$46°25'36'' = \frac{46{,}427}{57{,}3}$

$= 0{,}81 \text{ rad}$

Summative assessment

SB page 109

1. 1.1 Sexagesimal measurement (1)
   1.2 Lines of longitude (1)
   1.3 Centesimal measurement (1)
   1.4 Lines of latitude (1)
   1.5 Coordinates (1)

2. $\text{Map distance} = \frac{\text{ground distance in mm}}{\text{scale}}$

$= \frac{45 \times 1\,000}{500}$

$= 90 \text{ mm}$ (2)

3. True distance = map distance × scale

True distance = 65 × 5 000

= 325 000 mm

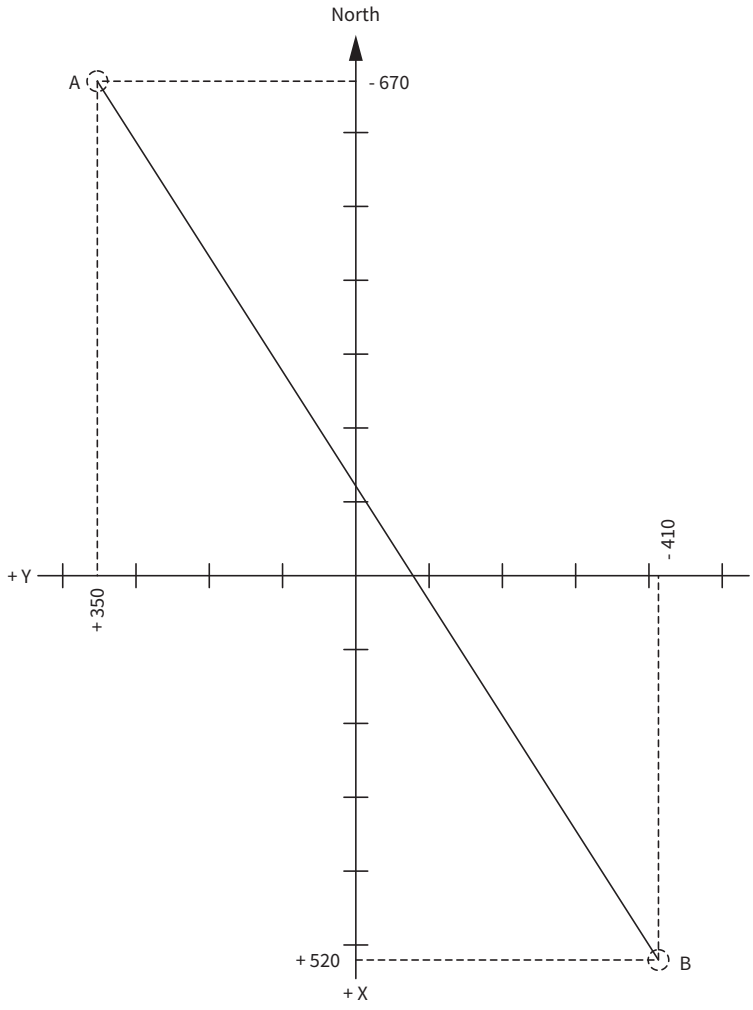
= 325 m (2)

4.
   - The lines of longitude are used instead of the equator.
   - The system is a rectangular grid with the *y*-axis running parallel to the equator and the *y*-values are positive to the west and negative to the east.
   - The *x*-axis runs from north to south and the *x*-values are positive to the south.
   - The system consists of belts of 2° of longitude width.
   - Each belt consists of one central meridian that is an odd meridian and two boundary meridians that are even meridians.
   - The central meridians are referred to as Lo 23°, Lo 25°, etc. (5 × 1)

5. Coordinates are values in metres of a point on the ground represented on a plan or map.
   Coordinates consist of ordinates, the *y*-value and the *x*-values.
   The ordinates are measured perpendicular to the axis.
   The *y*-value is always written first.
   Each of the coordinates is written with its algebraic signs. (6)

6. Lines of latitude are imaginary horizontal mapping lines on the earth. They run parallel to the equator. (2)

7.



(6)

Total: 28 marks

5 *Angular measurement*

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

- explain how the horizontal and vertical angular measurement are related on points on ground;
- explain the types and uses of theodolites;
- explain 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;
- explain the correct procedures when setting up a theodolite and taking readings;
- explain the procedure in the following methods of horizontal angles measurement:
  - repetition method
  - reiteration method;
- calculate the horizontal angle by means of circle left and circle right observations; and
- determine the following:
  - collimation error of the horizontal axis
  - index error.

The measurement of angles is an integral part of surveying. This module will detail the instruments and methods involved in taking these measurements. Theodolites are surveying instruments which are critical to obtaining accurate angular measurements in horizontal and vertical planes.

Exercise 5.1

SB page 122

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	
	01:01:02	01:00:58	01:01:00
T	105:04:44	285:04:40	
Q	168:11:41	348:11:43	
	63:06:57	63:07:03	63:07:00

2.

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

3.

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

4.

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

5.

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 5.2

SB page 125

1. Index error exists when the vertical angle in both circle left and circle right are observed and the sum of the observation is not equal to 360°.

2. $E = \frac{1}{2}[(CR - 180) - CL]$

   $E = \frac{1}{2}[(227:15:48 - 180) - 47:15:33]$

   $E = \frac{1}{2}[00:00:15]$

   $E = 00:00:07,5$

3. 3.1 $\varepsilon = \frac{1}{2}[360° - (CL + CR)]$

   $\varepsilon = \frac{1}{2}[360° - (91:12:20 + 268:47:10)]$

   $\varepsilon = \frac{1}{2}(00:00:30$

   $\varepsilon = + 00:00:15$

   3.2 $CL = 91:12:20 + 00:00:15 = 91:12:35$

   $CR = 260:47:10 + 00:00:15 = 268:47:25$

   $360:00:00$

4. $E = \frac{1}{2}[(CR - 180) - CL]$

   $E = \frac{1}{2}[(276:48:00 - 180) - 96:43:20]$

   $E = \frac{1}{2}[00:00:00]$

   No collimation error

5. $E = \frac{1}{2}[(CR - 180) - CL]$

   $E = \frac{1}{2}[(196:15:40 - 180) - 16:15:22]$

   $E = \frac{1}{2}[00:00:18]$

   $E = 00:00:09$

6. $E = \frac{1}{2}[(CR - 180) - CL]$

   $00:00:03 = \frac{1}{2}[(218:21:15 - 180) - CL]$

   $00:00:06 = 38:21:15 - CL$

   $CL = 38:21:15 - 00:00:06$

   $CL = 38:21:09$

Summative assessment

SB page 126

1. 1.1 D
   1.2 B
   1.3 F
   1.4 A
   1.5 C (5)

2. Angular measurement involves measuring horizontal angle which are used primarily to obtain bearing and direction to a survey control point, and vertical angle which are used in obtaining the elevation of points and in reduction of sloping distance to the horizontal. (2)

3. Horizontal axis collimation error exists when the optical axis of the theodolite is not perpendicular to the telescope axis. (2)

4.

