Wyvern College

GCSE

MATHS

Knowledge Organisers

Pearson Edexcel 1MA1
Higher Tier

THINK. GROW. CARE.

THIS BOOK BELONGS TO

Make it yours.

Name _____

Tutor group _____

Maths teacher _____

My current focus _____

START HERE

Course and exams	3
Understand memory	4
Retrieve, space, interleave	5–8
Try a practical strategy	6, 9–10
Support at home	11
Plan your reviews	12
Track your progress	13

A few focused minutes. An honest check. A return visit.
Keep making the knowledge yours.

Make your revision count.

A welcome from Mr Rule

Dear students, parents and carers,

Year 11 is a busy time. You may be attending revision sessions, reading revision guides, highlighting pages, copying notes or making cue cards. These activities can help you understand ideas, organise information or improve your examination technique.

However, there is an important danger: they can make knowledge feel familiar without making it retrievable.

When your teacher is explaining something, or an answer is visible on the page, you may think, “Yes, I know this.” But recognising knowledge in front of you is not the same as retrieving it when it is not.

In an examination, your notes, revision guide and teacher will not be there to prompt you. You will need to retrieve what you have learned from your long-term memory.

Simply reading, highlighting or copying does not reliably make knowledge retrievable. Even making excellent cue cards creates a revision resource; it does not necessarily mean you have learned what is written on them.

Your teachers have selected the key information you need and organised it into these knowledge organisers. You do not need to spend hours reproducing them. Use your time to learn the knowledge they contain.

Follow the Look, Cover, Write, Check guidance on page 6: read and understand a small section, cover the answers, write what you can recall, then check and correct it. Practise this regularly.

It is perfectly natural not to remember everything on your first attempt. Some struggle is a normal part of learning; it shows you what to practise next. Ask for help if an idea does not make sense.

Learning research supports revisiting knowledge with gaps between attempts. Plan four or five reviews of each small set on different days as a starting routine, using the revision plan on page 12. Some knowledge needs more practice: check, correct and keep returning over time.

Use the red, amber and green tracker on page 13 to evaluate your topics. Focus first on your red topics, where recall is hardest. Revisit amber topics too, and check green ones after a longer gap.

Mr Rule | Headteacher

When you put this booklet aside, can you still remember what was on the page?

That is the difference between knowledge that feels familiar and knowledge that you can use in your examinations.

Find your way.

Use the printed page numbers to find a unit, choose a small set and start revising.

H01 Number and exact calculation	14
H02 Algebra and sequences	21
H03 Fractions, percentages and ratio	25
H04 Data and correlation	29
H05 Angles and right triangles	33
H06 Coordinates and graph families	39
H07 Measures and bounds	43
H08 Transformations and constructions	54
H09 Equations and inequalities	61
H10 Probability	65
H11 Multiplicative change and rates	68
H12 Congruence and similarity	70
H13 Further trigonometry	73
H14 Sampling and distributions	76
H15 Further quadratics and functions	78
H16 Circle reasoning	81
H17 Further algebra and proof	86
H18 Vectors and geometry proofs	87
H19 Non-linear graphs and proportion	89

LEARNING GUIDE

Welcome 1 · Course and exams 3 · Memory 4
Retrieval 5 · Look, Cover, Write, Check 6 · Spacing 7
Interleaving 8 · Blank-page recall 9 · Focus 10
Parents 11 · Revision plan 12 · Unit review tracker 13

REFERENCE

Learning research 91

Your course. Your exams.

Pearson Edexcel GCSE (9–1) Mathematics, qualification code 1MA1.

PAPER 1

Non-calculator

1 hour 30 minutes
80 marks
One third of the qualification

PAPER 2

Calculator allowed

1 hour 30 minutes
80 marks
One third of the qualification

PAPER 3

Calculator allowed

1 hour 30 minutes
80 marks
One third of the qualification

One tier for all three papers.

Foundation assesses grades 1–5. Higher assesses grades 4–9, with grade 3 available in defined circumstances. Your school confirms your tier of entry. All three papers must be at the same tier.

Expect a mix of mathematics.

Number; algebra; ratio, proportion and rates of change; geometry and measures; probability; statistics. Topics can appear across the papers, including in unfamiliar contexts.

Bring a black pen, pencil, ruler, a pair of compasses, a protractor (angle measurer) and a scientific calculator for Papers 2 and 3. Paper 1 is non-calculator. Use your personal exam timetable for dates and follow the paper instructions and your teacher's guidance about the formula sheet.

Pearson Edexcel 1MA1 specification

Make room for bigger thinking.

Understanding, retrieval and spaced returns help you build knowledge you can use.

PAY ATTENTION

Read, listen and make sense of the idea first.

→

WORKING MEMORY

The small amount of information you can hold and work with right now.

Learn →

← Retrieve

LONG-TERM MEMORY

Knowledge you can bring back and connect to new ideas.

Retrieval helps strengthen long-term memory.

Hide the answer and bring it to mind. Check and correct your attempt, then return on another day. This is part of learning, not just a way to test whether you already know it.

Keep the load manageable.

Choose a small set of related items. Understand them, then use Look, Cover, Write, Check. A gap tells you what to practise next.

Knowledge frees room for thinking.

When facts are secure, you can give more attention to explaining, connecting ideas and choosing an approach.

You cannot join the dots until you have the dots.

Build accurate knowledge through retrieval, feedback and spaced returns, then practise using it in new questions.

Research: see the learning research references at the end of this book.

Make your revision stick.

Retrieval practice means bringing knowledge to mind before checking. It is one of the most effective ways to build lasting learning.

HIGHLY EFFECTIVE

Retrieval practice

Cover, write and check; blank-page recall; a friend quizzing you with the answers hidden.

Trying to remember, checking and correcting strengthens later recall. Repeat after gaps to help knowledge last.

LESS EFFECTIVE ON THEIR OWN

Rereading, highlighting and copying

These can help you understand or organise a topic, but looking at an answer can make it feel familiar without showing that you can recall it.

Use them to get ready. Then close or cover the material and test yourself.

This book is built for retrieval.

The prompt-and-answer tables let you cover one column, recall the missing information, then uncover it to check. Turn each row into a question for yourself.

CHOOSE	RECALL	CHECK	RETURN
A few taught items	Answer from memory	Correct the gaps	Try again after a gap

Remember it. Understand it. Use it.

Build on recall by explaining why, making connections and practising varied questions.

Research notes: 2, 3, 4, 9 / see page 91

Look. Cover. Write. Check.

A plain sheet of paper turns the organiser into a quiz. Write your answers in an exercise book or on a whiteboard.

PROMPT	ANSWER
Prime number	PLAIN PAPER Answers hidden. Now retrieve them.
Factor	
Multiple	

For diagram items, cover the picture or labels and redraw the idea on separate paper.

1. **LOOK: read and understand**
   Choose a few related rows. Ask about anything that does not make sense.

2. **COVER: hide the answer**
   Leave the prompt visible. Keep the answer out of sight.

3. **WRITE: retrieve from memory**
   Write or draw the answer without peeking. Commit to your attempt.

4. **CHECK: correct precisely**
   Compare with the organiser. Correct errors and missing details in another colour. Retry after a gap.

Check meaning, not just a tick.

Accurate formulae, vocabulary and diagrams matter. Use the organiser for the complete answer, then test again later without looking.

Come back before it fades.

One study session is not a reliable route to lasting learning. Return on different days and retrieve again.

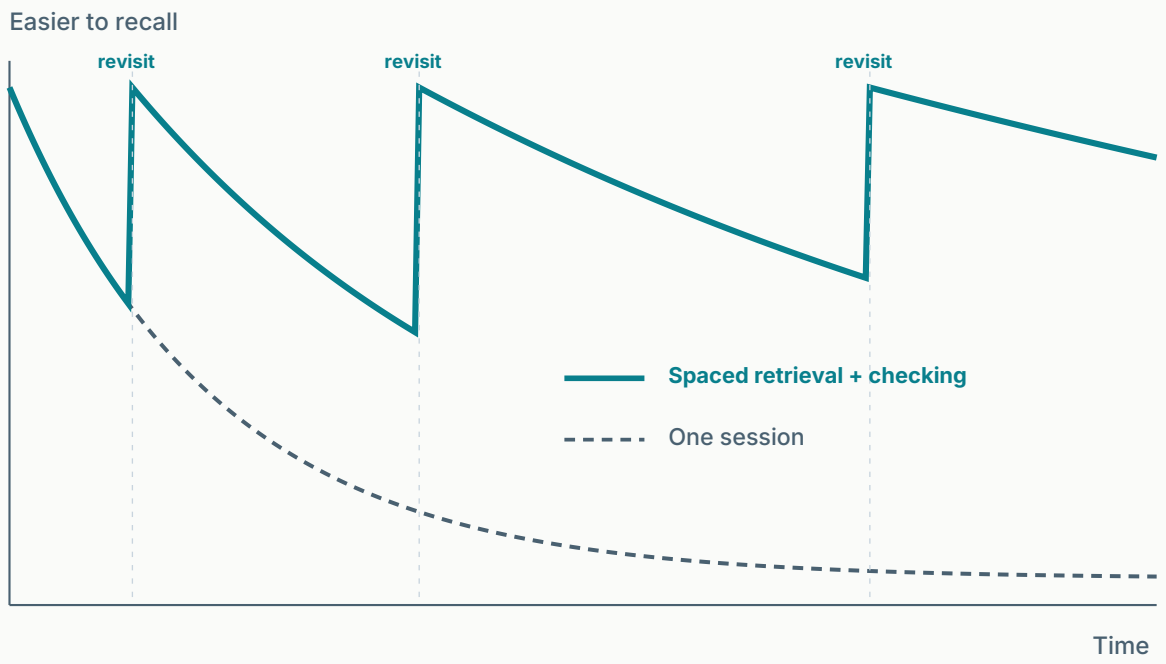


Illustration only: the curves show an idea, not measured scores or a fixed prediction for your memory.

A starting plan

Plan at least 3–5 meaningful, spaced retrieval sessions as a starting routine. Then return again.

Meaningful means: attempt with the answer hidden, check, correct and retry after a gap. Adapt the next gap to what you can recall.

Use your teacher's timetable and the date of your assessment to plan reviews.

A practical starting routine, not a scientific threshold.

Three to five sessions do not guarantee learning. Return again and adapt: revisit weak answers sooner; check secure knowledge after longer gaps.

Research notes: 2, 5 / see page 91

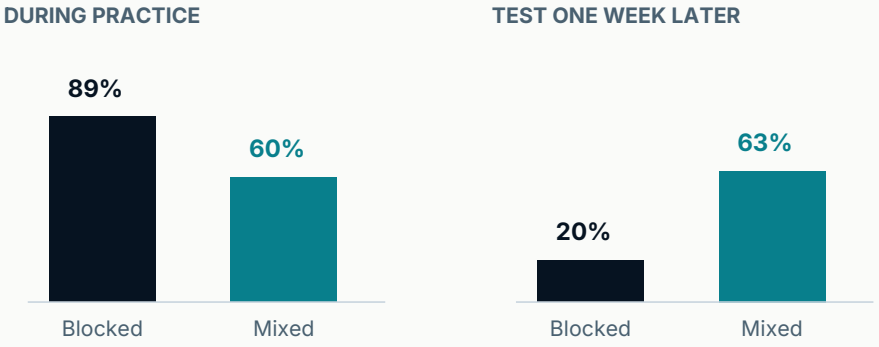
Mix questions. Choose what you know.

Interleaving means alternating between related topics or question types, instead of finishing all of one before another.

BLOCKED	A	A	A	B	B	B	C	C	C
MIXED	A	B	C	B	C	A	C	A	B

A, B and C = small sets from three related tables you have already learned.

Easier now does not always mean stronger later.



University students solving maths problems: average accuracy. This study compared practice with a later test; these are not predicted GCSE scores.

Try it with this booklet.

Choose a few items from table A. Cover, recall and check. Move to table B, then C. Return to A with the answers hidden, and vary the order next time.

Do not just reread the same table repeatedly. Mixing means you have to recognise which knowledge fits each prompt. Start with taught material and keep the sets small.

A: fraction facts · B: percentages · C: ratio

Mix within a session; space your returns across days.

A → B → C → A is mixing. Coming back tomorrow and next week is spacing. Keep both in your revision plan.

Rohrer & Taylor (2007), Experiment 2, Figure 4. DOI: 10.1007/s11251-007-9015-8

Start with a blank page.

Put the organiser away. Recall the detail: definitions, facts, quotations, formulae and labelled sketches.

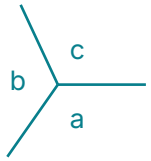
ANGLE FACTS

Parallel lines

Corresponding angles are equal.
Alternate angles are equal.
Co-interior angles add up to 180°.

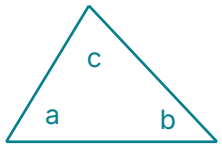
Angles around a point

Angles around a point add up to 360°.
a + b + c = 360°



Triangles

Angles in a triangle add up to 180°.
a + b + c = 180°



Special triangles

Base angles in an isosceles triangle are equal.
All angles in an equilateral triangle are 60°.

Go beyond the headings. Then check the detail.

Add precise facts beneath each branch. Uncover the organiser, correct gaps in another colour, then retrieve the missing details again after a gap.

A worked model of the level of detail to aim for, not a complete list of everything in this topic.

Make starting feel manageable.

Choose a short, specific task and protect time for it. A timer can help you organise the session.

2 min

CHOOSE

Pick your topic and a small set of items.

12 min

RETRIEVE

Cover, quiz, write or draw without looking.

4 min

CHECK

Correct gaps and practise a hard item.

2 min

PLAN

Record the next review and pack away.

Pomodoro is a timing tool.

You might try 25 minutes of focused work followed by a 5-minute break. Or begin with 10 minutes. The interval is adjustable; the learning comes from what you do during it.

Build a routine you can keep.

Have the book, paper and equipment ready. Put your phone away. Take a break and protect time for rest. Follow your teacher's homework priorities rather than adding an unmanageable workload.

A useful daily habit starts small.

"I will retrieve six angle facts after tea" is easier to start than "I will revise Maths". Daily contact can involve different topics.

You do not need to be a subject expert.

Parents, carers and study partners can help by making practice calm, regular and easy to start.

A five-minute quiz

Agree a few rows and keep the answers where only you can see them. Read the prompt. Give thinking time. Ask the student to explain or draw. Compare the answer with the book.

Helpful things to say

“What do you remember before we look?”
“Which part is missing?”
“How could you explain that?”
“When will you come back to it?”

Respond to gaps calmly.

Let the student try before offering a clue. If needed, read the relevant line together, cover it and try a smaller question. Praise the correction and the habit of returning to it.

Help make a workable routine.

Build a realistic revision plan together. Choose small topic or item sets, schedule return dates and protect manageable study time. Fit it around lessons, homework and rest. Quiz kindly with answers hidden.

Confidence can follow practice.

Forgetting during a quiz does not mean the session has failed. Finding a gap and learning how to repair it is useful progress.

Make a rolling revision plan.

Begin with material already taught and understood. Keep each set small; build a routine you can repeat.

EACH STUDY DAY	CHOOSE A SMALL SET	RETRIEVE, THEN CHECK
New / taught set	A few understood rows, when ready	Look, Cover, Write, Check
Yesterday's set	Items introduced on the previous day	Cover, write and check
Last week's set	Items due from about seven days ago	Blank-page recall
An older set	Items due from two to four weeks ago	Blank-page recall

Schedule every new set's returns.

Example: day 0 → 1 → 3 → 7 → 14 → 28.
Day 0 is the first session. These are elapsed days, not weekdays.
Write the actual future dates beside the item codes.

Keep the plan realistic and flexible.

Use short attempts from each set due today. Hide answers, check and correct. Bring weak sets back sooner. A missed day means reschedule; it does not mean start everything again.

A starting schedule, not a universal optimum.

Plan several future returns for every new set, then adapt to recall. Only add new material that is taught and understood; protect time for homework, rest and later reviews.

See your progress. Choose your next focus.

Use recall attempts, assessment results and teacher feedback to rate each unit.

R / RED
Need help or cannot recall yet.

A / AMBER
Some secure; gaps remain.

G / GREEN
Recall accurately after a gap.

Date each review. Colour each box or write R, A or G. Leave unstudied units blank.

