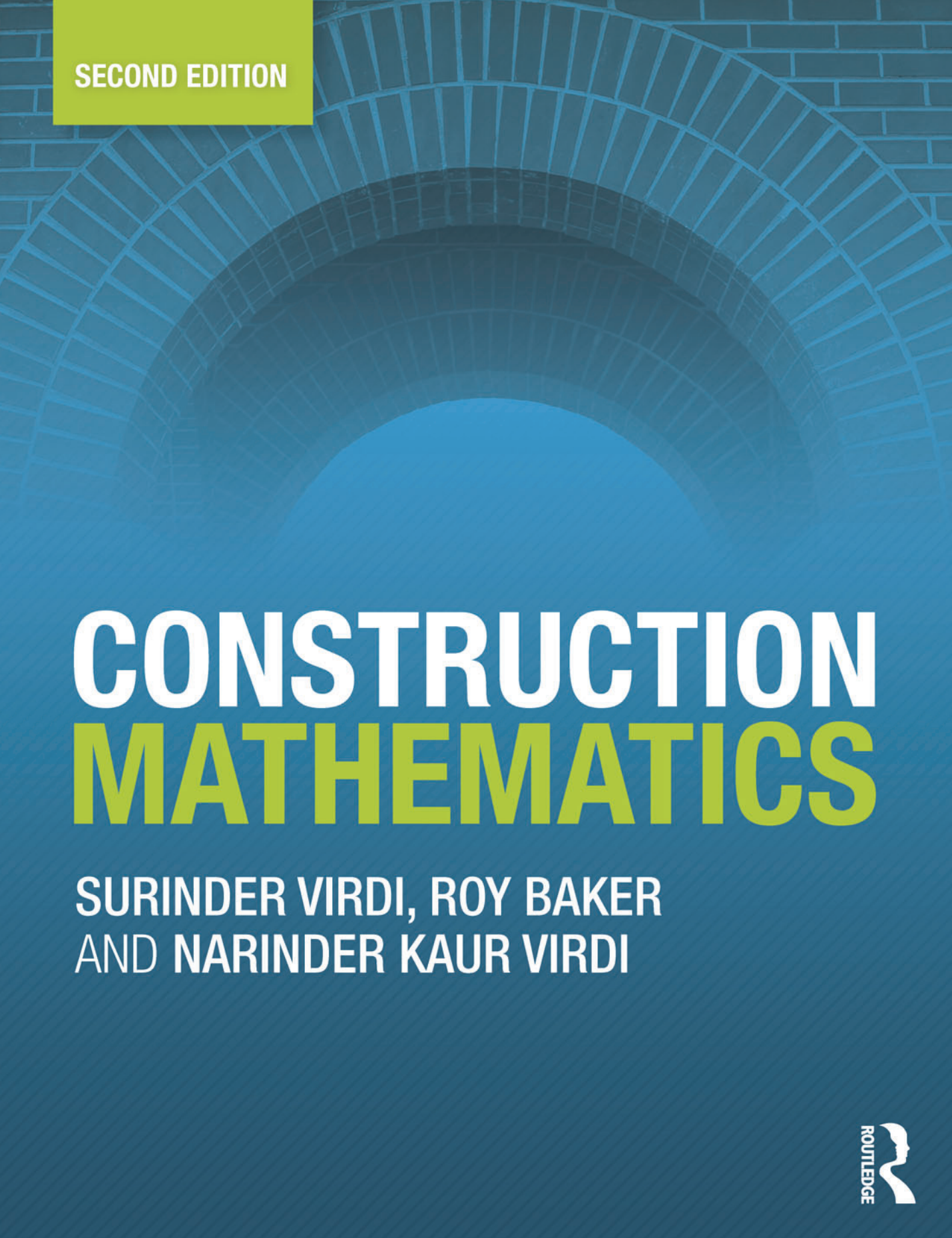
SECOND EDITION
CONSTRUCTION
MATHEMATICS
SURINDER VIRDI, ROY BAKER
AND NARINDER KAUR VIRDI
ROUTLEDGE

Construction Mathematics

Construction Mathematics is an introductory level mathematics text, written specifically for students of construction and related disciplines.

- Learn by tackling exercises based on real-life construction maths. Examples include: costing calculations, labour costs, cost of materials and setting out of building components.
- Suitable for beginners and easy to follow throughout.
- Learn the essential basic theory along with the practical necessities.