Target	Circle left	Circle right	Mean angle	Correction	Corrected mean angle
P	98:42:21	275:41:45			
Q	184:18:15	04:18:55			
	85:35:54	85:37:10	85:36:32	+00:00:56	85:37:28
Q	184:18:15	04:18:55			
R	281:25:10	101:25:50			
	97:06:55	97:06:55	97:06:55	+00:00:56	97:07:51
R	281:25:10	101:25:50			
S	358;22:14	178:22:54			
	76:57:04	76:57:04	76:57:04	+00:00:56	76:58:00
S	358;22:14	178:22:54			
T	06:31:40	186:32:06			
	08:09:26	08:09:12	08:09:19	+00:00:56	08:10:15
T	06:31:40	186:32:06			
P	98:42:30	278:32:16			
	92:10:50	92:00:10	92:05:30	+00:00:56	92:06:26
			359:55:20		360:00:00

(11)

Total: 20 marks

6 *Setting out*

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

- define the term *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; and
- explain the procedure of setting out:
  - two points A and B, stationed on the third point of known coordinates
  - a building from a baseline
  - a sloping out rectangular site for excavation and levelling
  - a rectangular site along a road using the road as reference.

Surveying is a process of forming maps and plans of a particular site or area, while setting out is the transferring of detail from the drawing to a piece of ground.

Exercise 6.1

SB page 134

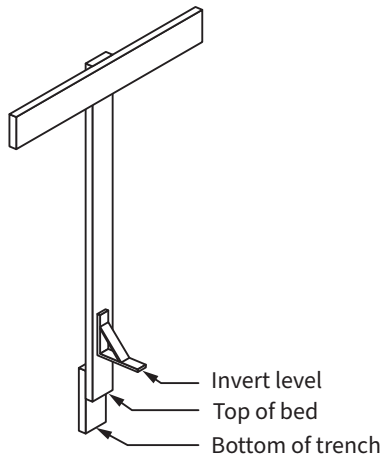
1. 1.1 A gradient is the rate of rise or fall along the ground or trench length

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

2.
   - Set up the instrument and calculate the direction between the point on which the instrument is set up (instrument station) and point M and the distance between the two points.
   - Also calculate the direction between 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 put 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 put a peg.

3.

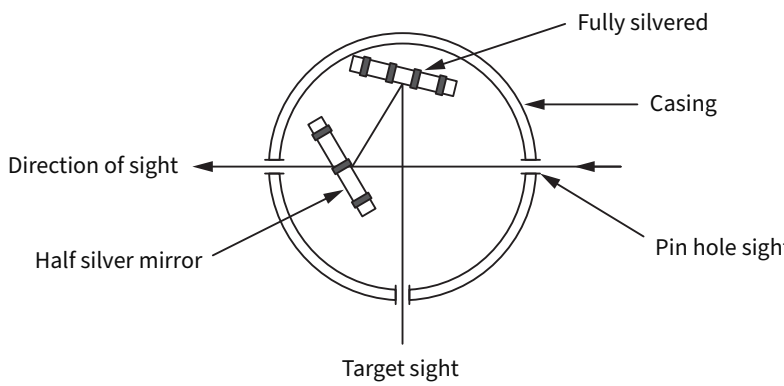


Exercise 6.2

SB page 137

1. Any five of the following:
   - Spirit level
   - Index arm
   - Vernier
   - Protractor
   - Telescope
   - Eyepiece

2.



Horizontal section through the optical square

3. - Hold the instrument 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.

Summative assessment

SB page 137

1. Setting out is the transferring of details from a drawing to a piece of ground.

2. The purpose of setting out to ensure that the various parts of the structure are correct in all three dimensions; that is each, is its required correct size, in its correct position and its correct reduced level, and that the work is not delayed and minimise cost.

3. Sight rails are part of a series of horizontal rails supported by posts driven into the ground on either side of the trench. They are used to check the gradient of a pipe in a trench.

4.
   - Set up the instrument and calculate the direction between the point on which the instrument is set up (instrument station) and point A and the distance between the two points.
   - Also calculate the direction between instrument station and point B and the distance between the two points.
   - Orientate direction from the instrument to point A, using the calculated direction of point A, and measure the distance between the instrument station and point A and put a peg.
   - Swing the instrument to point B using the calculated direction of point B and measure the distance between the instrument station and point A and put a peg.

5.
   - Cross staff
   - Optical square
   - Abney level

7 Area and volume

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

- calculate the area of the following shapes:
  - rectangles
  - triangles
  - trapezium
  - segments
  - circle
  - parallelogram
  - polygons with more than four sides
  - irregular shapes
  - planimeter; and
- calculate the volume of different shapes (earthworks, opencast mining, etc.)

In construction works, the calculation of areas and volumes is essential to determine the catchment area of rivers or reservoirs, the area of fields required for the planning and management of projects, and areas required for the title documents of land. When dealing with excavation and the carting away of earth, the calculation of volumes is necessary in order to make good estimates of volumes of earthwork excavated or to determine the capacity of dams and reservoirs.

Exercise 7.1

SB page 146

1. Area = L × B

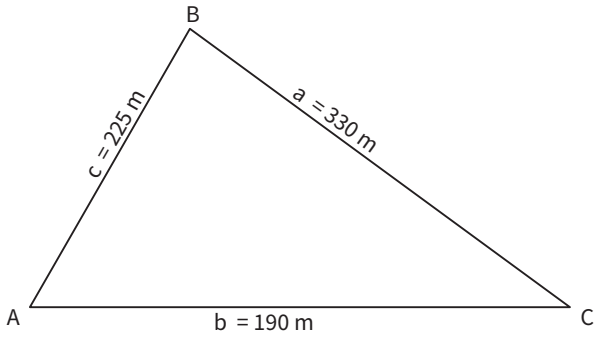
$$= \frac{350 \times 5\,000}{1\,000} \times \frac{210 \times 5\,000}{1\,000}$$

$$= 1\,750 \times 1\,050$$

$$= 1\,837\,500 \text{ m}^2$$

$$= 183{,}75 \text{ ha}$$

2.