UNIT / TOPIC	PAGE	1	2	3	4	5	6	7	8	9	10
REVIEW DATE (day / month)		__/__	__/__	__/__	__/__	__/__	__/__	__/__	__/__	__/__	__/__
H01 Number and exact calculation	14										
H02 Algebra and sequences	21										
H03 Fractions, percentages and ratio	25										
H04 Data and correlation	29										
H05 Angles and right triangles	33										
H06 Coordinates and graph families	39										
H07 Measures and bounds	43										
H08 Transformations and constructions	54										
H09 Equations and inequalities	61										
H10 Probability	65										
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H12 Congruence and similarity	70										
H13 Further trigonometry	73										
H14 Sampling and distributions	76										
H15 Further quadratics and functions	78										
H16 Circle reasoning	81										
H17 Further algebra and proof	86										
H18 Vectors and geometry proofs	87										
H19 Non-linear graphs and proportion	89										

Start with red and amber items; note their codes in your revision plan (page 12). Recheck green units after a gap.

H01 | Number and exact calculation

Edexcel 1MA1 | Higher Tier | Prompt + Recall Answer | Unit Page 1 of 7

MY RETRIEVAL PRACTICE

R	A	G	Home	School	Date	R	A	G	Home	School	Date
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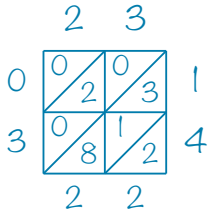
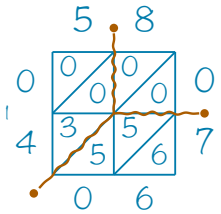
Number and notation

H01.01 **Integer**	A whole number, positive, negative or zero.
H01.02 **Place value**	A digit's value depends on its position. Each place is ten times the place to its right. Hundred thousands, Ten thousands, Thousands, Hundreds, Tens, Units . Tenths, Hundredths, Thousandths Decimal point
H01.03 **Decimal point**	Separates the units from the tenths.
H01.04 **Ascending order**	Smallest to largest.
H01.05 **Descending order**	Largest to smallest.

Number and notation

H01.06 **Negative number**	A number less than zero. – 0 +
H01.07 **Order of operations**	Use BIDMAS in the order shown. On each shared line, work from left to right. First **B** Brackets **I** Indices (powers and roots) **D M** Division or multiplication **A S** Addition or subtraction Last E.g. $25 - 18 \div 3$ $= 25 - 6$ $= 19$ Division before subtraction.

Four operations

H01.08 **Multiplication**	Use lattice (gelosia) multiplication. In a lattice, split each cell into tens and ones; add diagonally from the bottom right, carrying when needed. For decimals, place the decimal point using the total number of decimal places in the factors. 23×14  $23 \times 14 = 322$ Add along diagonals from bottom right. 5.8×0.7  Follow the decimal points to place the answer's decimal. $5.8 \times 0.7 = 4.06$

H01 | Number and exact calculation

MY RETRIEVAL PRACTICE

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☐	☐	☐	☐	☐		☐	☐	☐	☐	☐	

Four operations

H01.09
Division

Use short division: divide from left to right, carrying each remainder to the next digit. The explanation below is what to think; the short-division layout is what to write. Keep decimal points aligned. For a decimal divisor, multiply both numbers by the same power of 10 first.

846 ÷ 3

```
    2 8 2
3 | 8²4 6
```

8.46 ÷ 3

```
    2 . 8 2
3 | 8 . ²4 6
```

For 846 ÷ 3, think:
8 ÷ 3 = 2 remainder 2.
Carry the 2; next divide 24 by 3.

You do not need to write these sentences.

Four operations

H01.10
Addition

Use column addition. Align place values and decimal points; add from right to left and carry to the next column when needed. Use zeros to fill empty decimal places.

268 + 157

```
  1 1
  2 6 8
+ 1 5 7
  4 2 5
```

12.7 + 3.86

```
  1
  1 2 . 7 0
+   3 . 8 6
  1 6 . 5 6
```

Four operations

H01.11
Subtraction

Use column subtraction. Align place values and decimal places; subtract from right to left, exchanging from the next column when needed. Use zeros to fill empty decimal places.

402 - 178

```
  3 9 12
  4 0 2
- 1 7 8
  2 2 4
```

6.2 - 1.47

```
  5   11 10
  6 . 2 0
- 1 . 4 7
  4 . 7 3
```

Signed number rules

H01.12
Positive times positive

+ve × +ve = +ve.
Positive answer: $a \times b = ab$.
E.g. $3 \times 4 = 12$

H01.13
Negative times negative

-ve × -ve = +ve.
Positive answer: $(-a) \times (-b) = ab$.
E.g. $(-3) \times (-4) = 12$

H01 | Number and exact calculation

MY RETRIEVAL PRACTICE

R	A	G	Home	School	Date	R	A	G	Home	School	Date
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☐	☐	☐	☐	☐		☐	☐	☐	☐	☐	

Signed number rules

H01.14 **Negative times positive**	-ve × +ve = -ve. Negative answer: $(-a) \times b = -ab$. E.g. $(-3) \times 4 = -12$
H01.15 **Positive times negative**	+ve × -ve = -ve. Negative answer: $a \times (-b) = -ab$. E.g. $3 \times (-4) = -12$
H01.16 **Adding a negative**	Adding A Negative Is The Same As Subtracting A Positive. $a + (-b) = a - b$. E.g. $-5 + (-3) = -5 - 3 = -8$
H01.17 **Subtracting a negative**	Subtracting A Negative Is The Same As Adding A Positive. $a - (-b) = a + b$. E.g. $4 - (-3) = 4 + 3 = 7$
H01.18 **Square of a negative**	Positive answer: $(-a)^2 = a^2$. E.g. $(-5)^2$ $= (-5) \times (-5) = 25$
H01.19 **Cube of a negative**	Negative answer: $(-a)^3 = -a^3$. E.g. $(-2)^3$ $= (-2) \times (-2) \times (-2)$ $= -8$
H01.20 **Even powers of negatives**	Positive answer: an even positive integer power of a negative number is positive. E.g. $(-2)^4$ $= (-2) \times (-2)$ $\times (-2) \times (-2)$ $= 16$ (positive).

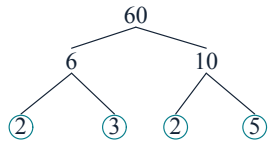
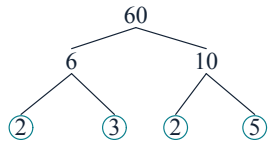
Signed number rules

H01.21 **Odd powers of negatives**	Negative answer: an odd positive integer power of a negative number is negative. E.g. $(-2)^5$ $= (-2) \times (-2) \times (-2) \times (-2) \times (-2)$ $= -32$ (negative).

Factors and prime factorisation

H01.22 **Factor**	An integer that divides another integer exactly. E.g. factors of 12: 1, 2, 3, 4, 6, 12.
H01.23 **Multiple**	The result of multiplying a number by an integer. E.g. positive multiples of 7: 7, 14, 21, 28, 35, ...
H01.24 **Prime number**	A positive integer with exactly two positive factors: 1 and itself.
H01.25 **The number 1**	Neither prime nor composite.
H01.26 **Composite number**	A positive integer greater than 1 with more than two factors. It can be written as a product of two or more prime factors. $12 = 2 \times 2 \times 3$, so 12 is composite.
H01.27 **Prime factorisation**	An integer written as a product of prime factors.

Factors and prime factorisation

H01.28 **Prime factor tree**	Split each non-prime number into two factors. Continue until every branch ends in a prime; circle the primes. 
H01.29 **Product of prime factors**	Multiply all the circled primes at the ends of the factor tree. Repeated primes can be written using powers.  $60 = 2 \times 2 \times 3 \times 5$ $60 = 2^2 \times 3 \times 5$

HCF and LCM

H01.30 **Highest common factor**	The greatest positive integer that is a factor of each given integer. Factors of 12 = 1, 2, 3, 4, 6, 12. Factors of 14 = 1, 2, 7, 14. Highest common factor = 2

H01 | Number and exact calculation

MY RETRIEVAL PRACTICE

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HCF and LCM

H01.31 Lowest common multiple

The least positive integer that is a multiple of each given positive integer.

Multiples of 12 =

12, 24, 36, 48, 60, 72, 84

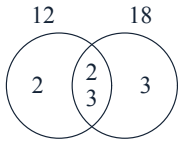
Multiples of 14 =

14, 28, 42, 56, 70, 84

Lowest common multiple = 84

H01.32 Prime factors in a Venn diagram

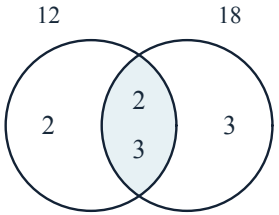
Use one circle per number. Put matching prime factors in the overlap, one occurrence per matched pair. Put remaining factors in the correct outer region.



HCF and LCM

H01.33 HCF from a Venn diagram

Multiply the prime factors in the shaded intersection. If it is empty, the HCF is 1.

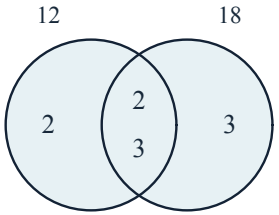


HCF: shaded overlap

HCF of 12 and 18
$= 2 \times 3 = 6$

H01.34 LCM from a Venn diagram

Multiply all the prime factors inside the shaded circles, counting each factor in the intersection once.



LCM: both shaded circles

LCM of 12 and 18
$= 2 \times 2 \times 3 \times 3 = 36$

HCF and LCM

H01.35 HCF from prime powers

The product of common prime factors, each to the lowest power present in all the numbers.

E.g. 72 and 180

$72 = 2^3 \times 3^2$

$180 = 2^2 \times 3^2 \times 5$

Lowest common powers

HCF

$= 2^2 \times 3^2 = 36$

H01.36 LCM from prime powers

The product of every prime factor present, each to the highest power present.

E.g. 72 and 180

$72 = 2^3 \times 3^2$

$180 = 2^2 \times 3^2 \times 5$

Highest power of each prime

LCM

$= 2^3 \times 3^2 \times 5 = 360$

H01 | Number and exact calculation

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Powers and roots

H01.37 **Square number**	An integer multiplied by itself: n^2. $5^2 = 5 \times 5 = 25$
H01.38 **Cube number**	An integer multiplied by itself twice: n^3. $3^3 = 3 \times 3 \times 3 = 27$
H01.39 **Square root**	A number whose square equals the given number. $\sqrt{a}$ denotes the non-negative root. $\sqrt{49} = 7$ because $7^2 = 49$.
H01.40 **Cube root**	A number whose cube equals the given number. $\sqrt[3]{125} = 5$ because $5^3 = 125$.
H01.41 **Reciprocal**	Flip a non-zero fraction: the reciprocal of $\frac{a}{b}$ is $\frac{b}{a}$. A number times its reciprocal is 1. For a decimal, write it as a fraction first. Reciprocal of $5 = \frac{5}{1}$ is $\frac{1}{5}$. Reciprocal of $\frac{2}{3}$ is $\frac{3}{2}$. For $0.6 = \frac{3}{5}$, the reciprocal is $\frac{5}{3}$.
H01.42 **Product rule for counting**	For successive independent choices with m and n options, there are mn combinations. E.g. 3 starters and 4 mains: $3 \times 4 = 12$ meal choices.

Index laws

H01.43 **Multiplying powers**	For the same base: $a^m a^n = a^{m+n}$. E.g. $2^3 \times 2^4 = 2^{3+4} = 2^7 = 128$
H01.44 **Dividing powers**	For the same base, subtract the powers: $\frac{a^m}{a^n} = a^{m-n}$. The base a must not be zero. E.g. $\frac{5^6}{5^4} = 5^{6-4} = 5^2 = 25$
H01.45 **Power of a power**	$(a^m)^n = a^{mn}$. E.g. $(3^2)^3 = 3^{2 \times 3} = 3^6 = 729$
H01.46 **Power of a product**	$(ab)^n = a^n b^n$. E.g. $(2 \times 3)^2 = 2^2 \times 3^2 = 4 \times 9 = 36$
H01.47 **Zero power**	For $a \neq 0$: $a^0 = 1$. E.g. $7^0 = 1$
H01.48 **Negative power**	For $a \neq 0$: $a^{-n} = \frac{1}{a^n}$. E.g. $2^{-3} = \frac{1}{2^3} = \frac{1}{8}$
H01.49 **Fractional power**	For positive a: $a^{1/n} = \sqrt[n]{a}$. E.g. $81^{\frac{1}{4}} = \sqrt[4]{81} = 3$

Index laws

H01.50 **General fractional power**	For positive a: $a^{m/n} = (\sqrt[n]{a})^m$. E.g. $27^{\frac{2}{3}} = (\sqrt[3]{27})^2 = 3^2 = 9$

Standard form

H01.51 **Standard form**	$a \times 10^n$, where $1 \leq a < 10$ and n is an integer, for a positive number. E.g. $2.4 \times 10^3 = 2400$
H01.52 **Positive standard form exponent**	The number is at least 10 when $n > 0$. E.g. $5.6 \times 10^4 = 56000$
H01.53 **Negative standard form exponent**	The exponent is negative. The positive number is between 0 and 1. E.g. $3.2 \times 10^{-3} = 0.0032$
H01.54 **Standard form multiplication**	$(a \times 10^m)(b \times 10^n) = ab \times 10^{m+n}$. The coefficient may need normalising. E.g. $(4 \times 10^3)(3 \times 10^5) = 12 \times 10^8 = 1.2 \times 10^9$
H01.55 **Standard form division**	$\frac{a \times 10^m}{b \times 10^n} = \frac{a}{b} \times 10^{m-n}$. E.g. $\frac{3 \times 10^4}{6 \times 10^7} = 0.5 \times 10^{-3} = 5 \times 10^{-4}$

H01 | Number and exact calculation

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Standard form

H01.56 **Adding standard form**	Convert to ordinary numbers, add, then convert the answer back to standard form. E.g. $2.5 \times 10^4 + 3 \times 10^3$ $= 25000 + 3000$ $= 28000 = 2.8 \times 10^4$
H01.57 **Subtracting standard form**	Convert to ordinary numbers, subtract, then convert the answer back to standard form. E.g. $4.2 \times 10^5 - 7 \times 10^4$ $= 420000 - 70000$ $= 350000 = 3.5 \times 10^5$

Accuracy and comparison

H01.58 **Decimal places**	The number of digits after the decimal point. E.g. round 7.386 to 2 d.p. Keep the hundredths digit (8). The next digit is 6, so round up. $7.386 \approx 7.39$.
H01.59 **Significant figures**	Count from the first non-zero digit. Zeros after that digit can be significant. E.g. round 0.004762 to 2 s.f. The first two significant digits are 4 and 7. The next digit is 6. $0.004762 \approx 0.0048$. Whole-number example: 24800 to 2 s.f. Keep 2 and 4; the next digit is 8. $24800 \approx 25000$. The zeros keep the place value.

Accuracy and comparison

H01.60 **Rounding threshold**	A following digit of 5 or more rounds up; less than 5 rounds down. E.g. to 1 decimal place: $6.24 \approx 6.2$ (4 is less than 5). $6.25 \approx 6.3$ (5 rounds up).
H01.61 **Estimate**	An approximate value. To estimate a calculation, typically round the numbers to one significant figure. E.g. estimate $\frac{19.7 \times 4.12}{0.49}$. Round each number to 1 s.f.: $\frac{20 \times 4}{0.5} = \frac{80}{0.5} = 160$.
H01.62 **Not equal**	$a \neq b$ means that a and b have different values.