The second edition of this popular textbook is fully updated to match new curricula, and expanded to include even more learning exercises. End of chapter exercises cover a range of theoretical as well as practical problems commonly found in construction practice, and three detailed assignments based on practical tasks give students the opportunity to apply all the knowledge they have gained.

Construction Mathematics addresses all the mathematical requirements of Level 2 construction NVQs from City & Guilds/CITB and Edexcel courses, including the BTEC First Diploma in Construction. Additional coverage of the core unit Construction Mathematics from BTEC National Construction, Civil Engineering and Building Services courses makes this an essential revision aid for students who do not have Level 2 mathematics experience before commencing their BTEC National studies. This is also the ideal primer for any reader who wishes to refresh their mathematics knowledge before going into a construction HNC or BSc.

Surinder Virdi is a lecturer in construction at South and City College Birmingham. He worked as a structural engineer for a number of years before starting his teaching career in further education. He has been teaching mathematics, construction science and construction technology on BTEC National and Higher National courses for the last 25 years.

Roy Baker spent forty years teaching mathematics, construction science and structural mechanics at the City of Wolverhampton College before retiring in 2005. He now works as a visiting lecturer.

Narinder Kaur Virdi is a programme manager at the South and City College Birmingham and responsible for managing the provision of basic skills. She worked as a biochemist for a number of years before becoming a trained teacher. She has been teaching literacy and numeracy for the last 15 years.

This is an excellent resource for construction students with step by step instructions helping them to understand and enjoy mathematics. Each chapter has an instruction and methodology section with solutions and testing at the end, enabling individual tracking and progression. This book will help my students improve their numeracy skills to achieve their diploma qualification.

Michael Cook, Lecturer, The Sheffield College

Construction Mathematics has proved to be an ideal text for Construction and Civil Engineering students at National Certificate level, whilst providing Undergraduates with a well laid out revision text. The logical progression of ideas and the simple and clear examples prove valuable to students as they pass onto a higher level of study.

Derek Spalton, Senior Lecturer, University of Derby

Construction Mathematics

Second Edition

Surinder Virdi, Roy Baker and
Narinder Kaur Virdi

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Contents

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Preface to the second edition

This book is intended to provide the essential mathematics required by students on construction technician/craft courses. It covers the learning outcomes of the mathematics part of the unit 'Construction Science and Mathematics' for BTEC Level 2 Diploma course in construction. The book is also intended to help students studying the subject of Mathematics in Construction and Built Environment in the BTEC National/Extended Diploma in construction/civil engineering/building services and Higher National Certificate/Diploma courses in construction, although these syllabuses are not covered in their entirety.

Little previous knowledge is needed by students who use this text. The basic concepts and examples are explained in such a way that those construction students whose first interest is not mathematics will find it easy to follow. The contents have been divided into 20 chapters, providing information on a range of topics in algebra, geometry, trigonometry and statistics. Wherever applicable the basic concepts have been used to solve practical tasks in construction. Three assignments and 20 exercises are included to check and reinforce readers' learning.

This edition includes the solution of all questions included in the end of chapter exercises. The solutions will be beneficial to learners who may need some help in arriving at the right answers while solving questions from the exercises.

The authors would like to thank their students and colleagues for the interest they have shown in this project. A big thank-you to: Brian Guerin (Commissioning Editor, Routledge), Alice Aldous (Editorial Assistant) and Alanna Donaldson (Production Editor) for their support during the publication of this edition.

S.S. Virdi
R.T. Baker
N.K. Virdi

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Preface to the first edition

This book is intended to provide the essential mathematics required by construction craft students. It covers the learning outcomes of the mathematics part of the unit Construction Science and Mathematics for BTEC First Diploma course in construction. The book is also intended to help construction students studying the subject of analytical methods in the BTEC National Diploma/Certificate in Construction and BTEC National Certificate in Civil Engineering, although these syllabuses are not covered in their entirety.

Little previous knowledge is needed by students who use this text. The basic concept and examples are explained in such a way that those construction students whose first interest is not mathematics will find it easy to follow. There are 20 exercises and two assignments for the students to check and reinforce their learning.

The authors would like to thank their wives, Narinder and Anne, for the encouragement and patience during the preparation of this book. The authors extend their thanks to the publishers and their editors, Rachel Hudson (Commissioning Editor) and Doris Funke, for their advice and guidance.