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

$$s = \frac{330 + 190 + 225}{2}$$

$$s = 372{,}5$$

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

$$= \sqrt{372{,}5(372{,}5 - 330)(372{,}5 - 190)(372{,}5 - 225)}$$

$$= 20\,643{,}58 \text{ m}^2$$

3. Given: $\theta = 65°$ and D = 12 m, therefore r = 6 m

$$\text{Area} = \frac{\theta}{360}(\pi r^2) - \frac{r^2 \sin\theta}{2}$$

$$= \frac{\theta}{360}(\pi r^2) - \frac{r^2 \sin\theta}{2}$$

$$= 20{,}42 - 16{,}314$$

$$= 4{,}11 \text{ m}^2$$

4.

$$\text{Area} = L \times B$$

$$= \frac{402 \times 5\,000}{1\,000} \times \frac{310 \times 5\,000}{1\,000}$$

$$= 2\,010 \times 1\,550$$

$$= 3\,115\,500 \text{ m}^2$$

$$= 311{,}55 \text{ ha}$$

5. Given: s = 5 m and N = 5 (a pentagon has five sides)

$$\text{Area} = \frac{s^2 N}{4 \tan\frac{180}{N}}$$

$$= \frac{5^2(5)}{4 \tan\frac{180}{5}}$$

$$= 43{,}01 \text{ m}^2$$

6. Area = $\frac{1}{2}$base × perpendicular height

Ground area = $\frac{1}{2} \times \frac{460 \times 5\,000}{1\,000} \times \frac{180 \times 5\,000}{1\,000}$

$= 0{,}5 \times 2\,300 \times 900$

$= 1\,035\,000\ m^2$

$= 103{,}5$ ha

7. Given: $\theta = 69°$ and $r = 15$ m

$$\text{Area} = \frac{\theta}{360}(\pi r^2)$$

$$= \frac{69}{360}(\pi \times 15^2)$$

$$= 135{,}48\ m^2$$

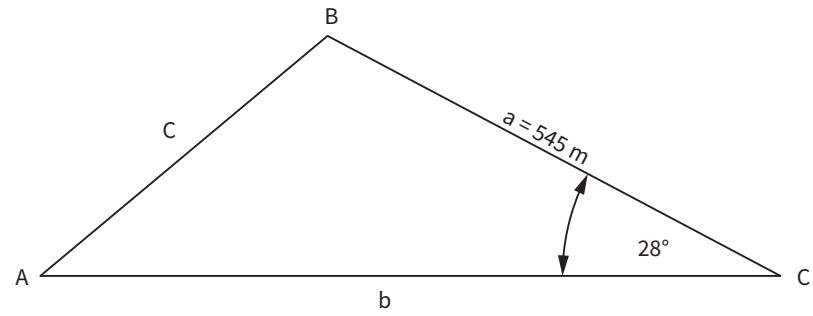
8. Given: $s = 4{,}8$ m and $N = 8$ (an octagon has eight sides)

$$\text{Area} = \frac{s^2 N}{4 \tan \frac{180}{N}}$$

$$= \frac{(4{,}8)^2(8)}{4 \tan \frac{180}{8}}$$

$$= 111{,}25\ m^2$$

9.



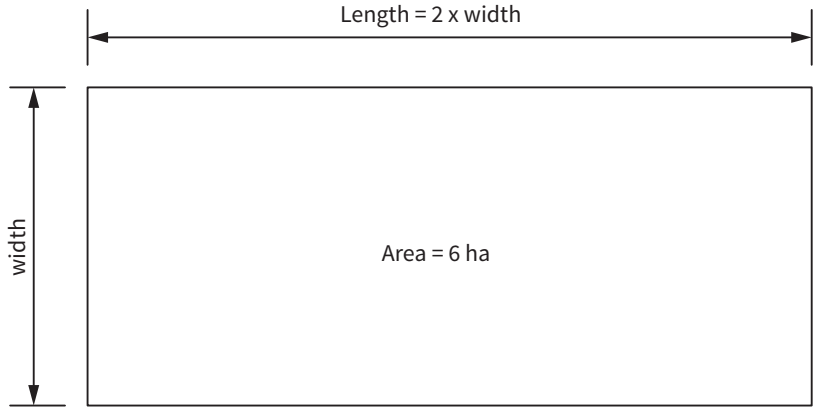
$\frac{1}{2}$ab sinC = area

$$\frac{545 \times b \times \sin 28}{2} = 2{,}975 \times 10\,000$$

$$127{,}931\ b = 29750$$

$$b = 232{,}55\ \text{m} = AC$$

10.



$$\text{Length} \times \text{width} = \text{area}$$
$$(2 \times \text{width}) \times \text{width} = 60\,000 \ldots\ldots\ldots\ldots\ldots\ldots (6 \text{ ha} = 60\,000 \text{ m}^2$$
$$2(\text{width})^2 = 60\,000$$
$$(\text{Width})^2 = 30\,000$$
$$\text{Width} = \sqrt{30\,000}$$
$$\text{Width} = 173{,}21 \text{ m}$$
$$\text{Length} = 2 \times \text{width} = 2 \times 173{,}21 = 346{,}42 \text{ m}$$

11. $\text{Area} = \frac{\theta}{360}(\pi R^2) - \frac{R^2 \sin\theta}{2}$

$= \frac{65}{360}(\pi \times 8^2) - \frac{8^2 \sin 65}{2}$

$= 36{,}303 - 29{,}002$

$= 7{,}301 \text{ m}^2$

12. $\text{Area} = \frac{1}{2}\text{base} \times \text{perpendicular height}$

$\text{Ground area} = \frac{1}{2} \times \frac{338 \times 2\,5000}{1\,000} \times \frac{185 \times 2\,5000}{1\,000}$

$= 0{,}5 \times 8\,450 \times 4\,625$

$= 19\,540\,625 \text{ m}^2$

$= 1{,}954 \text{ ha}$

13. Given: s = 32 m and N = 10 (a decagon has 10 sides)

$\text{Area} = \frac{s^2 N}{4 \tan \frac{180}{N}}$

$= \frac{(32)^2(10)}{4 \tan \frac{180}{10}}$

$= 7\,878{,}9 \text{ m}^2$

Exercise 7.2

SB page 154

1. $\text{Area} = \text{width}\left(\frac{\text{1st ord.} + \text{last ord.}}{2} + \text{sum of other ordinates}\right)$