Exact values and surds

H01.63 **Rational number**	A number expressible as $\frac{a}{b}$, where a,b are integers and $b \neq 0$. E.g. Integer: $-3 = \frac{-3}{1}$ Terminating decimal: $0.75 = \frac{3}{4}$ Recurring decimal: $0.333... = \frac{1}{3}$ Fraction: $\frac{2}{7}$

Exact values and surds

H01.64 **Irrational number**	A real number that cannot be expressed as a ratio of two integers. Its decimal is non-terminating and non-recurring: no fixed block of digits repeats indefinitely. E.g. $\pi = 3.1415926535...$
H01.65 **Surd**	An irrational root left in exact root form. E.g. $\sqrt{2}$ and $3\sqrt{5}$ are surds: the roots are left exact. $\sqrt{9} = 3$ is not a surd.
H01.66 **Product of square roots**	For non-negative numbers: $\sqrt{a}\sqrt{b} = \sqrt{ab}$. E.g. $\sqrt{3}\sqrt{12} = \sqrt{36} = 6$
H01.67 **Quotient of square roots**	$\frac{\sqrt{a}}{\sqrt{b}} = \sqrt{\frac{a}{b}}$. Use real square roots and a non-zero denominator. E.g. $\frac{\sqrt{50}}{\sqrt{2}} = \sqrt{25} = 5$
H01.68 **Like surds**	$p\sqrt{a} + q\sqrt{a} = (p+q)\sqrt{a}$. E.g. $3\sqrt{2} + 5\sqrt{2}$ $= (3+5)\sqrt{2} = 8\sqrt{2}$

H01 | Number and exact calculation

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Exact values and surds

H01.69 **Exact value**	An unrounded value, such as a fraction, surd or multiple of π.
H01.70 **Simplifying a square root surd**	Find the largest square-number factor of the number under the root. Write it as a product, then take the square factor's root outside. E.g. $\sqrt{72} = \sqrt{36 \times 2}$ $= 6\sqrt{2}$ 36 is the largest square factor of 72.
H01.71 **Simplest square root surd**	In $a\sqrt{b}$, the positive integer b has no square-number factor greater than 1. E.g. $\sqrt{32} = \sqrt{4 \times 8} = 2\sqrt{8}$ Not simplest: 8 still has the square factor 4. $\sqrt{32} = \sqrt{16 \times 2} = 4\sqrt{2}$ Simplest: 2 has no square factor greater than 1.
H01.72 **Taking out a square factor**	For $a,b > 0$: $\sqrt{a^2 b} = a\sqrt{b}$. E.g. $\sqrt{5^2 \times 3} = 5\sqrt{3}$

Recall primes

H01.73 **Primes up to 100**	2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, 41, 43, 47, 53, 59, 61, 67, 71, 73, 79, 83, 89, 97.

Recall squares

H01.74	1^2	1
H01.75	2^2	4
H01.76	3^2	9

Recall squares

H01.77	4^2	16
H01.78	5^2	25
H01.79	6^2	36
H01.80	7^2	49
H01.81	8^2	64
H01.82	9^2	81
H01.83	10^2	100

Recall square roots

H01.84	$\sqrt{1}$	1
H01.85	$\sqrt{4}$	2
H01.86	$\sqrt{9}$	3
H01.87	$\sqrt{16}$	4
H01.88	$\sqrt{25}$	5
H01.89	$\sqrt{36}$	6
H01.90	$\sqrt{49}$	7
H01.91	$\sqrt{64}$	8

Recall square roots

H01.92	$\sqrt{81}$	9
H01.93	$\sqrt{100}$	10

Recall cubes

H01.94	1^3	1
H01.95	2^3	8
H01.96	3^3	27
H01.97	4^3	64
H01.98	5^3	125
H01.99	10^3	1000

Recall cube roots

H01.100	$\sqrt[3]{1}$	1
H01.101	$\sqrt[3]{8}$	2
H01.102	$\sqrt[3]{27}$	3
H01.103	$\sqrt[3]{64}$	4
H01.104	$\sqrt[3]{125}$	5
H01.105	$\sqrt[3]{1000}$	10

H02 | Algebra and sequences

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Algebra language

H02.01 **Variable**	A symbol whose value can vary. E.g. in $3x + 5$, x is a variable: its value can change.
H02.02 **Constant**	A fixed value. E.g. in $3x + 5$, 5 is the constant term.
H02.03 **Coefficient**	A numerical factor multiplying a variable or variable term. E.g. in $-4x^2$, the coefficient is -4.
H02.04 **Term**	A single part of an expression separated from other terms by addition or subtraction. E.g. $3x^2 - 2x + 5$ has terms $3x^2$, $-2x$ and 5.
H02.05 **Expression**	A mathematical combination of numbers, variables and operations; it has no equality sign. E.g. $3x + 5$ and $a^2 - 2b$ are expressions.
H02.06 **Equation**	A statement that two expressions are equal. E.g. $3x + 5 = 17$ is an equation.
H02.07 **Identity**	An equality true for every permitted value of its variables. E.g. $2(x + 3) \equiv 2x + 6$ for every x.

Algebra language

H02.08 **Formula**	An equation expressing a relationship between quantities. E.g. $A = lw$ relates a rectangle's area, length and width.
H02.09 **Subject of a formula**	The variable isolated on one side of the equation. E.g. in $y = 3x + 2$, y is the subject.
H02.10 **Changing the subject of a formula**	Isolate the required variable on one side. Undo the operations in reverse order, doing the same operation to both sides. Write the new subject on the left. Make x the subject of $y = 3x + 5$. Subtract 5 from both sides: $y - 5 = 3x$ Divide both sides by 3: $\frac{y-5}{3} = x$ So $x = \frac{y-5}{3}$.
H02.11 **Substitution**	Replacing a variable with a specified value or expression. E.g. $3x^2 + 2$ when $x = -2$: $3(-2)^2 + 2 = 12 + 2 = 14$.

Algebra language

H02.12 **Like terms**	Terms with the same variable part, including the same powers. E.g. $3x$ and $-5x$ are like terms. $3x$ and $3x^2$ are not.
H02.13 **Collecting like terms**	Group like terms with the sign in front of each term. Add or subtract their coefficients. Keep unlike terms separate. $3x + 2y - 4x + 5 - y - 2$ $= (3x - 4x) + (2y - y) + (5 - 2)$ $= -x + y + 3$ $a + a + a = 3a$ But $a \times a \times a = a^3$.
H02.14 **Algebraic product notation**	ab means $a \times b$. E.g. $3x = 3 \times x$.
H02.15 **Algebraic quotient notation**	$\frac{a}{b}$ means $a \div b$, for $b \neq 0$. E.g. $\frac{x}{4} = x \div 4$.

H02 | Algebra and sequences

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Algebra language

H02.16 Algebraic power notation

a^n means multiply n copies of a together, for a positive integer n.

E.g. $a^4 = a \times a \times a \times a$.

Expressions and equations

H02.17 Distributive law

$a(b + c) = ab + ac$.

×	b	c
a	ab	ac

Multiplication grid

$a(b + c)$

$= ab + ac$

E.g. $3(x - 2) = 3x - 6$.

H02.18 Factorising by removing the HCF

Put the highest common factor outside the bracket. Divide each term by it to find the terms inside. Check by expanding.

E.g. $6x^2 + 9x$

HCF of $6x^2$ and $9x$ is $3x$.

$6x^2 + 9x = 3x(2x + 3)$

Check by expanding:

$3x(2x + 3) = 6x^2 + 9x$.

Expressions and equations

H02.19 Two binomials

$(a + b)(c + d) = ac + ad + bc + bd$.

$(x + 2)(x - 3)$

FOIL

First terms

$x \times x = x^2$

Outer terms

$x \times (-3) = -3x$

Inner terms

$2 \times x = 2x$

Last terms

$2 \times (-3) = -6$

Grid

×	x	-3
x	x^2	$-3x$
2	$2x$	-6

Both give the same four products.

$(x + 2)(x - 3)$

$= x^2 - 3x + 2x - 6$

$= x^2 - x - 6$.

Collect the like terms.

Expressions and equations

H02.20 Square of a sum

$(a + b)^2 = a^2 + 2ab + b^2$.

$(x + 3)(x + 3)$

FOIL

First terms

$x \times x = x^2$

Outer terms

$x \times 3 = 3x$

Inner terms

$3 \times x = 3x$

Last terms

$3 \times 3 = 9$

Grid

×	x	3
x	x^2	$3x$
3	$3x$	9

Both give the same four products.

$(x + 3)^2$

$= x^2 + 3x + 3x + 9$

$= x^2 + 6x + 9$.

H02 | Algebra and sequences

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Expressions and equations

H02.21 Square of a difference

$$(a-b)^2 = a^2 - 2ab + b^2.$$

$$(x-4)(x-4)$$

FOIL

First terms

$x \times x = x^2$

Outer terms

$x \times (-4) = -4x$

Inner terms

$(-4) \times x = -4x$

Last terms

$(-4) \times (-4) = 16$

Grid

×	x	-4
x	x^2	$-4x$
-4	$-4x$	16

Both give the same four products.

$(x-4)^2$
$= x^2 - 4x - 4x + 16$
$= x^2 - 8x + 16.$

Expressions and equations

H02.22 Difference of two squares

$$a^2 - b^2 = (a-b)(a+b).$$

E.g. $9x^2 - 25 = (3x-5)(3x+5).$

Sequences

H02.23 Sequence

An ordered list of terms following a rule.

H02.24 Term to term rule

A rule relating one term to another term.

$3 \xrightarrow{+4} 7 \xrightarrow{+4} 11 \xrightarrow{+4} 15$

H02.25 Position to term rule

A rule giving a term from its position n; also called an n-th term rule.

E.g. $u_n = 3n + 2$:
$u_5 = 3(5) + 2 = 17.$

Sequences

H02.26 Arithmetic sequence

A sequence with a constant difference between consecutive terms.

$10 \xrightarrow{-3} 7 \xrightarrow{-3} 4 \xrightarrow{-3} 1$

H02.27 Arithmetic / linear nth term

Find the common difference d. Compare the sequence with the d times table. Add or subtract the constant adjustment to get the nth-term rule.

Compare with the 3 times table

5	8	11	14	17
↑ +2	↑ +2	↑ +2	↑ +2	↑ +2
3	6	9	12	15

Add 2 to every term of 3n

Nth term $= 3n + 2.$

H02 | Algebra and sequences

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Sequences

H02.28 **Geometric sequence**	A sequence with a constant multiplier between consecutive terms. 3 → 6 → 12 → 24 × 2 × 2 × 2
H02.29 **Geometric nth term**	First term a, common ratio r: $u_n = ar^{n-1}$. E.g. first term 3, ratio 2: $u_n = 3 \times 2^{n-1}$ $u_4 = 3 \times 2^3 = 24$.
H02.30 **Quadratic sequence**	Its second differences are constant and non-zero. Terms: 5, 11, 19, 29, 41 First differences: 6, 8, 10, 12 Second differences: 2, 2, 2

Sequences

H02.31 **Quadratic second difference**	For $an^2 + bn + c$, half the constant second difference is a. Subtract an^2 from the sequence, then find the linear nth-term rule of the remainder. Terms: 5, 11, 19, 29, 41 First differences: 6, 8, 10, 12 Second differences: 2, 2, 2 Subtract n² term by term n^2: 1, 4, 9, 16, 25 Remainder: 4, 7, 10, 13, 16 Second difference 2 gives $a = 1$, so the quadratic part is n^2. Remainder: 4, 7, 10, 13, 16. Its difference is 3, so compare with $3n$: 3, 6, 9, 12, 15. Add 1: remainder $3n + 1$. Therefore nth term $= n^2 + 3n + 1$. Alternative: for $an^2 + bn + c$, first term $a + b + c = 5$; first difference $3a + b = 6$; second difference $2a = 2$. So $a = 1$, $b = 3$, $c = 1$.

Sequences

H02.32 **Fibonacci type sequence**	Each new term is the sum of the previous two terms. E.g. start at 2 and 3: 2, 3, 5, 8, 13, ... $2 + 3 = 5$; $3 + 5 = 8$.
H02.33 **Triangular numbers**	The numbers of dots in triangular patterns: 1, 3, 6, 10, 15, ... The nth triangular number is $\frac{n(n+1)}{2}$. 1 3 6 10 15 Add a new row each time

Identity notation

H02.34 **Identity symbol**	≡ means identically equal: the equality holds for every permitted value. E.g. $3(x + 2) \equiv 3x + 6$.

Sequence vocabulary

H02.35 **Finite sequence**	A sequence with a limited number of terms.
H02.36 **Infinite sequence**	A sequence with no final term.

H03 | Fractions, percentages and ratio

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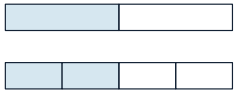
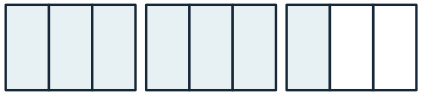
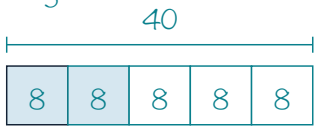
Fraction operations

H03.01 **Numerator**	The top number of a fraction. Numerator ↓ $\frac{a}{b}$
H03.02 **Denominator**	The bottom number of a fraction; it cannot be zero. $\frac{a}{b}$ ↑ Denominator
H03.03 **Equivalent fractions**	Fractions with the same value. $\frac{a}{b} = \frac{ka}{kb}$ for $k \neq 0$.  Same proportion shaded $\frac{1}{2} = \frac{1 \times 2}{2 \times 2} = \frac{2}{4}$.
H03.04 **Simplest form**	Numerator and denominator have no common positive factor greater than 1. E.g. $\frac{18}{24} = \frac{18 \div 6}{24 \div 6} = \frac{3}{4}$.
H03.05 **Proper fraction**	For positive fractions, the numerator is smaller than the denominator. E.g. $\frac{3}{5} < 1$ because $3 < 5$.

Fraction operations

H03.06 **Improper fraction**	For positive fractions, the numerator is at least the denominator. E.g. $\frac{7}{3} > 1$; $\frac{4}{4} = 1$ is also improper.
H03.07 **Mixed number**	A whole-number part plus a proper fraction.  $2\frac{1}{3} = \frac{7}{3}$ E.g. $2\frac{1}{3} = 2 + \frac{1}{3} = \frac{7}{3}$.
H03.08 **Fraction of an amount**	Divide by the denominator (bottom), then multiply by the numerator (top): $\frac{a}{b}$ of Q is $(Q \div b) \times a$. E.g. $\frac{2}{5}$ of 40  One part: $40 \div 5 = 8$. Two parts: $8 \times 2 = 16$.
H03.09 **Adding: common denominator**	With a common non-zero denominator: $\frac{a}{b} + \frac{c}{b} = \frac{a+c}{b}$. E.g. $\frac{2}{7} + \frac{3}{7} = \frac{2+3}{7} = \frac{5}{7}$.

Fraction operations

H03.10 **Adding: different denominators**	Use the LCM of the denominators. Multiply the top and bottom of each fraction by the same number to make this denominator; then add the numerators. E.g. $\frac{1}{3} + \frac{1}{4}$. LCM of 3 and 4 is 12. $\frac{1}{3} = \frac{1 \times 4}{3 \times 4} = \frac{4}{12}$ $\frac{1}{4} = \frac{1 \times 3}{4 \times 3} = \frac{3}{12}$ $\frac{4}{12} + \frac{3}{12} = \frac{7}{12}$.
H03.11 **Subtracting: common denominator**	With a common non-zero denominator: $\frac{a}{b} - \frac{c}{b} = \frac{a-c}{b}$. E.g. $\frac{6}{7} - \frac{2}{7} = \frac{6-2}{7} = \frac{4}{7}$.
H03.12 **Subtracting: different denominators**	Use the LCM of the denominators. Multiply the top and bottom of each fraction by the same number to make this denominator; then subtract the numerators. E.g. $\frac{3}{4} - \frac{1}{6}$. LCM of 4 and 6 is 12. $\frac{3}{4} = \frac{3 \times 3}{4 \times 3} = \frac{9}{12}$ $\frac{1}{6} = \frac{1 \times 2}{6 \times 2} = \frac{2}{12}$ $\frac{9}{12} - \frac{2}{12} = \frac{7}{12}$.
H03.13 **Multiplying fractions**	$\frac{a}{b} \times \frac{c}{d} = \frac{ac}{bd}$, for non-zero denominators. $\frac{2}{3} \times \frac{9}{10} = \frac{18}{30} = \frac{3}{5}$. For mixed numbers, convert first: $1\frac{1}{2} \times 2\frac{1}{3} = \frac{3}{2} \times \frac{7}{3}$ $= \frac{7}{2} = 3\frac{1}{2}$.

Shading identifies the relevant region.