S.S. Virdi
R.T. Baker

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How to use this book

Students pursuing level 3/4 courses should study all chapters in this book. Students pursuing level 2 courses should study all chapters except Chapters 4, 17, 18 and 19. The solutions for all questions included in the end of chapter exercises are given in Appendix 2. The reader should first try to solve the questions on their own, and only refer to the solutions if they experience some difficulty in finding the right answer.

Chapter 21 has three contextualised assignments, which the reader should attempt after studying topics relevant to the assignment tasks. The solutions are given online at www.routledge.com/9780415810784.

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Acknowledgements

We are grateful to HMSO for permission to quote regulations on stairs from Building Regulations – Approved Document K.

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Abbreviations and units

Units

Quantity	Name of unit	Symbol
Length	millimetre centimetre metre	mm cm m
Mass	kilogram	kg
Time	second	s
Fahrenheit temperature	degrees Fahrenheit	°F
Plane angle	radian degrees	rad °
Force	Newton	N
Stress	stress	N/mm^2 kN/mm^2
Fluid pressure	Pascal	Pa
Acceleration due to gravity	g	m/s^2
Potential difference	volts	V
Electrical resistance	Ohms	Ω
Celsius temperature	degrees Celsius	°C
Coefficient of thermal transmittance	U-value	W/m^2 °C
Heat loss	watt	W
Luminous intensity	candela	cd
Illuminance	lux	lx

Prefixes

Name	Symbol	Factor
Tera	T	10^{12}
Giga	G	10^{9}
Mega	M	10^{6}
Kilo	k	10^{3}
Hecto	h	10^{2}
Deca	da	10
Deci	d	10^{-1}
Centi	c	10^{-2}
Milli	m	10^{-3}
Micro	μ	10^{-6}
Nano	n	10^{-9}
Pico	p	10^{-12}

Abbreviations/symbols

Description	Symbol
Approximately	Approx.
For example	e.g.
Triangle	Δ
Less than	<
Greater than	>
Degrees, minutes, seconds	° ′ ″
Angle	∠
Significant figures	s.f.
Therefore	∴
Decimal places	d.p.

CHAPTER 1

Using a scientific calculator

Learning outcomes:

(a) Identify the right keys to perform a calculation

(b) Perform a range of calculations

1.1 Introduction

The use of electronic calculators became popular during the early 1970s. Before the invention of calculators, slide-rules and tables of logarithms and antilogarithms were used to perform simple as well as complex calculations. The exercises and assignments in this book require the use of a scientific calculator; this chapter deals with the familiarisation of some of the main keys of a calculator.

With most calculators the procedure for performing general calculations is similar. However, with complex calculations this may not be the case. In that situation the reader should consult the instructions manual that came with their calculator. The dissimilarity in calculators is not just limited to the procedure for calculations, as the layout of the keys could be different as well.

The sequence in which the keys of a new calculator are pressed is the same as the sequence in which a calculation is written. With the old calculators this might not be the case. All calculations given in this section are based on the new calculators. Scientific calculators have a range of special function keys and it is important to choose one that has all the functions most likely to be needed. Some of the commonly used keys are shown in Section 1.2.

1.2 Keys of a scientific calculator

The keys of a typical scientific calculator are shown in Figure 1.1.