$\text{Area} = 50\left(\frac{21 + 21}{2} + 26 + 22 + 23\right)$

$\text{Area} = 50 \times 92$

$= 4\,600\ \text{m}^2$

2. 2.1 **Trapezoidal rule**

$\text{Area} = \frac{\text{width}}{2}[\text{1st ord.} + \text{last ord.} + 2(\text{sum of other ordinates})]$

$\text{Area} = \frac{10}{2}[75 + 80 + 2(85 + 95 + 105 + 110 + 125 + 110 + 100)]$

$\text{Area} = 5(75 + 80 + 1460)$

$= 5(1\,615)$

$= 8\,075\ \text{m}^2$

2.2 **Mid-ordinate rule**

$\text{Area} = \text{width}\left(\frac{\text{1st ord.} + \text{last ord.}}{2} + \text{sum of other ordinates}\right)$

$\text{Area} = 10\left(\frac{75 + 80}{2} + 85 + 95 + 105 + 110 + 125 + 110 + 100\right)$

$= 50 \times 807{,}5$

$= 8\,075\ \text{m}^2$

3. $\text{Area} = \text{width}(\text{sum of all mid} - \text{ordinates})$

$\text{Area} = 10(42 + 46 + 44 + 48 + 52 + 50)$

$= 50 \times 282$

$= 2\,820\ \text{m}^2$

4. 4.1 **Simpson's rule**

$\text{Area} = \frac{\text{width}}{3}[\text{1st ord.} + \text{last ord.} + 4(\text{sum of even ordinates}) + 2(\text{sum of odd ordinates})]$

$\text{Area} = \frac{25}{3}[65 + 76 + 4(68 + 73 + 81) + 2(70 + 75)]$

$= 8{,}333(1\,319)$

$= 10\,991{,}227\ \text{m}^2$

4.2 **Trapezoidal rule**

$\text{Area} = \frac{\text{width}}{2}[\text{1st ord.} + \text{last ord.} + 2(\text{sum of other ordinates})]$

$\text{Area} = \frac{25}{2}[65 + 76 + 2(68 + 70 + 73 + 75 + 81)]$

$= 12{,}5(871)$

$= 10\,887{,}5\ \text{m}^2$

Exercise 7.3

SB page 155

1. Depth of excavation = 374,75 − 368,25 = 6,5 m

$$\text{Volume} = \frac{68{,}27 + 92{,}44}{2} \times 47{,}38 \times 6{,}5$$
$$= 24\,746{,}929 \text{ m}^3$$

2. Depth of fill = 300 − 225,5 = 74,5 m

$$\text{Volume} = \frac{50 + 25}{2} \times 40 \times 74{,}5$$
$$= 111\,750 \text{ m}^3$$

3. Depth of excavation = 578,32 − 575,47 = 2,85 m

$$\text{Area of swimming pool} = \frac{S^2 N}{4\tan\frac{180}{N}}$$
$$= \frac{3{,}2^2 \times 6}{4\tan\frac{180}{6}}$$
$$= 26{,}604 \text{ m}^2$$

$$\text{Volume of excavation} = \text{area} \times \text{depth}$$
$$= 26{,}604 \times 2{,}85$$
$$= 75{,}821 \text{ m}^3$$

4. Depth of pit = 578,32 − 575,47 = 2,85 m

4.1 $$\text{Area} = \frac{27}{3}[55 + 67 + 4(58 + 73 + 83) + 2(67 + 75 + 75)]$$
$$= 9(1\,412)$$
$$= 12\,708 \text{ m}^2$$

4.2 $$\text{Volume} = \text{area} \times \text{depth}$$
$$= 12\,708 \times 16{,}78$$
$$= 213\,240{,}24 \text{ m}^3$$

Summative assessment

SB page 156

1.
- Select a starting point on the boundary of the area to be measured and place the tracer point there.
- Set the counter on the wheel to zero.
- Move the tracer point once around the boundary of the region being measured.
- As the tracer point moves, the wheel partially rolls and partially slides on the paper.
- Record its motion perpendicular to the tracer arm. (5)

2. $\text{Area} = \frac{1}{2}ac\sin B$

$\text{Area} = \frac{255 \times 192 \times \sin 50{:}10{:}25}{2}$

$\text{Area} = 18\,800{,}36\ m^2$ (3)

3. $\text{Area} = \frac{\theta}{360}(\pi r^2) - \frac{r^2 \sin\theta}{2}$

$= \frac{60}{360}(\pi \times 8{,}5^2) - \frac{8{,}5^2 \sin 60}{2}$

$= 37{,}83 - 31{,}29$

$= 7{,}54\ m^2$ (5)

4. $\text{Area} = \frac{s^2 N}{4 \tan \frac{180}{N}}$

$= \frac{(6{,}4)^2(5)}{4 \tan \frac{180}{5}}$

$= 70{,}47\ m^2$

$\text{Volume} = 70{,}47 \times 4{,}5$

$= 317{,}12\ m^3$ (5)

5. $\text{Average length} = \frac{72 + 118}{2} = 95\ m$

$\text{Volume} = L \times B \times H$

$= 95 \times 49{,}8 \times 9{,}8$

$= 46\,363{,}8\ m^3$ (5)

Total: 23 marks

8 *Plane table surveying*

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

- explain the functions, advantages and disadvantages of a plane table
- draw, explain and list the components of plane table equipment
- list the important points to consider when setting up a plane table
- explain, list and draw the following methods involved in plane tabling:
  - traversing
  - radiation
  - intersection (triangulation)
  - resection

Plane table surveying involves the measurement of distance and angles while simultaneously plotting these observations in the field. Methods used in plane tabling involve traversing, radiation, intersection and resection.

Exercise 8.1

SB page 170

1. Plane table surveying is a graphical method of surveying in which the field observations and plotting are done simultaneously.

2.
- The table should be level when erected.
- The table should be at a workable height.
- Keep all the equipment to be used on hand.
- Do not attempt to work in bad weather.
- First acquaint yourself with the area to be surveyed.
- Select well-defined stations for orientation.
- Orientate the table accurately.
- Select stations that are recognised on the map.
- Always recheck your orientation.
- The point on the table should be directly above the point on the ground which it represents.

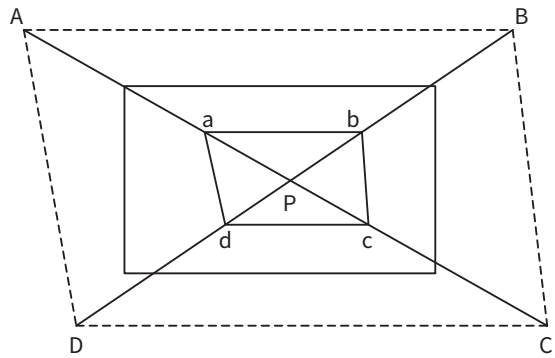
- Each ray should be easily identified.
- A notebook should be kept to enter written descriptions of each ray.
- Use reference numbers to refer to each ray.