H03 | Fractions, percentages and ratio

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Fraction operations

H03.14 **Dividing fractions**	KFC: Keep the first fraction; Flip the second; Change division to multiplication. $\frac{a}{b} \div \frac{c}{d} = \frac{a}{b} \times \frac{d}{c}$. Denominators and the divisor must not be zero. $\frac{3}{4} \div \frac{2}{5} = \frac{3}{4} \times \frac{5}{2}$ $= \frac{15}{8} = 1\frac{7}{8}$. Convert mixed numbers first: $1\frac{1}{2} \div \frac{3}{4} = \frac{3}{2} \times \frac{4}{3} = 2$.
H03.15 **Fraction as division**	$\frac{a}{b} = a \div b$. The denominator must not be zero. E.g. $\frac{3}{8} = 3 \div 8 = 0.375$.
H03.16 **Terminating decimal**	A decimal with finitely many digits after the decimal point. E.g. $0.125 = \frac{1}{8}$ terminates.
H03.17 **Recurring decimal**	A digit or block of digits repeats forever. Put a dot over a repeating single digit, or over the first and last digits of a repeating block. $0.333... = 0.\dot{3}$ $0.272727... = 0.\dot{2}\dot{7}$ $0.341341... = 0.\dot{3}4\dot{1}$

Fraction operations

H03.18 **Decimal termination test**	A fraction in simplest form terminates exactly when its positive denominator has only prime factors 2 and/or 5. E.g. $\frac{3}{40}$ terminates because $40 = 2^3 \times 5$. $\frac{1}{6}$ recurs: 6 has a factor 3.

Percentage facts

H03.19 **Per cent**	Per hundred: $p\% = \frac{p}{100}$. E.g. $35\% = \frac{35}{100} = \frac{7}{20}$.
H03.20 **Percentage of an amount**	$p\%$ of Q is $\frac{p}{100} \times Q$. E.g. 15% of £80: $\frac{15}{100} \times 80$ $= 15 \div 100 \times 80$ $= 0.15 \times 80 = 12$, so £12.
H03.21 **Finding 50%**	Divide the amount by 2. 50% of £80: $80 \div 2 = 40$, so £40.00.
H03.22 **Finding 25%**	Divide the amount by 4. 25% of £80: $80 \div 4 = 20$, so £20.00.
H03.23 **Finding 20%**	Divide the amount by 5. 20% of £80: $80 \div 5 = 16$, so £16.00.

Percentage facts

H03.24 **Finding 10%**	Divide the amount by 10. 10% of £80: $80 \div 10 = 8$, so £8.00.
H03.25 **Finding 5%**	Divide the amount by 20. 5% of £80: $80 \div 20 = 4$, so £4.00.
H03.26 **Finding 1%**	Divide the amount by 100. 1% of £80: $80 \div 100 = 0.8$, so £0.80.
H03.27 **Percentage as a decimal**	$p\% = p \div 100$. E.g. $7\% = 7 \div 100 = 0.07$.
H03.28 **Increase multiplier**	For an increase of $p\%$: $1 + \frac{p}{100}$. Increase £80 by 15%. $100\% + 15\% = 115\%$ Multiplier $= 115 \div 100 = 1.15$. $80 \times 1.15 = 92$, so £92.
H03.29 **Decrease multiplier**	For a decrease of $p\%$: $1 - \frac{p}{100}$. Decrease £80 by 15%. $100\% - 15\% = 85\%$ Multiplier $= 85 \div 100 = 0.85$. $80 \times 0.85 = 68$, so £68.
H03.30 **Percentage change**	$\frac{\text{change}}{\text{original}} \times 100\%$. State increase or decrease. E.g. £40 increases to £46: $\frac{46 - 40}{40} \times 100\% = 15\%$ increase.
H03.31 **Original amount**	$\text{original} = \frac{\text{final}}{\text{multiplier}}$, for a non-zero multiplier. E.g. £72 after a 20% reduction: Original $= 72 \div 0.8 = 90$, so £90.

H03 | Fractions, percentages and ratio

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Ratios and proportion

H03.32 Ratio

A multiplicative comparison of quantities, written in a stated order.

Red : blue

$6 : 4$

$\div 2$ $\div 2$

$3 : 2$

H03.33 Equivalent ratios

Every part is multiplied or divided by the same non-zero number.

Equivalent ratios

$12 : 18$

$\div 6$ $\div 6$

$2 : 3$

H03.34 Ratio units

Comparable quantities must be expressed in the same units before simplifying their ratio.

2 m : 50 cm = 200 cm : 50 cm

$200 : 50$

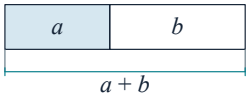
$\div 50$ $\div 50$

$4 : 1$

Ratios and proportion

H03.35 Ratio as a fraction of a whole

For positive ratio $a{:}b$, the first share is $\frac{a}{a+b}$ of the total.

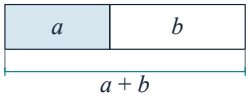


E.g. red : blue = 2:3:

red fraction $= \frac{2}{2+3} = \frac{2}{5}$.

H03.36 Ratio as a fraction of another part

For ratio $a{:}b$, the first quantity divided by the second is $\frac{a}{b}$.



E.g. red : blue = 2:3:

red quantity $= \frac{2}{3}$ of blue quantity.

H03.37 Sharing a total in a ratio

For total T in ratio $a{:}b$, the first share is $\frac{aT}{a+b}$.

E.g. share £35 in ratio 2 : 5

2 parts shaded; 5 unshaded.
One part: 35 ÷ 7 = 5.
Shares: 2 × 5 = 10 and
5 × 5 = 25: £10 and £25.

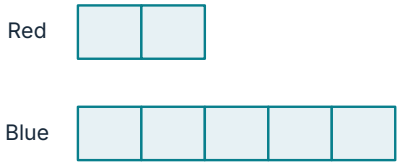
Ratios and proportion

H03.38 Ratio: one share given

Use the known share to find the value of one part. Multiply by the number of parts in the other share.

Red : blue = 2 : 5

Red = 8 counters



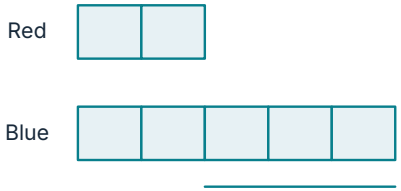
2 parts = 8, so 1 part = 4.
Blue = 5 × 4 = 20 counters.

H03.39 Ratio: difference given

Subtract the numbers of parts. Divide the given difference by that many parts, then work out each share.

Red : blue = 2 : 5

Blue has 12 more counters



Difference: 3 parts = 12

1 part = 12 ÷ 3 = 4.
Red = 8; blue = 20 counters.

Shading identifies the relevant region.

H03 | Fractions, percentages and ratio

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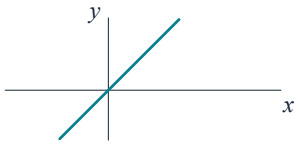
Ratios and proportion

H03.40 **Scale factor**	The multiplier from an original length to the corresponding image length. **Original** **Image** 4 : 10 ÷ 4 ÷ 4 1 : 2.5 Scale factor = 2.5.
H03.41 **Scale drawing**	Lengths in the drawing and real object are in a fixed ratio. **Map (cm)** **Real (m)** 1 : 5 × 3 × 3 3 : 15 3 cm represents 15 m.
H03.42 **Unit ratio**	A ratio with one part equal to 1. 1 : n 6 : 15 ÷ 6 ÷ 6 1 : 2.5 n : 1 6 : 15 ÷ 15 ÷ 15 0.4 : 1

Ratios and proportion

H03.43 **Direct proportion**	One quantity is a constant multiple of the other: $y = kx$. E.g. $y = 3x$. When $x = 4$: $y = 3 \times 4 = 12$.
H03.44 **Direct proportion graph**	A straight line through the origin. 
H03.45 **Direct proportion invariant**	For $x \neq 0$, $\frac{y}{x} = k$ is constant. E.g. $x = 4$, $y = 12$: $k = 12 \div 4 = 3$.
H03.46 **Constant of proportionality**	The constant multiplier k in a proportional relationship. $y = kx$; $y = 15$ when $x = 3$. $15 = k \times 3$ $k = 15 \div 3 = 5$ So $y = 5x$.

Recall equivalents

H03.47 **One half**	$\frac{1}{2} = 0.5 = 50\%$.
H03.48 **One quarter**	$\frac{1}{4} = 0.25 = 25\%$.
H03.49 **Three quarters**	$\frac{3}{4} = 0.75 = 75\%$.
H03.50 **One fifth**	$\frac{1}{5} = 0.2 = 20\%$.
H03.51 **One tenth**	$\frac{1}{10} = 0.1 = 10\%$.
H03.52 **One eighth**	$\frac{1}{8} = 0.125 = 12.5\%$.
H03.53 **One third**	$\frac{1}{3} = 33\frac{1}{3}\%$. Its decimal is 0.333... recurring.

Recurring decimals and currency

H03.54 **Pure recurring decimal**	If a block of k digits represents integer n and repeats immediately after the decimal point, its value is $\frac{n}{10^k - 1}$. E.g. $x = 0.272727...$ $100x = 27.272727...$ $99x = 27$, so $x = \frac{27}{99} = \frac{3}{11}$.
H03.55 **Currency conversion**	The exchange rate is a multiplier between the two currency amounts, for a fixed rate. **Pounds** **Euros** 1 : 1.20 × 50 × 50 50 : 60 Example rate: £1 = €1.20. £50 converts to €60.

H04 | Data and correlation

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Data vocabulary

H04.01 **Categorical data**	Qualitative data recorded as categories or labels, for example colour or type of transport. E.g. eye colour, favourite colour or type of transport.
H04.02 **Discrete data**	Quantitative (numerical) data taking separate, countable values, for example the number of students in a class. E.g. UK shoe sizes or the number of pupils in a class.
H04.03 **Continuous data**	Quantitative (numerical) data that can take any value within an interval. Its precision depends on the measuring instrument. E.g. height, mass or time. A height recorded as 152 cm is rounded to the nearest centimetre; more precise measurement could give 152.4 cm.
H04.04 **Frequency**	The number of times a value or category occurs.
H04.05 **Two way table**	A table classifying data by two variables. Example: one language per pupil.

	French	German	Total
Boys	8	12	20
Girls	14	6	20
Total	**22**	**18**	**40**

Data vocabulary

H04.06 **Class interval**	A range used to group numerical data; boundaries must make membership unambiguous. E.g. $10 < x \le 20$ includes 20 but excludes 10.
H04.07 **Class midpoint**	$\frac{\text{lower boundary} + \text{upper boundary}}{2}$. E.g. class $10 < x \le 20$: Midpoint $= \frac{10+20}{2} = 15$.

Averages and spread

H04.08 **Mean**	Sum of all values divided by the number of values. E.g. data 2, 3, 7: Mean $= \frac{2+3+7}{3} = 4$.
H04.09 **Median**	The middle value of ordered data; with an even count, the mean of the two middle values. E.g. ordered data 2, 4, 7, 9: Median $= \frac{4+7}{2} = 5.5$. For 2, 4, 7, the median is 4.
H04.10 **Mode**	The most frequently occurring value or category. There can be more than one mode. E.g. 2, 3, 3, 5, 5: The modes are 3 and 5.
H04.11 **Range**	Maximum value minus minimum value. E.g. 2, 4, 7, 9: Range $= 9 - 2 = 7$.

Averages and spread

H04.12 **Mean from a frequency table**	Sum of (value × frequency), divided by total frequency. E.g. number of pets

Value x	Freq. f	x × f
1	2	2
2	3	6
3	5	15
Total	10	23

Mean $= \frac{23}{10} = 2.3$ pets.

H04.13 **Estimated grouped mean**	Sum of (class midpoint × frequency), divided by total frequency. E.g. seedling heights h in cm

Height h	Freq. f	Midpoint m	m × f
$0 < h \le 10$	2	5	10
$10 < h \le 20$	5	15	75
$20 < h \le 30$	3	25	75
Total	10	—	160

Estimated mean $= \frac{160}{10} = 16$ cm.

H04 | Data and correlation

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Averages and spread

H04.14 Modal class

The class interval with the greatest frequency.

Height h (cm)	Frequency
$0 < h \leq 10$	3
$10 < h \leq 20$	5
$20 < h \leq 30$	2

Highest frequency 5 → $10 < h \leq 20$

H04.15 Spread

How dispersed the data values are.

H04.16 Mean and extreme values

The mean is affected by extreme values; the median is usually less affected.

E.g. 2, 3, 4 has mean and median 3.
Change 4 to 40: mean 15, median still 3.

H04.17 Comparing distributions

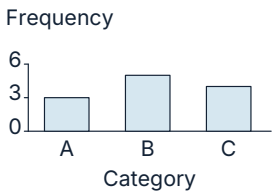
Compare an average, then a measure of spread. State what the comparisons mean in context, using values to support them.

E.g. test scores: Class A median 70, range 12; Class B median 60, range 20.
Class A typically scored higher: its median was 70 compared with 60.
Class A was more consistent: its range was 12 compared with 20.

Charts and correlation

H04.18 Bar chart

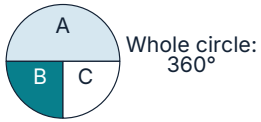
Separate bars compare categories. Their heights or lengths show frequencies.



Charts and correlation

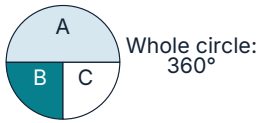
H04.19 Pie chart total

The full circle represents 360° and the entire data set.



H04.20 Pie chart sector angle

$$\frac{\text{frequency}}{\text{total frequency}} \times 360°.$$



E.g. 15 of 60 pupils:
Sector angle $= \frac{15}{60} \times 360° = 90°$.

H04.21 Stem and leaf key

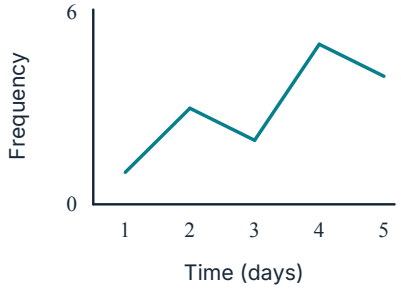
States how a stem and leaf combine to represent one data value.

Stem	Leaves
1	2 5 8
2	0 3 3 7
3	1 4

Key: 2 | 3 means 23

H04.22 Time series graph

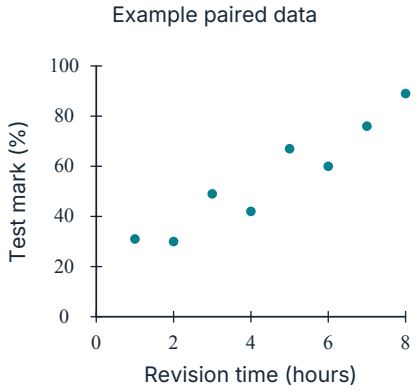
Values plotted against time to show change.



Charts and correlation

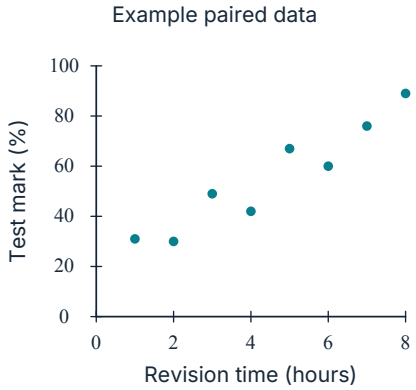
H04.23 Scatter graph

Plots paired numerical data to show a relationship.



H04.24 Positive correlation

As one value goes up, the other usually goes up too.



H04 | Data and correlation

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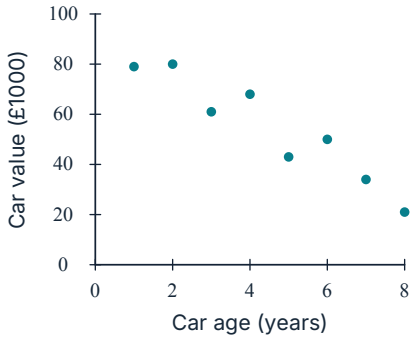
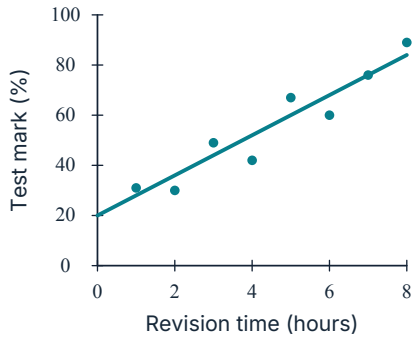
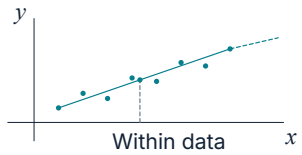
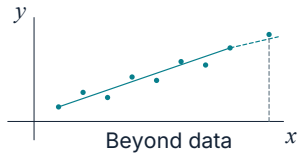
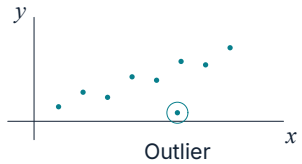
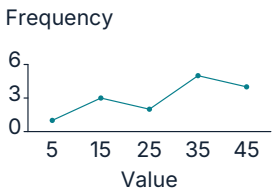
Charts and correlation

H04.25 **Negative correlation**	As one value goes up, the other usually goes down. Example paired data 
H04.26 **No correlation**	There is no clear upward or downward trend in the points. Example paired data

Charts and correlation

H04.27 **Correlation and causation**	Two things changing together does not prove that one causes the other. Another factor may affect both. E.g. hot weather can increase both ice-cream sales and swimming. Buying ice cream does not cause people to swim.
H04.28 **Line of best fit**	Draw a straight line following the overall trend, with roughly as many points above as below it. It does not have to go through the origin. Example paired data 

Charts and correlation

H04.29 **Interpolation**	Estimating within the observed data range. 
H04.30 **Extrapolation**	Estimate outside the range of the collected data. This is less reliable: do not assume the trend continues beyond the data. 
H04.31 **Outlier**	A value unusually far from the overall pattern. 
H04.32 **Frequency polygon**	Points at class midpoints and their frequencies, joined by straight segments. 