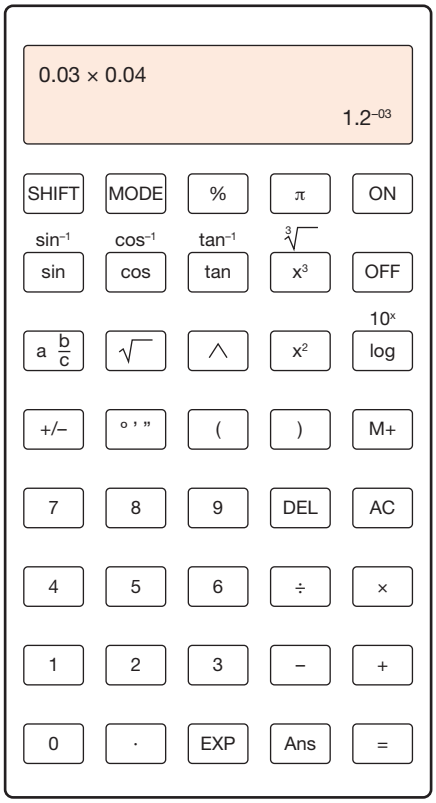

Figure 1.1

+	Adds two or more numbers
–	Subtracts a number from another
÷	Divides a number by another
×	Used to multiply two or more numbers
AC	Cancels or clears an existing calculation
SHIFT	Press this key to use the second function of a key
MODE	Use this key to set the calculator for performing calculations in terms of degrees or radians
√	Calculates the square root of a number
$\sqrt[3]{}$	Calculates the cube root of a number
x^2	Use this key to determine the square of a number
x^3	Use this key to determine the cube of a number
^ or $x^{\square}$	A number can be raised to any power by pressing this key
π	Use this key wherever π occurs in a formula
sin cos tan	Use the appropriate key to determine the sine/cosine/tangent of an angle

[sin⁻¹] [cos⁻¹] [tan⁻¹]	If the sin/cos/tan of an angle is given, use the appropriate key to determine the angle
[log]	Use this key if the calculation involves logarithm to the base 10
[10^x]	This key is used to calculate antilogarithms, i.e. the reverse of log
[EXP]	Use this key to raise 10 to the power of a given number
[$a\frac{b}{c}$]	Use this key to perform calculations involving fractions
[M+]	This key is used to input values into memory
[%]	Press this key to express the answer as a percentage
[°,,,]	This key is used to convert an angle into degrees, minutes and seconds
[(] [)]	These keys will insert brackets in the calculations involving complicated formulae.
[DEL]	Press this key to delete the number at the current cursor position

Example 1.1

Calculate 37.80 – 40.12 + 31.55

Solution:

The sequence of pressing the calculator's keys is:

[3] [7] [.] [8] [0] [–] [4] [0] [.] [1] [2] [+]

[3] [1] [.] [5] [5] [=] **29.23**

Example 1.2

Calculate $\frac{34.9 \times 57.3}{41.66}$

Solution:

The sequence of inputting the information into your calculator is:

[3] [4] [.] [9] [×] [5] [7] [.] [3] [÷] [4] [1] [.] [6]

[6] [=] **48.0**

Example 1.3

Calculate $\frac{87.3 \times 67.81}{23.97 \times 40.5}$

Solution:

This question can be solved in two ways. The calculator operations are:

(1) 87.3 × 67.81 ÷ 23.97 ÷ 40.5

8	7	.	3	×	6	7	.	8	1	÷	2	3	.

9	7	÷	4	0	.	5	=	**6.098**

(2) 87.3 × 67.81 ÷ (23.97 × 40.5). In this method it is important to put 23.97 × 40.5 within brackets. Failure to do so will result in the wrong answer.

8	7	.	3	×	6	7	.	8	1	÷	(	2	3

.	9	7	×	4	0	.	5	)	=	**6.098**

Example 1.4

Calculate √4.5 × √5.5 + √3.4

Solution:

The calculator operation is shown below:

√	4	.	5	×	√	5	.	5	+	√	3	.	4

=	**6.819**

Example 1.5

Calculate the value of πr^2 if $r = 2.25$

Solution:

The calculator operation is:

π	×	2	.	2	5	x^2	=	**15.904**

Example 1.6

Find the value of (2.2 × 4.8) + (5.2 × 3)

Solution:

The sequence of calculator operation is:

(	2	.	2	×	4	.	8	)	+	(	5	.	2

×	3	)	=	**26.16**

Example 1.7

Evaluate $\dfrac{6^3 \times 4^4}{2^5}$

Solution:

In this question the [^] key will be used to raise a number to any power.
Press the following keys in the same sequence as shown:

[6] [^] [3] [×] [4] [^] [4] [÷] [2] [^] [5] [=] **1728**

Example 1.8

Calculate $10 \log_{10} \left(\frac{4 \times 10^{-7}}{2 \times 10^{-12}} \right)$

Solution:

The [EXP] key will be used to raise 10 to any power, as shown:

[1] [0] [LOG] [(] [4] [EXP] [+/–] [7] [÷] [2] [EXP] [+/–]
[1] [2] [)] [=] **53.01**

Example 1.9

Calculate $\frac{\sin 60^\circ}{\cos 60^\circ}$

Solution:

The calculator must show D in the display area. If the calculator displays R or G then use the [MODE] key or the [SETUP] key to change the angle unit to degrees, and press the following keys:

[sin] [6] [0] [÷] [cos] [6] [0] [=] **1.732**

Example 1.10

Find the angle if: (a) the sine of an angle is 0.6
(b) the cosine of an angle is 0.45
(c) the tangent of an angle is 0.36

Solution:

Use the [MODE] key or the [SETUP] key to change the angle unit to degrees. As this question involves the determination of angles, the process is the reverse of that used in Example 1.9. Instead of sin, cos or tan keys, use $\sin^{-1}$, $\cos^{-1}$ and $\tan^{-1}$.