3.
- Radiation
- Triangulation
- Traversing
- Resection

4.
- Plane table
- Alidade
- Plane table compass
- Plumbing fork
- Spirit level

5.
- It is a comparatively rapid method of surveying.
- Field notes are reduced to a minimum.
- Gross mistakes are unlikely, as the area surveyed is in view.
- Tedious measurements of long distances are avoided.
- The work is interesting and the surveyor sees the plan growing.
- The surveyor gains thorough knowledge of the area.
- Methods are fairly easily mastered.
- Office work merely entails tidying up the plan.
- Required checks are done immediately.

6.



- P is the selected point on the ground, ensuring that all stations to be surveyed are visible.
- At point P a peg is driven into the ground and the exact position of the station is marked with a nail on the peg.
- The plane table is set up and levelled over the central position.

- The board is placed horizontally and clamped in a suitable position, ensuring that the whole survey can be contained on the drawing paper to the selected scale.
- The position P on which the plane table is set is marked on the drawing paper with the aid of the plumbing fork.
- Using the alidade, rays from point P to stations A, B, C and D and other important features of the site under survey are noted – in this case a tree.
- The distances PA, PB, PC and PD are measured either by chaining or by optical alidade.
- The distances are then plotted to the selected scale to give corresponding points a, b, c and d on the drawing paper, and these points are connected to give a plan of the site.
- Magnetic north is indicated by means of a compass.

Summative assessment

SB page 171

1. 1.1 Bent
   1.2 Station
   1.3 Drawing paper
   1.4 Upper arm
   1.5 Points
   1.6 Ground
   1.7 Plumb bob
   1.8 Lower arm
   1.9 Corresponds
   1.10 Upper arm (10 × 1)

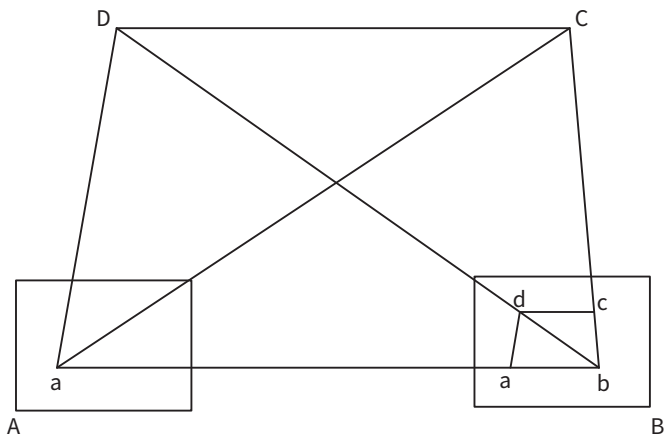
2. Orientation of the plane table means positioning the table so that the lines on the paper are parallel to the lines on the ground which they represent. (2)

3.
   - Production of maps and plans of small areas
   - Preparation of reconnaissance and exploratory survey maps and plans
   - Filling in details between control points established
   - Reviewing existing maps and plans
   - Location of contours (5 × 1)

4.
- Centring
- Levelling
- Orientating (3 × 1)

5.
- The equipment is bulky and awkward.
- Rain and wind stop the activities.
- Prolonged bad weather leads to serious delays, as work is done in the field.
- It is impractical in heavy-wooded or dense bush areas.
- The absence of field notes may prove a disadvantage on some jobs.
- It is a very time-consuming operation.
- It is not as accurate as other methods of surveying.
- The scale to which it is drawn may be limited by the size of the plane table. (5 × 1)

6.



- A suitable baseline, in this case AB, is selected, and the distance between the two stations is carefully measured.
- Line *ab* is plotted on the plane table at a suitable position to a required scale, ensuring that there is enough space to accommodate all other points in the survey on the drawing.
- The plane table is set up and levelled over station A using the plumbing fork to ensure that point *a* on the drawing is vertically over point A on the ground and using the alidade to orientate *pq* on the drawing with the baseline AB on the ground.
- With the alidade at *a*, points C and D are sighted, respectively, and resection rays are drawn and marked with a corresponding reference near the edge of the paper so as not to interfere with the next lines at the next station.

- Using a compass, the direction of magnetic north is established and indicated on the paper.
- The plane table is then moved, set up and levelled over station B using the plumb fork to ensure that point *b* on the drawing is vertically over point B on the ground. The alidade is used to orientate *ab* on the drawing with the baseline AB on the ground.
- Again, check the orientation using the compass. It should give exactly the same direction of magnetic north as obtained at the previous station.
- With the alidade at *q*, points C and D are sighted, respectively, and the rays are drawn to intersect with the corresponding rays drawn at b, giving *c* and *d*. (8)

Total: 33 marks

9 Compass surveying

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

- explain the advantages and disadvantages of the compass surveying;
- describe the requirements for the magnetic needle of a compass;
- identify the following types of the magnetic compasses:
  - prismatic compass
  - surveyor's compass; and
- calculate the following types of systems of bearing:
  - whole circle bearing
  - quadrantal bearing.

Compass surveying involves the location of points using compass bearings and is used to establish the direction of magnetic north. The core principle of compass surveying involves traversing, which students will learn about in this module.

Exercise 9.1

SB page 181

1. 1.1 The true meridian is the line on a plane passing through the geographical north pole or the geographical south pole.
   1.2 Local attraction is the magnetic material that causes the disturbing influence on the magnetic needle of the compass.
   1.3 Magnetic declination is the angular difference between the direction of true north and magnetic north.

2. Advantages
   - Some types of compasses are very light and portable.
   - Observations are made more rapidly than with a theodolite.
   - Each bearing is determined independently of the other so that errors do not accumulate, but tend to compensate.
   - The bearing of a line can be observed from any point on it.
   - Intermediate points can be established on a long line of known bearings.
   - The compass needs much less time for setting.
   - The mechanism of the instrument is very easy to use.

Disadvantages

- It is less precise and an error of one degree could result in an error of one unit in sixty.
- Errors may also arise due to inaccurate levelling of the compass.
- There may be errors in compass surveying due to local attraction.
- Distance is not measured by the compass.
- A compass does not record elevation, which could be used for a contour map.

3. 3.1 The prism is used for both bisection and taking readings.
   3.2 The mirror facilitates the sighting of the bearing of an object at high or low altitudes.
   3.3 A damping device is used to dampen the vibration of the needle.