H04 | Data and correlation

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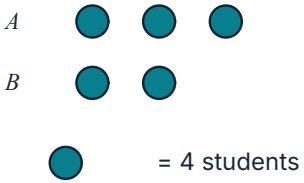
Additional chart types

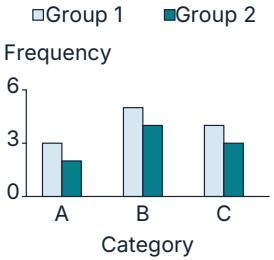
H04.33
Pictogram key

States how many items each picture represents.



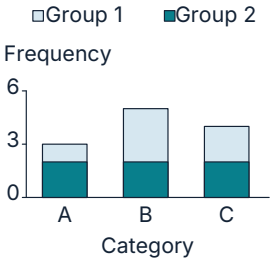
H04.34
Comparative bar chart

Bars for different groups are shown side by side for each category.



H04.35
Composite bar chart

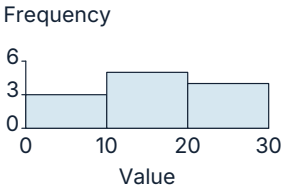
Each bar is divided into sections showing its component groups.



Additional chart types

H04.36
Equal width histogram

When class widths are equal, bar height is proportional to frequency.



Medians from tables

H04.37
Median from a frequency table

Add the frequencies to find the number of values n. For odd n, locate value number $\frac{n+1}{2}$. For even n, average values number $\frac{n}{2}$ and $\frac{n}{2}+1$. Count through the ordered frequencies to locate them.

Value	f	Positions
0	1	1
1	3	2–4
2	4	5–8
3	2	9–10

f = frequency

There are 10 values. The 5th and 6th values are both 2.

Median $= \frac{2+2}{2} = 2$.

Medians from tables

H04.38
Median class from grouped data

Find the middle position or positions, then count through the frequencies to find the interval containing them. Grouped data do not give the exact median. If two middle values fall in different intervals, report that limitation.

Height h	f	Positions
$0 < h \leq 10$	3	1–3
$10 < h \leq 20$	5	4–8
$20 < h \leq 30$	8	9–16
$30 < h \leq 40$	4	17–20

f = frequency

There are 20 values. Positions 10 and 11 are both in $20 < h \leq 30$.
Median class: $20 < h \leq 30$.
The exact median cannot be found.

H05 | Angles and right triangles

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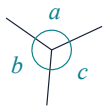
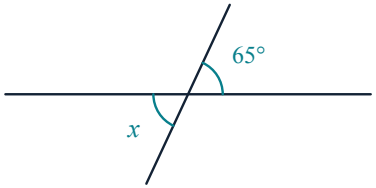
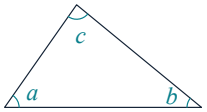
☐	☐	☐	☐	☐		☐	☐	☐	☐	☐	

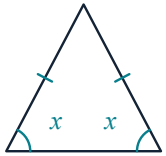
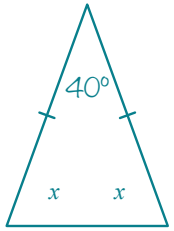
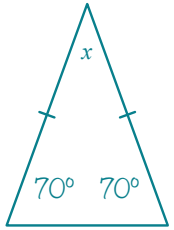
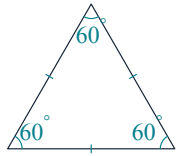
Angles and polygons

H05.01 **Acute angle**	Greater than 0° and less than 90°.
H05.02 **Right angle**	Exactly 90°.
H05.03 **Obtuse angle**	Greater than 90° and less than 180°.
H05.04 **Reflex angle**	Greater than 180° and less than 360°.
H05.05 **Straight line angles**	Angles on a straight line add up to 180°. E.g. adjacent angle 125°: Other angle = 180° − 125° = 55°.

Angles and polygons

H05.06 **Angles at a point**	Angles around a point add up to 360°.  E.g. angles 90°, 140° and x around a point: x = 360° − 90° − 140° = 130°
H05.07 **Vertically opposite angles**	Vertically opposite angles are equal.  x = 65° (vertically opposite angles).
H05.08 **Triangle angle sum**	Angles in a triangle add up to 180°. $a + b + c = 180°$.  E.g. triangle angles 50°, 65° and x: x = 180° − 50° − 65° = 65°.

Angles and polygons

H05.09 **Isosceles triangle**	Base angles in an isosceles triangle are equal. Two sides are equal.   x = (180 − 40) ÷ 2 = 70°  x = 180 − 70 − 70 = 40°
H05.10 **Equilateral triangle**	Each angle in an equilateral triangle is 60°. All three sides are equal. 

Matching ticks show equal lengths.

H05 | Angles and right triangles

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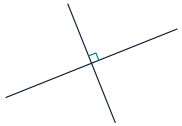
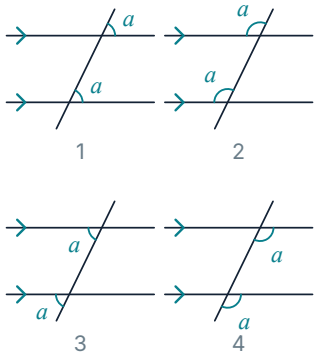
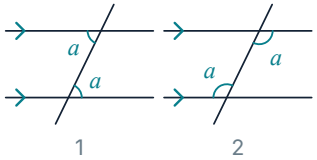
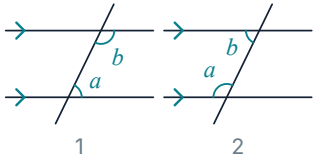
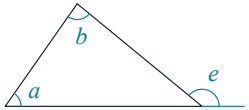
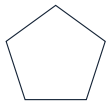
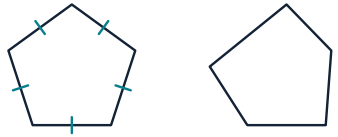
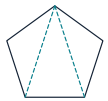
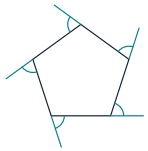
Angles and polygons

H05.11 **Quadrilateral angle sum**	Angles in a quadrilateral add up to 360°. $a + b + c + d = 360°$. E.g. quadrilateral angles 80°, 90°, 110° and x: $x = 360° - 280° = 80°$.
H05.12 **Parallel lines**	Lines in a plane that stay the same perpendicular distance apart and never meet.
H05.13 **Perpendicular lines**	Lines meeting at 90°. 
H05.14 **Corresponding angles**	Corresponding angles are equal. For parallel lines. 

Angles and polygons

H05.15 **Alternate angles**	Alternate angles are equal. For parallel lines. 
H05.16 **Co interior angles**	Co-interior angles add up to 180°. For parallel lines: $a + b = 180°$.  E.g. one co-interior angle is 112°: The other $= 180° - 112° = 68°$.
H05.17 **Triangle exterior angle**	The exterior angle of a triangle is equal to the sum of the two opposite interior angles. $e = a + b$.  E.g. opposite interior angles 40° and 65°: Exterior angle $= 40° + 65° = 105°$.
H05.18 **Polygon**	A closed 2D shape made from straight sides. 

Angles and polygons

H05.19 **Regular polygon**	A polygon with all sides equal and all interior angles equal.  Regular Irregular
H05.20 **Polygon interior angle sum**	For a simple polygon with n sides: $(n - 2) \times 180°$.  n sides give n - 2 triangles E.g. a hexagon: Sum $= (6 - 2) \times 180° = 720°$.
H05.21 **Regular interior angle**	For n sides: $\frac{(n-2)180°}{n}$. E.g. a regular pentagon: Each angle $= \frac{3 \times 180°}{5} = 108°$.
H05.22 **Exterior angle sum**	One exterior angle at each vertex of a convex polygon totals 360°. 

H05 | Angles and right triangles

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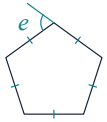
Angles and polygons

H05.23 Regular exterior angle

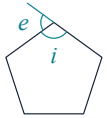
For n sides: $\frac{360°}{n}$.



E.g. a regular octagon:
Each exterior angle = 360° ÷ 8 = 45°.

H05.24 Interior and exterior pair

An interior angle and its adjacent exterior angle total 180°.

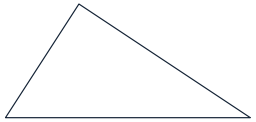


E.g. interior angle 120°:
Exterior angle = 180° − 120° = 60°.

Shape properties

H05.25 Scalene triangle

A triangle with no equal sides.



H05.26 Right angled triangle

A triangle with one angle of 90°. The square corner marks the right angle.

Shape properties

H05.27 Parallelogram

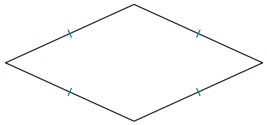
Both pairs of opposite sides are parallel. Opposite sides and angles are equal.

H05.28 Rectangle

A quadrilateral with four right angles. Opposite sides are equal.

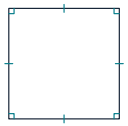
H05.29 Rhombus

A quadrilateral with four equal sides; opposite sides are parallel.



H05.30 Square

Four equal sides and four right angles.



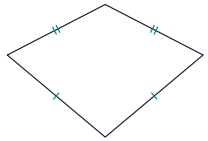
H05.31 Trapezium

A quadrilateral with a pair of parallel sides.

Shape properties

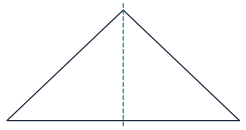
H05.32 Kite

A quadrilateral with two pairs of adjacent equal sides.



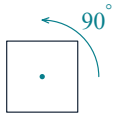
H05.33 Line symmetry

Reflection in a line maps the shape exactly onto itself.



H05.34 Rotational symmetry order

The number of times a shape matches itself during one full turn.

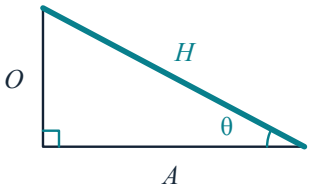


Square: 4 matches per full turn

Right triangles and SOHCAHTOA

H05.35 Hypotenuse

The side opposite the right angle; it is the longest side of a right-angled triangle.



Matching ticks show equal lengths.

H05 | Angles and right triangles

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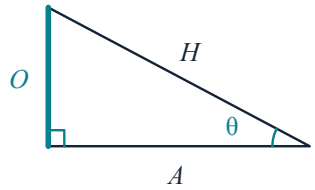
Right triangles and SOHCAHTOA

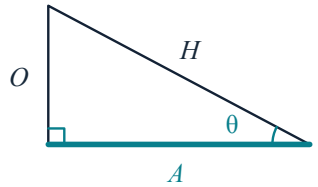
H05.36
Opposite side

The side opposite the chosen acute angle in a right-angled triangle.



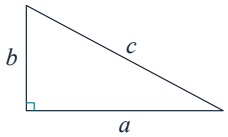
H05.37
Adjacent side

The side beside the chosen acute angle, excluding the hypotenuse.



H05.38
Pythagoras' theorem

In a right-angled triangle: $a^2 + b^2 = c^2$, with hypotenuse c.

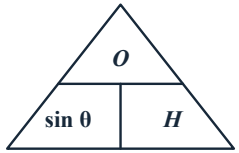


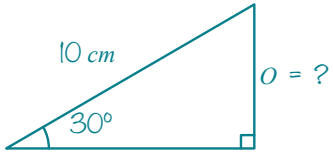
E.g. perpendicular sides 3 cm and 4 cm:
$3^2 + 4^2 = c^2$
$9 + 16 = c^2$
$25 = c^2$
$c = \sqrt{25} = 5$ cm.

Right triangles and SOHCAHTOA

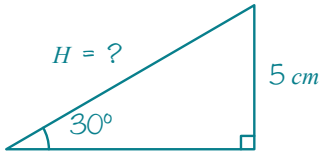
H05.39
Sine ratio: SOH

$\sin\theta = \frac{\text{opposite}}{\text{hypotenuse}}$.
O = opposite; H = hypotenuse.





$O = 10 \times \sin 30° = 5$ cm

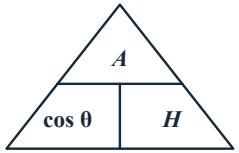


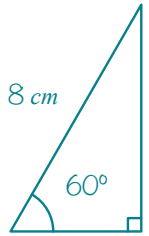
$H = 5 \div \sin 30° = 10$ cm

Right triangles and SOHCAHTOA

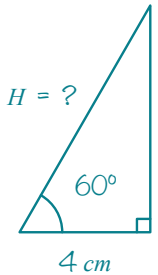
H05.40
Cosine ratio: CAH

$\cos\theta = \frac{\text{adjacent}}{\text{hypotenuse}}$.
A = adjacent; H = hypotenuse.





$A = ?$
$A = 8 \times \cos 60° = 4$ cm



$H = 4 \div \cos 60° = 8$ cm

H05 | Angles and right triangles

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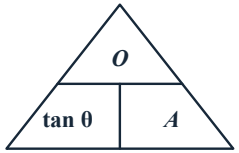
Right triangles and SOHCAHTOA

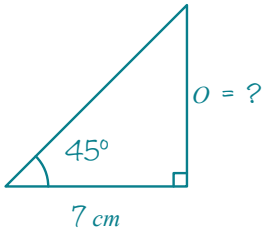
H05.41

Tangent ratio: TOA

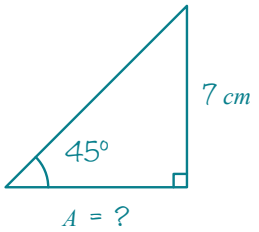
$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$.

O = opposite; A = adjacent.





$O = 7 \times \tan 45° = 7$ cm



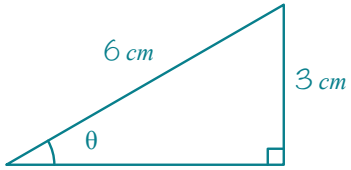
$A = 7 \div \tan 45° = 7$ cm

Right triangles and SOHCAHTOA

H05.42

Inverse trigonometric function

Use the inverse trigonometric button to find a missing angle from its ratio. Set the calculator to degrees.



$30° \xrightarrow{\sin} 0.5$

$0.5 \xrightarrow{\sin^{-1}} 30°$

$\sin\theta = \frac{3}{6} = 0.5$

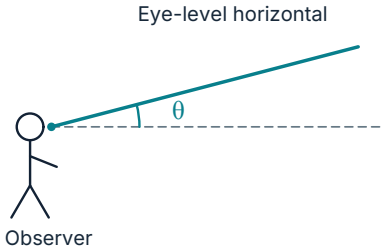
$\theta = \sin^{-1}(0.5) = 30°$.

Right triangles and SOHCAHTOA

H05.43

Angle of elevation

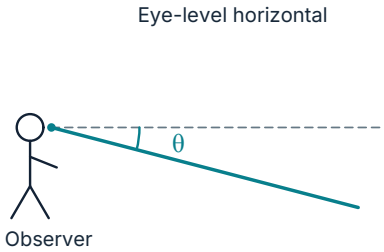
An angle measured upwards from a horizontal line.



H05.44

Angle of depression

An angle measured downwards from a horizontal line.

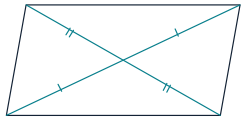


Diagonals, symmetry and names

H05.45

Parallelogram diagonals

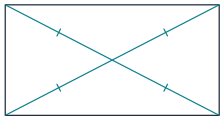
The diagonals bisect each other.



H05.46

Rectangle diagonals

The diagonals are equal in length and bisect each other.