(a) Use the following sequence to determine the angle as a decimal number first, and then change to the sexagesimal system (i.e. degrees, minutes and seconds)

[SHIFT] [sin] [0] [.] [6] [=] 36.8699° [°’”] **36°52′11.6″**

(b) [SHIFT] [cos] [0] [.] [4] [5] [=] 63.2563° [°’”] **63°15′22.7″**

(c) [SHIFT] [tan] [0] [.] [3] [6] [=] 19.7989° [°’”] **19°47′56″**

Exercise 1.1

The solutions to Exercise 1.1 can be found in Appendix 2.

1. Calculate $37.85 - 40.62 + 31.85 - 9.67$.
2. Calculate $\dfrac{33.9 \times 56.3}{45.66}$.
3. Calculate $\dfrac{67.3 \times 69.81}{25.97 \times 20.5}$.
4. Calculate $\sqrt{4.9} \times \sqrt{8.5} + \sqrt{7.4}$.
5. Calculate the value of πr^2 if $r = 12.25$.
6. Find the value of: (a) $(2.2 \times 9.8) + (5.2 \times 6.3)$
   (b) $(4.66 \times 12.8) - (7.5 \times 5.95)$
   (c) $(4.6 \times 10.8) \div (7.3 \times 5.5)$.
7. Evaluate: (a) $\dfrac{5^3 \times 3^4}{2^5}$.
   (b) $\dfrac{4^3 \times 6^3}{5^4}$.
8. Calculate $10 \log_{10} \left(\dfrac{9 \times 10^{-8}}{2 \times 10^{-11}} \right)$.
9. Calculate: (a) $\dfrac{\sin 70^\circ}{\cos 60^\circ}$
   (b) $\dfrac{\tan 45^\circ}{\cos 35^\circ}$.
10. Find the angle if: (a) the sine of an angle is 0.85
    (b) the cosine of an angle is 0.75
    (c) the tangent of an angle is 0.66.
11. Calculate the values of: (a) sin 62°42′35″
    (b) cos 32°22′35″
    (c) tan 85°10′20″.

Answers to Exercise 1.1

1. 19.41
2. 41.8
3. 8.83
4. 9.17
5. 471.44

6. (a) 54.32 (b) 15.02 (c) 1.24
7. (a) 316.41 (b) 22.12
8. 36.53
9. (a) 1.879 (b) 1.221
10. (a) 58°12′42″ (b) 41°24′34.64″ (c) 33°25′29.32″
11. (a) 0.8887 (b) 0.8445 (c) 11.8398

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CHAPTER 2

Numbers

Learning outcomes:

(a) Identify positive numbers, negative numbers, integers and decimal numbers

(b) Perform calculations involving addition, subtraction, multiplication and division

(c) Use order of operations (BODMAS) to perform calculations

2.1 Introduction

Mathematics involves the use of numbers in all of its branches like algebra, geometry, statistics, mechanics and calculus. The use of numbers also extends to other subjects like estimating, surveying, construction science and structural mechanics. As we shall be dealing with numbers in all sections of this book, it is appropriate to deal with the different types of numbers at this stage.

2.2 History of numbers

In early civilisations different types of counting systems were used in business and other fields. It all started with the use of lines, which later developed into alphabets (Rome, Greece), symbols (Babylon), hieroglyphics (Egypt), pictorials (China) and lines and symbols (India). The Roman numerals (I, V, X, L, C, D and M), although widely used in commerce and architecture had two major flaws. First, there was no zero; and second, for large numbers different types of systems were used.

Indian-Arab numerals, the forebears of modern numbers, were used in India more than 2500 years ago. Originally there were nine symbols to represent 1–9 and special symbols were used for tens, hundreds and thousands. It appears that the Indians later introduced zero in the form of a dot (to represent nothing), which they either borrowed from other systems or invented themselves. The credit for