4. 4.1 Isogonic lines join places on the earth's surface where the magnetic declination is the same at a given time, while agonic lines join places on the earth's surface where the magnetic declination of a given point is zero.
   4.2 The graduated ring of a prismatic compass rotates along the line of sight, while the graduated ring of a surveyor's compass is rigid.

5. True north is a fixed point on the earth and magnetic north is the direction a compass needle will point to and changes over time.

6.

Prismatic compass	Surveyor's compass
• Graduated ring is attached to the needle • Needle is broad • Graduations are marked 0° and 360° in a clockwise direction • Graduation ring rotates • 0 and 360 are marked at south, 180 at north, 90 at west and 270 at east • Measures whole bearing • Graduation engraved inverted • Can be handheld	• Graduated ring and needle separate • Needle is an edge bar type • Graduations are marked 0° and 90° in each quadrant • Graduation ring is rigid • East and west are interchanged • Measures quadrant bearing • Graduation engraved erect • Needs a tripod

Exercise 9.2

SB page 187

1. 1.1 Quadrant bearing is measured eastward or westward from north or south, whichever is nearer, while whole-circle bearing is measured in a clockwise direction from true north towards the line and varies from 0° to 360°.
   1.2 True bearing is the horizontal angle between true north and the survey line, while a magnetic bearing is measured from the magnetic north.

2. 2.1 WCB = 25°40' (in quadrant NE)
   QB = N 25°40' E
   2.2 WCB = 225°26' (in quadrant SW)
   QB = 225°26' – 180 = S45°26' W
   2.3 WCB = 295°30' (in quadrant NW)
   QB = 360 – 295°30' = N64°30' W
   2.4 WCB = 175°50' (in quadrant SE)
   QB = 180 – 175°50' = S4°10' E

3. 3.1 45°30' E is between 0° and 90°
   WCB = 45°30'
   3.2 N25°30' W is between 270° and 360°
   WCB = 360 – 25°15' = 344°45'
   3.3 S25°15' E is between 90° and 180°
   WCB = 180 – 25°15' = 154°45'
   3.4 S15°W is between 180° and 270°
   WCB = 180 + 15°= 195°

4. Declination is to the west, therefore:
   True bearing = magnetic bearing – declination
   True bearing AB = 143°40' – 8°49'
   = 134°51'

5. Declination is to the west, therefore:
   True bearing = magnetic bearing – declination
   225°40' = magnetic bearing – 8°49'
   Magnetic bearing = 225°40' + 8°49'
   = 230°50'

6. Magnetic bearing is a QB and in SW quadrant, converted to WCB
Magnetic bearing (WCB) = 180°+25°16'
= 205°16'
Declination is to the East
True bearing = magnetic bearing + declination
True bearing = 205°16' + 12°14'
= 217°30'

7. Magnetic bearing = 180 – 25°24'
= 154°36'
7.1 True bearing = 154°36' – 12°14'
= 142°22'
7.2 True bearing = 154°36' + 12°14'
= 166°50'

Summative assessment

SB page 188

1. 1.1 G
1.2 F
1.3 E
1.4 D
1.5 C
1.6 B (6 × 1)

2. 2.1 The magnetic bearing of a line is the horizontal angle between magnetic north and the survey line. (2)

2.2 The true bearing of a line is the horizontal angle between true north and the survey line, measured clockwise. (2)

3. WCB = 180 – 35°40'
= 144°20' (2)

4. Magnetic bearing (WCB) = 180 – 40°35'
= 139°25'

True bearing = 139°25' – 4°15'
= 135°10' (3)

Total: 15 marks

Exemplar examination paper memorandum

Question 1

1.1 Cadastral surveying is a survey done for the preparation of plans showing legal boundaries. (2)

1.2 Local attraction is the magnetic material that causes the disturbing influence on the magnetic needle of the compass (2)

1.3 Agonic lines are lines joining places on the earth's surface where the magnetic declination of a given point is zero. (2)

[6]

Question 2

2.1 The purpose of surveying to prepare drawings, such as maps, plans, cross sections or elevations, with profiles that have all the necessary information about natural and man-made features. These are then used by the architect and engineer to work on the design of the proposed structure. The final plan is then given to the surveyor, who sets out the work. (5)

2.2 Any FIVE of the following:

- Chain survey
- Levelling
- Traversing survey
- Tacheometric survey
- Trilateration survey
- Triangulation survey
- Compass survey
- Plane table survey
- Photographic survey (5 × 1)

2.3 Any FOUR of the following:

- Title page
- Index/Index diagram
- Surveyor's signature/name
- Field party names
- Job description
- Observations
- Benchmark description and location

- Sketches
- Descriptions
- Equipment list
- Weather information (4 × 1)

[14]

Question 3

3.1
- Natural scale
- Engineering scale
- Divided scale (3 × 1)

3.2 Area = $\frac{1}{2}$base × perpendicular height

Ground area = $\frac{1}{2} \times \frac{420 \times 2\,000}{1\,000} \times \frac{190 \times 2\,000}{1\,0000}$

= 0,5 × 840 × 380

= 159 600 m^2

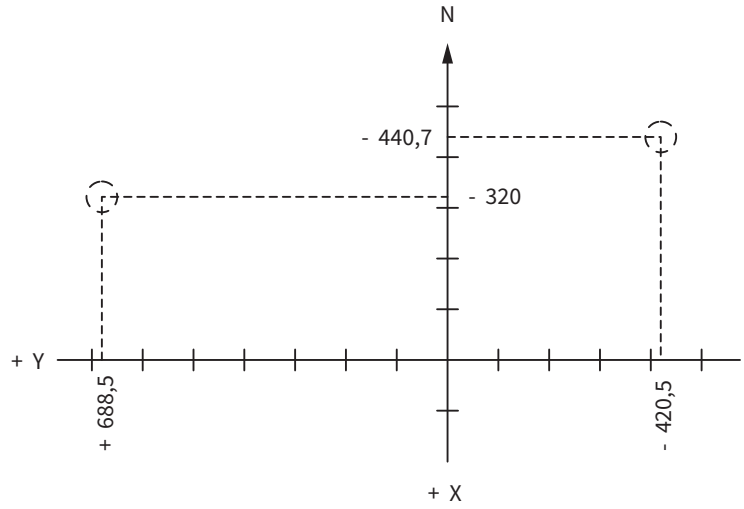
=15,96 ha (4)