Matching ticks show equal lengths.

H05 | Angles and right triangles

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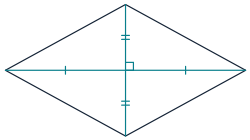
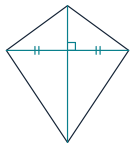
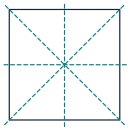
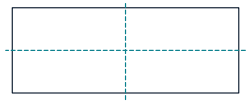
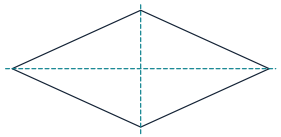
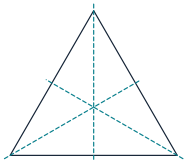
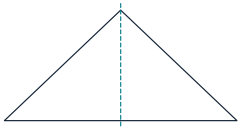
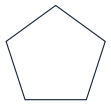
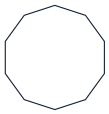
Diagonals, symmetry and names

H05.47 **Rhombus diagonals**	The diagonals bisect each other at right angles. 
H05.48 **Kite diagonal**	A symmetry diagonal perpendicularly bisects the other diagonal (for a non-rhombus kite). 
H05.49 **Square symmetry**	Four lines of symmetry and rotational symmetry of order 4. 
H05.50 **Rectangle symmetry**	A non-square rectangle has two lines of symmetry and rotational symmetry of order 2. 

Diagonals, symmetry and names

H05.51 **Rhombus symmetry**	A non-square rhombus has two lines of symmetry (its diagonals) and rotational symmetry of order 2. 
H05.52 **Equilateral triangle symmetry**	Three lines of symmetry and rotational symmetry of order 3. 
H05.53 **Isosceles triangle symmetry**	A non-equilateral isosceles triangle has one line of symmetry and rotational symmetry of order 1. 
H05.54 **Pentagon**	A polygon with 5 sides. 

Diagonals, symmetry and names

H05.55 **Hexagon**	A polygon with 6 sides.
H05.56 **Heptagon**	A polygon with 7 sides.
H05.57 **Octagon**	A polygon with 8 sides.
H05.58 **Decagon**	A polygon with 10 sides. 

Exact trigonometric values

θ	0°	30°	45°	60°	90°
$\sin\theta$	0	$\frac{1}{2}$	$\frac{\sqrt{2}}{2}$	$\frac{\sqrt{3}}{2}$	1
$\cos\theta$	1	$\frac{\sqrt{3}}{2}$	$\frac{\sqrt{2}}{2}$	$\frac{1}{2}$	0
$\tan\theta$	0	$\frac{\sqrt{3}}{3}$	1	$\sqrt{3}$	Not defined

Matching ticks show equal lengths.

H06 | Coordinates and graph families

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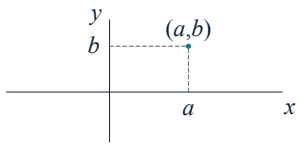
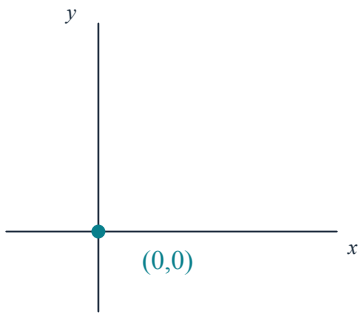
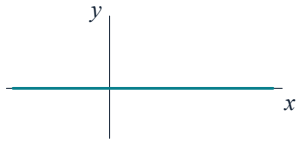
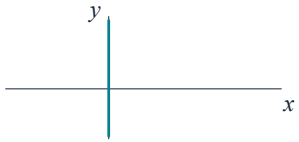
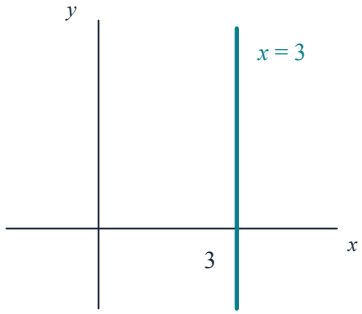
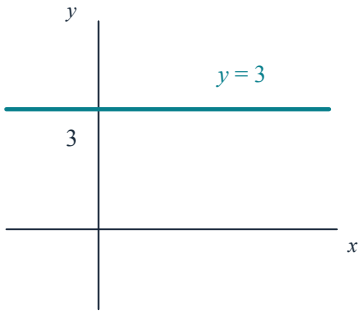
☐	☐	☐	☐	☐	_____	☐	☐	☐	☐	☐	_____

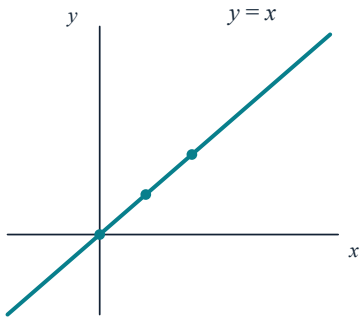
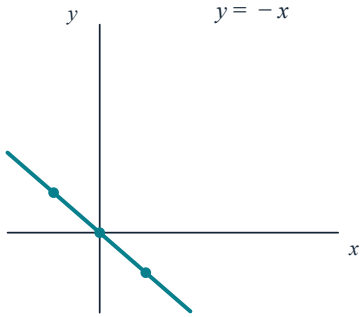
Coordinates and lines

H06.01 **Coordinates**	An ordered pair (x,y): horizontal position first, vertical position second. 
H06.02 **Origin**	The point $(0,0)$ where the coordinate axes meet. 
H06.03 **Horizontal axis**	The x-axis; its equation is $y = 0$. 

Coordinates and lines

H06.04 **Vertical axis**	The y-axis; its equation is $x = 0$. 
H06.05 **Vertical line**	Every point has the same x-coordinate. The line goes vertically. For example, $x = 3$. A vertical line has no defined gradient. 
H06.06 **Horizontal line**	Every point has the same y-coordinate. The line goes horizontally. For example, $y = 3$. Its gradient is zero. 

Coordinates and lines

H06.07 **The line y = x**	A diagonal through the origin; every point has equal x- and y-coordinates.  E.g. (0,0), (1,1), (2,2).
H06.08 **The line y = -x**	A diagonal through the origin with gradient -1.  E.g. (−1,1), (0,0), (1,−1).

H06 | Coordinates and graph families

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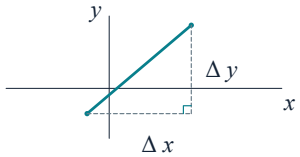
☐	☐	☐	☐	☐	_____	☐	☐	☐	☐	☐	_____

Coordinates and lines

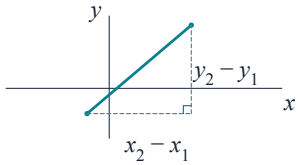
H06.09 Gradient

$m = \frac{\text{change in } y}{\text{change in } x}$. This is rise divided by run: the vertical step divided by the horizontal step. Δ means change in.



H06.10 Gradient from coordinates

$m = \frac{y_2 - y_1}{x_2 - x_1}$, where $x_1 \neq x_2$.

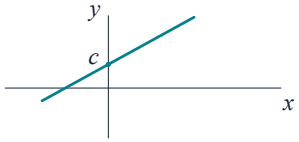


E.g. through (1,2) and (4,8):
$m = \frac{8-2}{4-1} = \frac{6}{3} = 2$.

Coordinates and lines

H06.11 Straight line equation

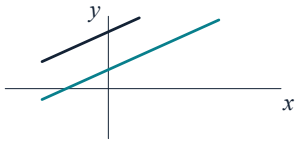
$y = mx + c$: m is the gradient and c is the y-intercept.



E.g. $y = 2x + 5$:
Gradient 2; y-intercept (0,5).

H06.12 Parallel gradients

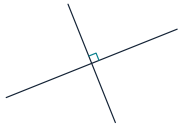
Distinct non-vertical parallel lines have equal gradients.



H06.13 Perpendicular gradients

Perpendicular non-vertical lines have negative reciprocal gradients. Flip the fraction and change its sign: $m_2 = -\frac{1}{m_1}$.

Horizontal and vertical lines are also perpendicular.

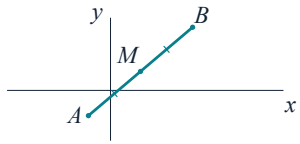


E.g. gradient 2 is perpendicular to gradient $-\frac{1}{2}$:
$2 \times (-\frac{1}{2}) = -1$.

Coordinates and lines

H06.14 Midpoint

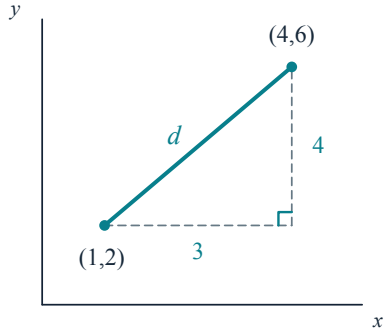
For endpoints (x_1, y_1), (x_2, y_2): $(\frac{x_1 + x_2}{2}, \frac{y_1 + y_2}{2})$.



E.g. midpoint of (2,1) and (8,5):
$(\frac{2+8}{2}, \frac{1+5}{2}) = (5,3)$.

H06.15 Distance between two points

$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$.



$d^2 = 3^2 + 4^2 = 25$
$d = \sqrt{25} = 5$ units.

Matching ticks show equal lengths.

H06 | Coordinates and graph families

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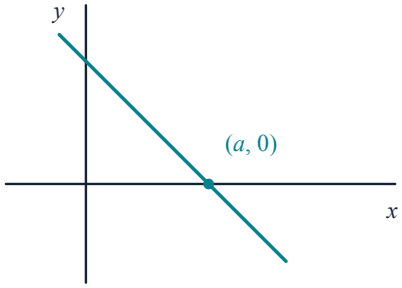
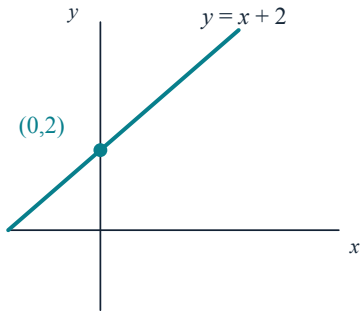
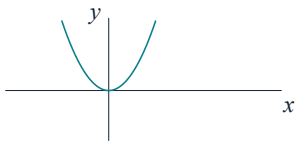
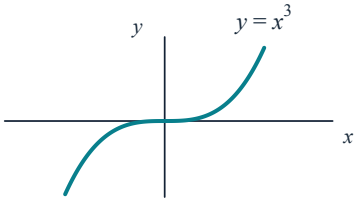
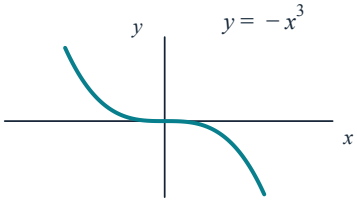
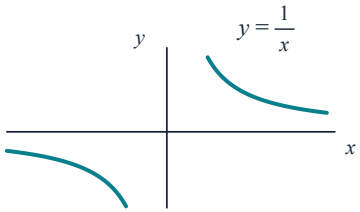
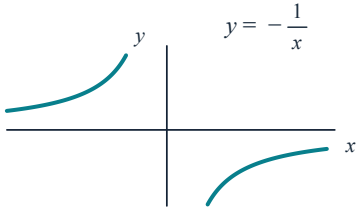
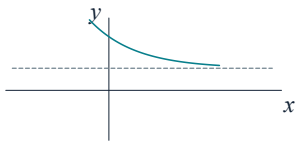
Coordinates and lines

H06.16 **Finding a line equation**	Start with $y = mx + c$. Substitute the gradient and a point on the line, then solve for c. Write the equation using m and c. Gradient 3, point (2,5): $y = 3x + c$ $5 = 3 \times 2 + c$ $5 = 6 + c$, so $c = -1$. The line is $y = 3x - 1$.
H06.17 **x intercept**	A point where the graph meets the x-axis; $y = 0$. 
H06.18 **y intercept**	A point where the graph meets the y-axis; $x = 0$. 

Graph families

H06.19 **Quadratic graph**	$y = x^2$ is a U-shaped parabola, symmetric about the y-axis. 
H06.20 **Cubic graph**	$y = x^3$ passes through the origin. $y = -x^3$ is its reflection in the x-axis. Both have rotational symmetry of order 2 about the origin.  

Graph families

H06.21 **Reciprocal graph**	$y = \frac{1}{x}$ and $y = -\frac{1}{x}$ each have two branches. The negative version is a reflection in the x-axis; $x = 0$ is excluded.  
H06.22 **Exponential graph**	For $a > 1$, $y = a^x$ increases and passes through $(0,1)$.
H06.23 **Asymptote**	A line a curve approaches arbitrarily closely.  Asymptote: y = c

H06 | Coordinates and graph families

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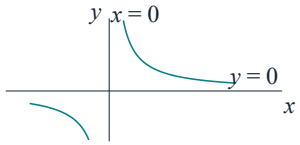
Graph families

H06.24 Reciprocal asymptotes

For $y = \frac{1}{x}$, the asymptotes are $x = 0$ and $y = 0$.

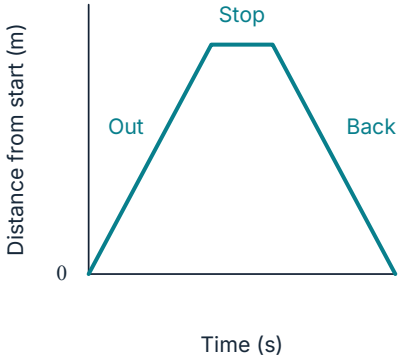


Graphs in context

H06.25 Distance time gradient

On a distance-from-start graph, the size of the gradient gives speed. A falling line shows a return towards the start, not a negative speed.

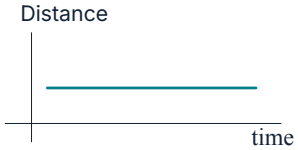
Returning: distance falls



Graphs in context

H06.26 Horizontal distance time segment

The distance is unchanged: the object is stationary.



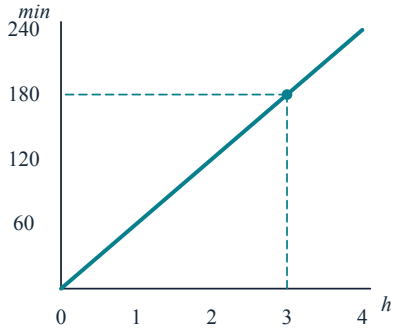
H06.27 Straight distance time segment

A straight sloping segment shows constant speed. If distance from the start decreases, the object is travelling back towards the start.

H06.28 Conversion graph

A graph linking values of the same quantity measured in different units.

Hours → minutes



Read up from 3 hours to the line, then across to the minutes axis: 3 × 60 = 180 minutes.

Motion graphs

H06.29 Motion graph links

For motion in one direction: the gradient of a speed-time graph is acceleration; the area underneath is distance travelled. Use seconds with m/s to obtain metres. Exam questions may use the term velocity-time.

Distance –time	Speed –time	Acceleration –time
Gradient →	Gradient →	
← Area*	← Area*	

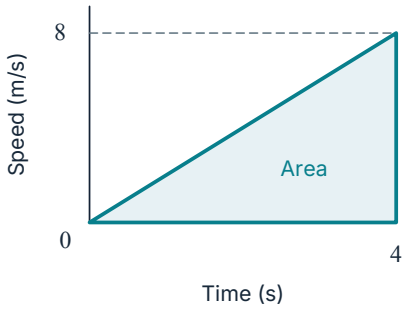
Motion in one direction.

Acceleration area = change in speed.

*Below the time axis: subtract area.

Speed area = distance travelled.

Gradient = 8 ÷ 4 = 2 m/s²



Distance = ½ × 4 × 8 = 16 m

H06.30 Speed time area

Area between the graph and time axis is distance travelled.

E.g. speed 2 m/s for 3 s, then 1 m/s for 2 s: Distance = 2(3) + 1(2) = 8 m.

H07 | Measures and bounds

Edexcel 1MA1 | Higher Tier | Prompt + Recall Answer | Unit Page 1 of 11

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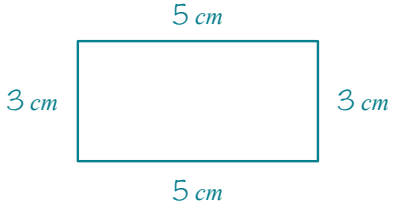
Perimeter and area

H07.01 Perimeter

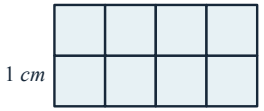
The total distance around a closed 2D shape.