3.3
- The table should be level when erected.
- The table should be at a workable height.
- Keep all the equipment to be used on hand.
- Do not attempt to work in bad weather.
- First acquaint yourself with the area to be surveyed.
- Select well-defined stations for orientation.
- Orientate the table accurately.
- Select stations that are recognised on the map.
- Always recheck your orientation.
- The point on the table should be directly above the point on the ground which it represents.
- Each ray should be easily identified.
- A notebook should be kept to enter written descriptions of each ray.
- Use reference numbers to refer to each ray. (5 × 1)

[12]

Question 4

4.1



(6)

4.2 Quadrant bearing = 215 – 180 = 35
Quadrant bearing = N35°E (2)

4.3 $\frac{x}{100} = \frac{60}{90}$

$x = \frac{60 \times 100}{90}$

$x = 66{,}7^{g}$ (2)

[10]

Question 5

5.1
- Coordinates are values in metres that indicate the latitude and longitude of the position of a point on the ground represented on a plan or map. Direction is the horizontal angle formed by the line between the coordinated points and a reference line.
- The observed direction and distance between two coordinated points are used to calculate the coordinates of other points in-between.
- Coordinates of points are used to determine the true direction and horizontal of a line between two coordinated points. (5)

5.2 Depth = 335,1 – 325,6
= 9,5 m

$V = \frac{74 + 39}{2} \times 24 \times 9,5$
$= 12\,882\ m^3$ (5)

5.3 $Area = \frac{\theta}{360}(\pi r^2) - \frac{r^2 \sin\theta}{2}$
$= \frac{65}{360}(\pi \times 8^2) - \frac{8^2 \sin 60}{2}$
$= 36,303 - 29$
$= 7,303\ m^2$ (5)

5.4 Orientation of the plane table means positioning the table so that the lines on the paper are parallel to the lines on the ground which they represent. (3)
[18]

Question 6

6.1
- It is a robust instrument.
- The chain can be dragged around over the ground.
- Reading a chain is fairly easy.
- The chain can be cleaned.
- Repairing a chain is fairly easy.
- The chain can be read from both sides. (4 × 1)

6.2 $C_t = L \times e(t_m - t_s)$
$C_t = 104 \times 0,0000113(15 - 20)$
$C_t = -0,006$

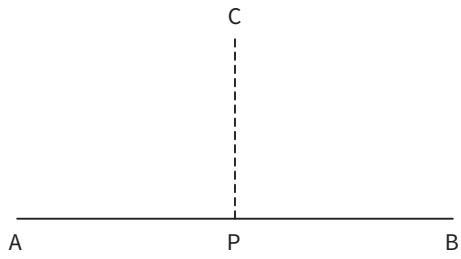
CD = 104 – 0,006
CD = 103,994 m (4)

6.3 $C_S = \frac{W^2 L^3}{24 T^2}$

$C_S = \frac{0,015^2 \times \left(\frac{85}{3}\right)^3}{24(7)^2} \times 3$
$= 0,004 \times 3$
$= 0,012$ m

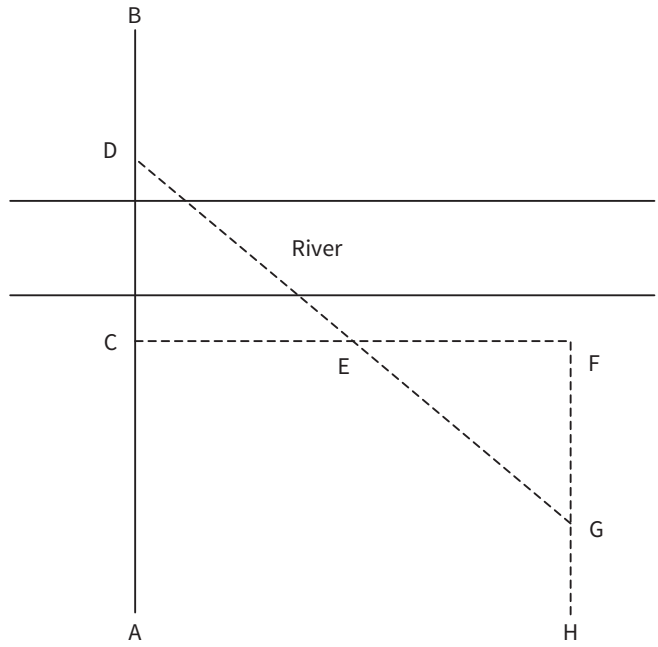
CD = 85 – 0,012
= 84,988 m (6)

6.4 6.4.1



Line AB is a known base line. To fix a perpendicular offset line to point C, an optical square is used to measure the right angle APC or BPC and distance PC. (3)

6.4.2



A chain line AB passes over a river. CD is the distance that must be measured; C and D are ranged on opposite sides of the river banks. To find CD, from point C set a perpendicular offset CEF so that CE is equal to EF. From point F set a perpendicular offset FH, so that FH is parallel to chain line AB. Move a ranging rod along the line FH until the rod is in line with point E and D. This will be point G. Now distance CD can be found by measuring FG. (4)

[21]

Question 7

7.1
- Spirit level
- Vernier
- Index
- Eyepiece
- Protractor
- Telescope (5 × 1)

7.2. 7.2.1 HC = 126,54 + 0,95
= 127,49 (2)

7.2.2 RL_N = 127,49 – 1,58
= 125,91 (2)

7.3. 7.3.1 Surveyor's compass: measures the quadrant bearing of a line (2)

7.3.2 Cross staff: measures offsets from a line (2)

7.3.3 Change plate: marks the change point position from a staff and prevents staff from sinking (2)

7.3.4 Electronic distance measuring instrument: measures distance using light and radio waves (2)

[8]

7.4
- Alcohol
- Chloroform (2 × 1)

[19]

Total: 100 marks

Glossary

A

Abney level – a handheld instrument to measure vertical angles

agonic lines – imaginary lines joining places on the earth's surface where the declination of a given point is zero

alidade – a sight rule with sighting vanes used for sighting the direction of a distant target arc – a curve or a section of a circle

artificial features – refers to roads, bridges, boundaries, engineering and mining structures

axis – the vertical line and horizontal line (*plural* axes) on a graph, forming coordinates; or a line on which an object would rotate

B

back sight – the first reading taken from a known point after the instrument has been set up

benchmark – a permanent mark showing the known height of that point above mean sea level

bisection – a division in two parts

bubble tube – a curved glass tube partly filled with a liquid, used for setting the line of sight of the instrument perpendicular to the direction of gravity

C

catenary – the U-shaped curve formed by a heavy inextensible cable, chain or rope of uniform density suspended from its endpoints

centesimal – a hundredth or relating to hundredth parts. The grade is an angular measure which is one-hundredth of a right angle

centigrade – one hundredth of a grad

chain surveying – use of a tape or chain as the principal instrument for the accurate measurement of lengths

change plate – a triangular steel plate with a pin at the centre and three corners turned down

change point – the point where the instrument is moved and the position of the previous foresight is used as the new back sight reading

clinometer – an instrument used for measuring the angle between an inclined surface and the horizontal surface;

closed traverse – is used in the survey of boundary lines. It starts from a known point and ends up at the same point

closure error – the difference between the elevations determined from the levelling survey and a known benchmark elevation

collimation error – occurs when the collimation line is not truly horizontal when the instrument is level

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

compass traversing – a traversing method in which the angles are measured with a compass

contour map – a topographic map that shows relief by means of contour lines

convex – having a surface which curves outward

coordinates – a set of numbers that details the exact position of something with reference to a set of axes

D

damping device – a device used to restrain the oscillation of the compass needle

datum – a point on the surface or line from which heights or levels of points are measured

decimal – related to the decimal numbering system and numbers based on tenth parts

dumpy level – an optical levelling instrument

E

erroneous – something that is incorrect or an error

equator – an imaginary line around the earth at an equal distance from the North- and South poles

F

fibreglass – material made from extremely fine fibres of glass

field observations – practical surveying work, including sighting and noting, which takes place outside the office

foresight – the last reading taken before the instrument is moved

forward intersection – a method of setting up a plane table in which the points on the ground are located by occupying two stations with the plane table

G

Gauss Conform Projection – also known as the Transverse Mercator Projection; the type of conform projection used in South Africa wherein each zone is wide

grade – a unit of measurement of an angle

graduation ring – a ring attached to the compass needle and used for taking readings

grid – the establishment of points of reference on-site to mark out a network from which other coordinates and lines can be set

grid north – the north that is established by using the vertical grid lines on a map

I

integration – a method used to obtain the area between a curve, the x-axis and specific ordinates or values of x

intermediate sight – the reading between the back sight and foresight

isogonic lines – imaginary lines joining places on the earth's surface where the magnetic declination is the same at a given time

K

kilogram-force – a unit of measurement of force, expressed as 1 kgF, where one unit is equal to 10 newtons (10 N)

L

latitude – an imaginary line denoting points around the earth's surface of equal distance north or south of the equator

levelling staff – a large ruler designed to make it easy to read a small section of the scale when seen through a telescope

local attraction – the magnetic material that causes the disturbing influence on the magnetic needle of a compass

local heights – the height to which an arbitrary height (value) has been assigned

longitude – the angular distance, east or west, of a point's meridian from the prime meridian, measured in degrees, minutes, and seconds

M

magnetic declination – the angular difference between the direction of true north and magnetic north

magnetic meridian – an imaginary great circle on the earth's surface that passes through the north and south magnetic poles

magnetic north – the direction in which a freely suspended compass needle points

mean sea level – average height of the surface of the sea, for all stages of the tide, over a long period, being determined from hourly readings of tidal height

mental lapse – an occurrence in which you fail to think or act in the usual or proper way for a brief time and make a mistake

mercator projection– cylindrical map projection

meridian – a circle of constant longitude passing through a given place on the earth's surface and the terrestrial poles

mid-ordinate rule – a method used to obtain the area under a curve, whereby the area is divided into rectangles of equal width and height

modulus of elasticity – the ratio of stress to strain in linear elasticity

N

natural feature – refers to rivers, hills, lakes, areas of land on the earth's surface

O

official heights – benchmarks which have been determined by precise levelling

open traverse – used when surveying along a river etc. It starts from a known point and ends at another known point

orient – to align the plane table with magnetic north

P

parallax – the apparent movement of the cross hairs relative to the object on to which the instrument is being sighted

parallel – two objects or lines running consistently at an equal distance apart

perpendicular – at right angles to another object

pivot – a centrally positioned part of the compass supporting the needle

plane table spirit level – a small spirit level placed on the surface of the plane table to check if the surface lies perpendicular to the direction of gravity

planimeter – a mechanical measuring instrument used to calculate irregular areas for which there is no formula

plumbing fork – a bent steel arm used to position the station point on the ground onto the drawing paper on the plane table

polyvinyl chloride – a common thermoplastic polymer based on vinyl used extensively in the construction industry

prism – right-angled triangular glass prism with convex sides for the bisection and taking of readings

prismatic – that which relates to a prism

Q

quadrantal bearing – the bearing of a line measured eastward or westward from north or south, dependent on whichever is nearer

R

radian – a unit of angular measurement

radiation – the emission of energy as electromagnetic waves or as moving subatomic particles

radiation (plane surveying) – a method of setting up a plane table in which the table is only set up once

reconnaissance – information obtained from a preliminary survey

reduced bearing – that which occurs when the whole circle bearing of a line is converted to a quadrantal bearing

representation – refers to a map or a plan which represents to scale, lines and features on a plane surface (sheet of paper)

resection – a method of setting up a plane table without using previously plotted stations, but two or more visible points already plotted on the plane table

reticule – a grid of fine lines in the eyepiece of an optical instrument to determine the scale or position of the object being viewed

S

sag – bending downwards

set out – to transfer points from the plan and peg them out on the ground

sexagesimal – a unit of angular measurement based on the number 60, where time is in hours, minutes and seconds and of angles in degrees, minutes and seconds

sighting vanes – arm-like projections which point upwards and are attached at opposite side of the compass box

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

staff bubble – a small circular bubble on an angle plate to ensure that the staff is held in a vertical position

standardisation – the process whereby the standard temperature and tension are determined when the tape is the exact length

subtending – an angle is subtended by an arc, line segment or any other section of a curve when its two rays pass through the endpoints of that arc, line segment or curve section

T

theodolite – an optical surveying instrument for measuring horizontal and vertical angles

tidal fluctuations – changes in the tides

tracer point – used to trace the boundary of the area

trapezoidal rule – a method of estimating the area under a curve by dividing the area into smaller trapezoids of equal width

traveller – also known as a boning rod; used to control an excavation to have a uniform depth

traversing (plane surveying)– a method of setting up a plane table in which the table is set up over each station in turn to fix the main survey lines

triangulation – a method used in surveying that divides an area of land into triangles

trigonometric beacon – also known as a trig-beacon or triangulation station; a fixed surveying station for geodetic surveying and surveying projects

trough compass – another name for a plane surveying compass, which is used to orient the plane table by magnetic north

true north – the direction of the meridian through a point towards the geographic North Pole of the earth

V

Vernier scale – a short auxiliary graduated scale

W

whole circle bearing – the bearing of a line measured in a clockwise direction from true north towards the line