$P = 3 + 5 + 3 + 5 = 16$ cm.

H07.02 Area

The amount of 2D space inside a boundary, measured in square units.



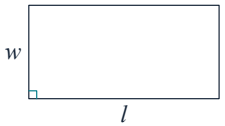
8 squares of 1 cm²

$8 \times 1\text{ cm}^2 = 8\text{ cm}^2$.

Perimeter and area

H07.03 Rectangle area

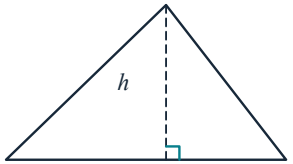
$A = lw$, with length l and width w.

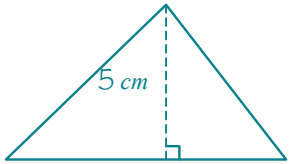


E.g. $l = 8$ cm, $w = 3$ cm:
$A = 8 \times 3 = 24$ cm².

H07.04 Triangle area

$A = \frac{1}{2}bh$, with base b and perpendicular height h.



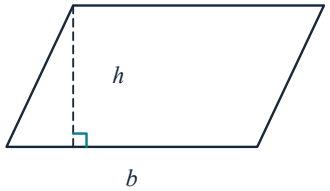


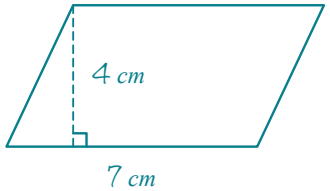
E.g. $b = 6$ cm, $h = 5$ cm:
$A = \frac{1}{2} \times 6 \times 5 = 15$ cm².

Perimeter and area

H07.05 Parallelogram area

$A = bh$, with base b and perpendicular height h.





E.g. $b = 7$ cm, $h = 4$ cm:
$A = 7 \times 4 = 28$ cm².

H07 | Measures and bounds

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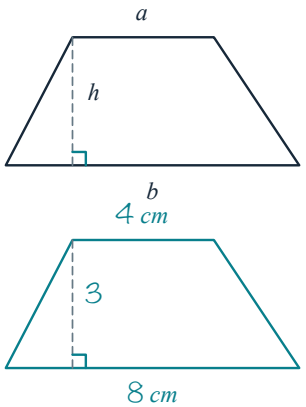
Perimeter and area

H07.06 Trapezium area

$A = \frac{1}{2}(a + b)h$, with parallel sides a,b and perpendicular height h.



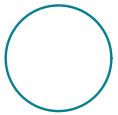
E.g. $a = 4$, $b = 8$, $h = 3$ cm:
$A = \frac{1}{2}(4 + 8) \times 3 = 18$ cm².

H07.07 Circle

Points in a plane a fixed distance from a centre.

H07.08 Circumference

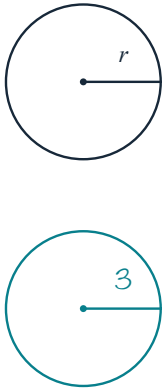
The boundary of a circle, or its length.



Perimeter and area

H07.09 Circle circumference

$C = 2\pi r$ or $C = \pi d$, with radius r and diameter d.

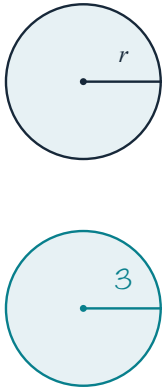


r = 3 cm

E.g. $r = 3$ cm:
$C = 2\pi \times 3 = 6\pi$ cm.

H07.10 Circle area

$A = \pi r^2$, with radius r.



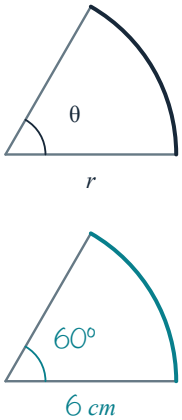
r = 3 cm

E.g. $r = 3$ cm:
$A = \pi \times 3^2 = 9\pi$ cm².

Perimeter and area

H07.11 Arc length

$L = \frac{\theta}{360} \times 2\pi r = \frac{\theta}{360} \times \pi d$, with θ in degrees and $d = 2r$.



E.g. $r = 6$ cm, $\theta = 60°$:
$L = \frac{60}{360} \times 2\pi \times 6 = 2\pi$ cm.

H07 | Measures and bounds

MY RETRIEVAL PRACTICE

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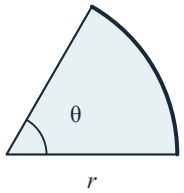
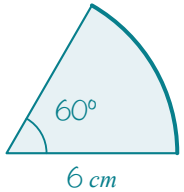
Perimeter and area

H07.12 Sector area

For radius r and central angle θ in degrees: $A = \frac{\theta}{360} \times \pi r^2$.



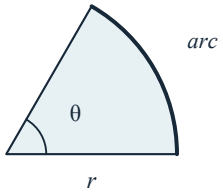


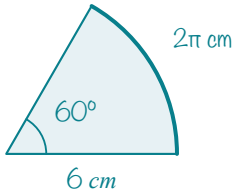
E.g. $r = 6$ cm, $\theta = 60°$:
$A = \frac{60}{360} \times \pi \times 6^2 = 6\pi$ cm².

Perimeter and area

H07.13 Sector perimeter

Arc length plus the two radii.

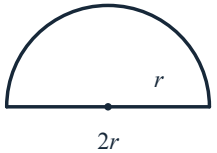


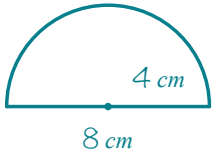


E.g. $r = 6$ cm and arc length 2π cm:
$P = 2\pi + 6 + 6 = 12 + 2\pi$ cm.

H07.14 Semicircle perimeter

$P = \frac{2\pi r}{2} + 2r = \pi r + 2r$. The diameter is part of the boundary.





E.g. $r = 4$ cm:
$P = 4\pi + 8$ cm.
Include the 8 cm diameter.

Perimeter and area

H07.15 In terms of pi

Leave π in the exact answer, with the other numbers simplified. Do not replace π by a decimal.

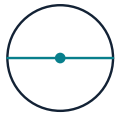
E.g. $\pi \times 5^2 = 25\pi$ cm².

H07.16 Radius

A line segment from the centre to the circumference.

H07.17 Diameter

A chord through the centre; $d = 2r$.



H07.18 Chord

A segment joining two points on the circumference.

H07.19 Tangent

A straight line touching a circle at exactly one point.

H07.20 Arc

Part of the circumference.

H07 | Measures and bounds

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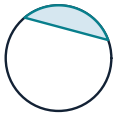
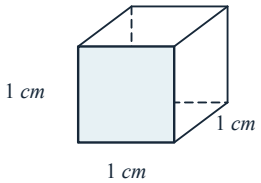
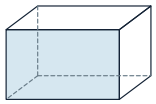
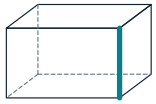
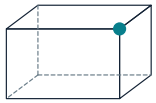
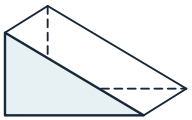
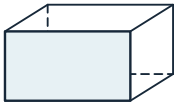
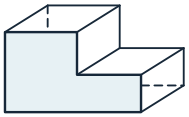
Perimeter and area

H07.21 **Segment**	A region bounded by a chord and an arc. 
H07.22 **Sector**	A region bounded by two radii and an arc.
H07.23 **Pi**	π is the ratio of circumference to diameter for every circle. It is irrational: $\pi = 3.14159...$.

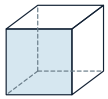
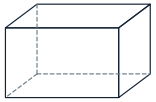
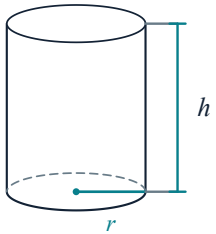
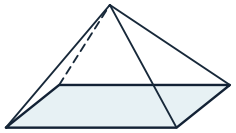
Solid vocabulary

H07.24 **Volume**	The amount of 3D space occupied, measured in cubic units. 1 cubic centimetre = 1 cm³ 
H07.25 **Surface area**	The total area of the exposed surfaces of a solid.
H07.26 **Face**	A flat surface of a 3D shape. A cuboid has six rectangular faces.  Shaded face

Solid vocabulary

H07.27 **Edge**	A straight edge is where two flat faces of a 3D shape meet. A cuboid has 12 edges.  Highlighted edge
H07.28 **Vertex**	A corner where edges meet; plural: vertices.  Highlighted vertex
H07.29 **Prism**	A solid with a uniform polygonal cross-section along its length.  Triangular prism  Cuboid  Irregular prism

Solid vocabulary

H07.30 **Cube**	A solid with six congruent square faces. 
H07.31 **Cuboid**	A solid with six rectangular faces meeting at right angles. 
H07.32 **Cylinder**	A solid with two parallel, congruent circular ends joined by a curved surface. 
H07.33 **Pyramid**	A solid with a polygonal base and triangular side faces meeting at an apex. Triangular-based  Square-based

Shading identifies the relevant region.

H07 | Measures and bounds

MY RETRIEVAL PRACTICE

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☐	☐	☐	☐	☐		☐	☐	☐	☐	☐	
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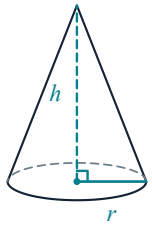
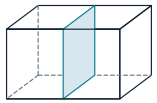
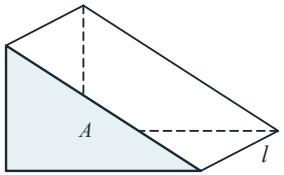
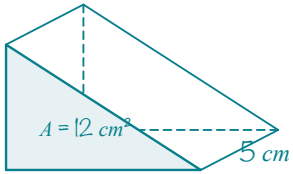
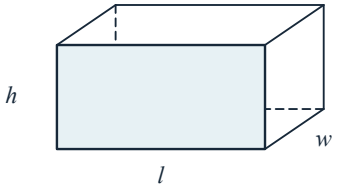
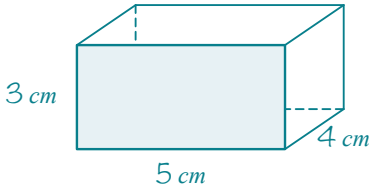
☐	☐	☐	☐	☐		☐	☐	☐	☐	☐	

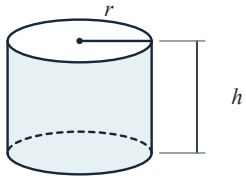
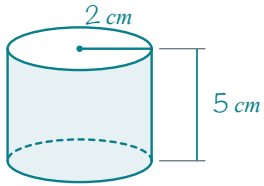
Solid vocabulary

H07.34 **Cone**	A solid with a circular base tapering to an apex. 
H07.35 **Sphere**	A surface whose points are all the same distance from its centre; also the corresponding solid.
H07.36 **Plane of symmetry**	A plane dividing a solid into two mirror-image halves.  One symmetry plane

Volume and surface area

H07.37 **Prism volume**	$V = Al$, where A is cross-sectional area and l is perpendicular length.   E.g. $A = 12$ cm², $l = 5$ cm: $V = 12 \times 5 = 60$ cm³.
H07.38 **Cuboid volume**	$V = lwh$, with perpendicular edge lengths l, w, h.   E.g. edges 3, 4 and 5 cm: $V = 3 \times 4 \times 5 = 60$ cm³.

Volume and surface area

H07.39 **Cylinder volume**	For radius r and perpendicular height h: $V = \pi r^2 h$.   E.g. $r = 2$ cm, $h = 5$ cm: $V = \pi \times 2^2 \times 5 = 20\pi$ cm³. ≈62.8 cm³ (1 d.p.).

MY RETRIEVAL PRACTICE

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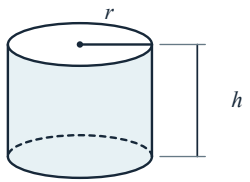
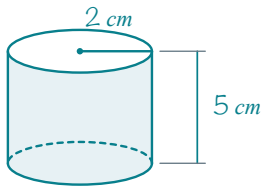
Volume and surface area

H07.40

Cylinder curved surface area

For a right cylinder of radius r and height h: $A = 2\pi rh$.





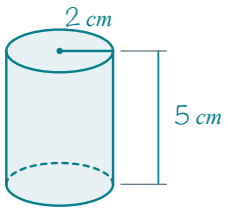
E.g. $r = 2$ cm, $h = 5$ cm:
$A = 2\pi \times 2 \times 5 = 20\pi$ cm².
≈62.8 cm² (1 d.p.).

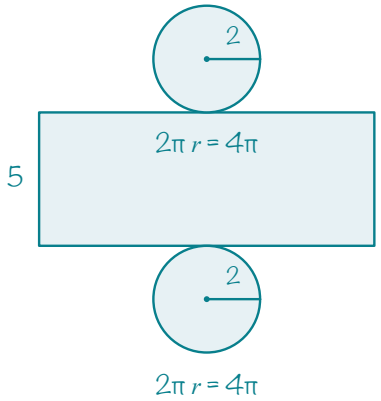
Volume and surface area

H07.41

Cylinder total surface area

For a closed right cylinder of radius r and height h: $A = 2\pi rh + 2\pi r^2$.





Dimensions in cm

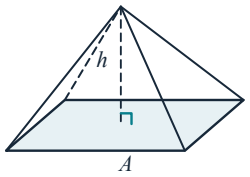
E.g. $r = 2$ cm, $h = 5$ cm:
$A = 20\pi + 2(4\pi) = 28\pi$ cm².
≈88.0 cm² (1 d.p.).

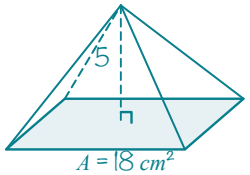
Volume and surface area

H07.42

Pyramid volume

$V = \frac{1}{3}Ah$, where A is base area and h is perpendicular height.





E.g. $A = 18$ cm², $h = 5$ cm:
$V = \frac{1}{3} \times 18 \times 5 = 30$ cm³.

MY RETRIEVAL PRACTICE

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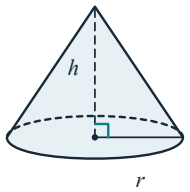
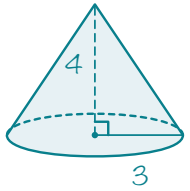
Volume and surface area

H07.43

Cone volume

For radius r and perpendicular height h: $V = \frac{1}{3}\pi r^2 h$.





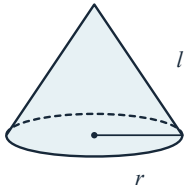
E.g. $r = 3$ cm, $h = 4$ cm:
$V = \frac{1}{3}\pi \times 3^2 \times 4 = 12\pi$ cm³.
≈37.7 cm³ (1 d.p.).

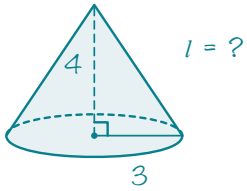
Volume and surface area

H07.44

Cone curved surface area

For a right cone of radius r and slant length l: $A = \pi rl$.





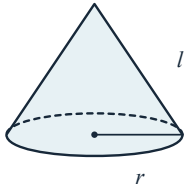
E.g. $r = 3$ cm, $h = 4$ cm:
$l^2 = 3^2 + 4^2 = 25$
$l = \sqrt{25} = 5$ cm.
$A = \pi \times 3 \times 5 = 15\pi$ cm².
≈47.1 cm² (1 d.p.).

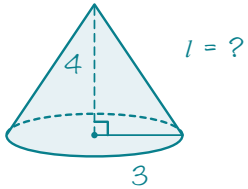
Volume and surface area

H07.45

Cone total surface area

For a closed right cone of radius r and slant length l: $A = \pi rl + \pi r^2$.





E.g. $r = 3$ cm, $h = 4$ cm:
$l^2 = 3^2 + 4^2 = 25$
$l = \sqrt{25} = 5$ cm.
$A = \pi \times 3 \times 5 + \pi \times 3^2$
$= 24\pi \approx 75.4$ cm² (1 d.p.).

MY RETRIEVAL PRACTICE

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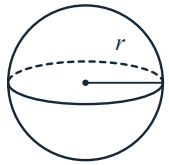
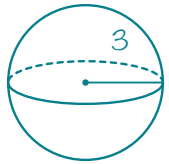
Volume and surface area

H07.46

Sphere volume

For radius r: $V = \frac{4}{3}\pi r^3$.





E.g. $r = 3$ cm:

$V = \frac{4}{3}\pi \times 3^3 = 36\pi$ cm³.

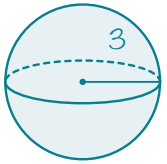
≈113.1 cm³ (1 d.p.).

Volume and surface area

H07.47

Sphere surface area

For radius r: $A = 4\pi r^2$.



E.g. $r = 3$ cm:

$A = 4\pi \times 3^2 = 36\pi$ cm².

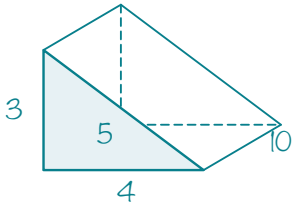
≈113.1 cm² (1 d.p.).

Volume and surface area

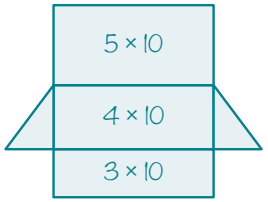
H07.48

Prism surface area

The sum of its two end areas and its rectangular side-face areas (for a right prism).



Dimensions in cm



2 triangular ends + 3 rectangles

E.g. triangular ends with perpendicular sides 3 cm and 4 cm; third side 5 cm. Prism length 10 cm.

Two ends: $2 \times \frac{1}{2} \times 3 \times 4 = 12$.

Three rectangles: $3 \times 10 + 4 \times 10 + 5 \times 10 = 120$.

Total area $= 12 + 120 = 132$ cm².

H07 | Measures and bounds

MY RETRIEVAL PRACTICE

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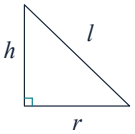
☐	☐	☐	☐	☐	_____	☐	☐	☐	☐	☐	_____

Volume and surface area

H07.49 Cone height and slant length

For a right cone, slant height l, radius r and perpendicular height h: $l^2 = r^2 + h^2$.

Half of a central cross-section



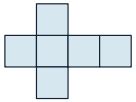
E.g. $r = 3$ cm, $h = 4$ cm:
$l = \sqrt{3^2 + 4^2} = 5$ cm.

Solids and views

H07.50 Net

A 2D arrangement of faces that folds to form a solid.

One possible net

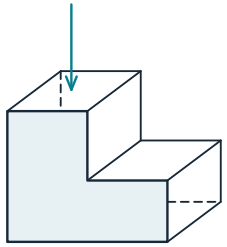


Solids and views

H07.51 Plan

A view from directly above.

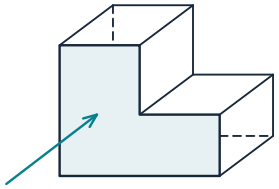
Look down



Plan

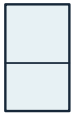
H07.52 Elevation

A view from a specified horizontal direction, such as front or side.



Front

Front



Side

Units and bounds

H07.53 Metres and centimetres

1 m = 100 cm.

H07.54 Centimetres and millimetres

1 cm = 10 mm.

H07.55 Kilometres and metres

1 km = 1000 m.

km $\xrightarrow{\times 1000}$ m $\xrightarrow{\times 100}$ cm $\xrightarrow{\times 10}$ mm

km $\xleftarrow{\div 1000}$ m $\xleftarrow{\div 100}$ cm $\xleftarrow{\div 10}$ mm

H07.56 Kilograms and grams

1 kg = 1000 g. Also 1 tonne = 1000 kg.

tonnes $\xrightarrow{\times 1000}$ kg $\xrightarrow{\times 1000}$ g

tonnes $\xleftarrow{\div 1000}$ kg $\xleftarrow{\div 1000}$ g

H07.57 Litres and cubic centimetres

1 litre = 1000 ml = 1000 cm^3.

litres $\xrightarrow{\times 1000}$ ml

litres $\xleftarrow{\div 1000}$ ml

H07.58 Millilitres and cubic centimetres

1 ml = 1 cm^3.

Shading identifies the relevant region.

H07 | Measures and bounds

Edexcel 1MA1 | Higher Tier | Prompt + Recall Answer | Unit Page 10 of 11

MY RETRIEVAL PRACTICE

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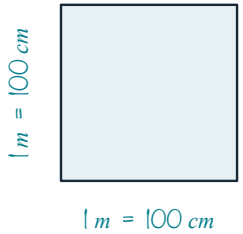
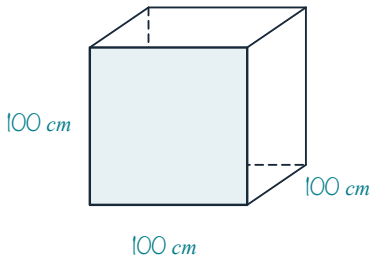
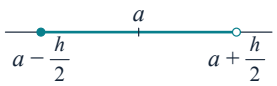
☐	☐	☐	☐	☐		☐	☐	☐	☐	☐	

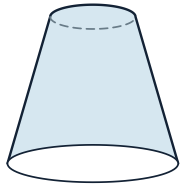
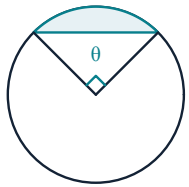
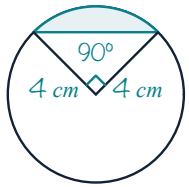
Units and bounds

H07.59 **Area conversion factor**	LSF = length scale factor; ASF = area scale factor. $\text{ASF} = \text{LSF}^2$. $\text{LSF} = \sqrt{\text{ASF}}$. Use the length conversion factor for LSF.  E.g. $1\text{ m}^2 = 100^2\text{ cm}^2$ $= 10000\text{ cm}^2$.
H07.60 **Volume conversion factor**	VSF = volume scale factor; LSF = length scale factor. $\text{VSF} = \text{LSF}^3$. $\text{LSF} = \sqrt[3]{\text{VSF}}$. Use the length conversion factor for LSF. 1 m = 100 cm on each edge  E.g. $1\text{ m}^3 = 100^3\text{ cm}^3$ $= 1000000\text{ cm}^3$.

Units and bounds

H07.61 **Error interval**	For a positive rounded measurement, subtract half the rounding step to find the lower bound. Add half the rounding step to find the upper bound. Include the lower bound; exclude the upper bound.  Lower included; upper excluded 8 cm to the nearest cm: Half the rounding step is 0.5 cm. Lower: 8 − 0.5 = 7.5 cm. Upper: 8 + 0.5 = 8.5 cm. $7.5 \le x < 8.5$ cm.
H07.62 **Lower bound**	The smallest possible value consistent with the stated accuracy.
H07.63 **Upper bound**	The upper endpoint of the possible values; it may be excluded.
H07.64 **Truncation**	Digits beyond a chosen place are removed without rounding. E.g. truncate 3.789 to 2 d.p.: 3.78 (do not round up).

Composite solids and areas

H07.65 **Frustum**	The part left when a pyramid or cone is cut by a plane parallel to its base and the smaller top part is removed.  Viewed from below E.g. whole cone 80 cm³, removed cone 10 cm³: Frustum volume = 80 − 10 = 70 cm³.
H07.66 **Minor segment area**	For a central angle up to 180°, sector area minus the area of the triangle formed by its two radii and chord.   E.g. $r = 4$ cm, central angle 90°: Fraction of circle $= \frac{90}{360} = \frac{1}{4}$. Segment area $= \frac{1}{4}\pi(4^2) - \frac{1}{2}(4)(4)$ $= 4\pi - 8\text{ cm}^2$.

Shading identifies the relevant region.

H07 | Measures and bounds

MY RETRIEVAL PRACTICE

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Composite solids and areas

H07.67 Hemisphere volume

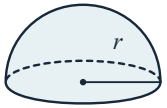
For radius r: $V = \frac{2}{3}\pi r^3$.

E.g. $r = 3$ cm:
$V = \frac{2}{3}\pi \times 3^3 = 18\pi$ cm³.
≈56.5 cm³ (1 d.p.).

Composite solids and areas

H07.68 Hemisphere curved area

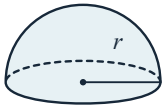
For radius r: $A = 2\pi r^2$.



E.g. $r = 3$ cm:
$A = 2\pi \times 3^2 = 18\pi$ cm².
≈56.5 cm² (1 d.p.).

H07.69 Hemisphere total area

Including the circular base, for radius r: $A = 3\pi r^2$.



Include the circular base

Include the circular base

E.g. $r = 3$ cm:
$A = 3\pi \times 3^2 = 27\pi$ cm².
≈84.8 cm² (1 d.p.).

Arithmetic with bounds

H07.70 Sum bounds

LB = lower bound; UB = upper bound.
$(A + B)_{LB} = A_{LB} + B_{LB}$.
$(A + B)_{UB} = A_{UB} + B_{UB}$.

E.g. $3 \le A < 4$, $5 \le B < 6$:
$3 + 5 \le A + B < 4 + 6$
$8 \le A + B < 10$.

H07.71 Difference bounds

LB = lower bound; UB = upper bound.
$(A - B)_{LB} = A_{LB} - B_{UB}$.
$(A - B)_{UB} = A_{UB} - B_{LB}$.

E.g. $8 \le A < 9$, $3 \le B < 4$:
Lower bound: $8 - 4 = 4$.
Upper bound: $9 - 3 = 6$.
$4 < A - B < 6$.

H07.72 Positive product bounds

For positive bounds on A and B.
LB = lower bound; UB = upper bound.
$(A \times B)_{LB} = A_{LB} \times B_{LB}$.
$(A \times B)_{UB} = A_{UB} \times B_{UB}$.

E.g. $2 \le A < 3$, $4 \le B < 5$:
$2 \times 4 \le AB < 3 \times 5$
$8 \le AB < 15$.

H07.73 Positive quotient bounds

For positive bounds on A and B.
LB = lower bound; UB = upper bound.
$(A \div B)_{LB} = \frac{A_{LB}}{B_{UB}}$.
$(A \div B)_{UB} = \frac{A_{UB}}{B_{LB}}$.
Bounds may be limiting values.

E.g. $4 \le A < 6$, $2 \le B < 3$:
Lower bound $= 4 \div 3 = \frac{4}{3}$.
Upper bound $= 6 \div 2 = 3$.

H08 | Transformations and constructions

Edexcel 1MA1 | Higher Tier | Prompt + Recall Answer | Unit Page 1 of 7

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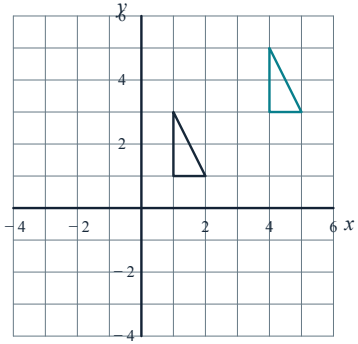
Transformations

H08.01
Translation

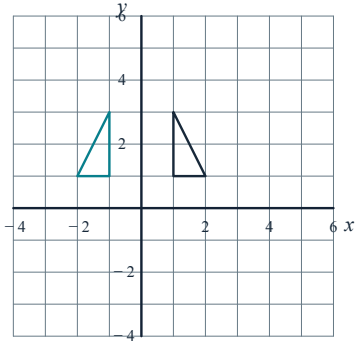
A movement by a fixed vector, with no change of orientation, size or shape. In $\begin{pmatrix} a \\ b \end{pmatrix}$, positive a means right and negative a means left; positive b means up and negative b means down.



Translate by (3, 2)

H08.02
Reflection

A mirror image in a line. Each point and its image are the same perpendicular distance from the mirror line.

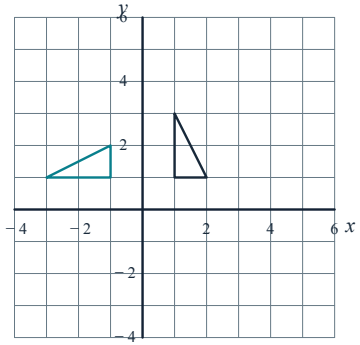


Reflect in x = 0

Transformations

H08.03
Rotation

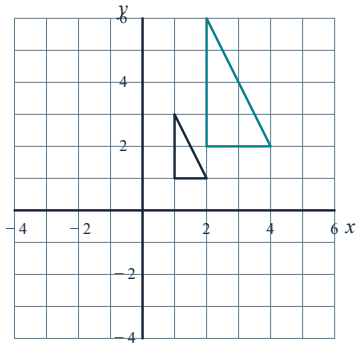
A turn about a fixed centre through a specified angle and direction.



90° anticlockwise about (0, 0)

H08.04
Enlargement

For positive scale factor k, distances from a fixed centre are multiplied by k.

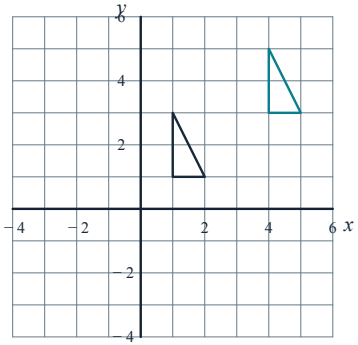


Scale factor 2, centre (0, 0)

Transformations

H08.05
Translation description

State translation and give a column vector $\begin{pmatrix} a \\ b \end{pmatrix}$. Top: horizontal (positive right, negative left). Bottom: vertical (positive up, negative down).



Translate by (3, 2)

E.g. translation $\begin{pmatrix} 3 \\ -2 \end{pmatrix}$:
3 right, 2 down.
(1,4) maps to (4,2).

H08 | Transformations and constructions

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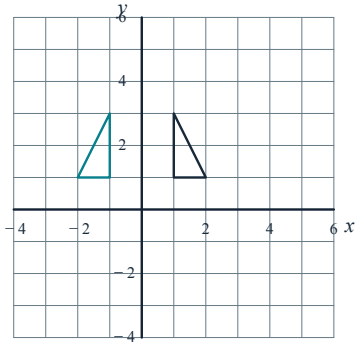
Transformations

H08.06
Reflection description

State reflection and give the equation of the mirror line.



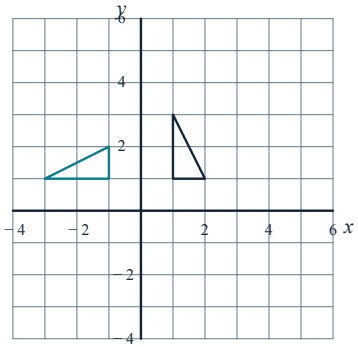
Reflect in x = 0

E.g. reflection in $x = 0$:
$(1,3)$ maps to $(-1,3)$.

Transformations

H08.07
Rotation description

State rotation; give the centre coordinates, angle of turn and direction (clockwise or anticlockwise; either direction for 180°).



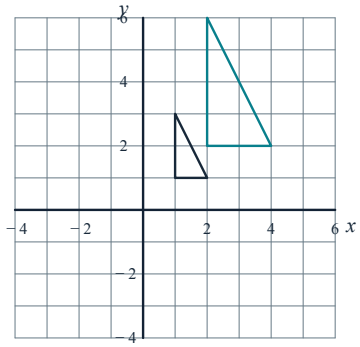
90° anticlockwise about (0, 0)

E.g. rotation about $(0,0)$, 90° anticlockwise:
$(2,1)$ maps to $(-1,2)$.

Transformations

H08.08
Enlargement description

State enlargement; give the centre coordinates and scale factor. A scale factor greater than 1 makes the image larger.



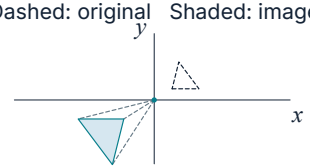
Scale factor 2, centre (0, 0)

E.g. enlargement, centre $(0,0)$, scale factor 2:
$(2,1)$ maps to $(4,2)$.

H08.09
Negative enlargement

For negative scale factor k, the image is on the opposite side of the centre and distances scale by the positive magnitude of k.

Dashed: original Shaded: image



Centre (0, 0); k < 0

E.g. centre $(0,0)$, factor -2:
$(1,3)$ maps to $(-2,-6)$.

H08 | Transformations and constructions

MY RETRIEVAL PRACTICE

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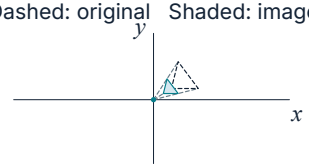
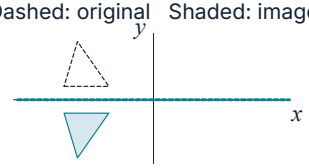
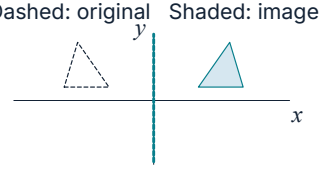
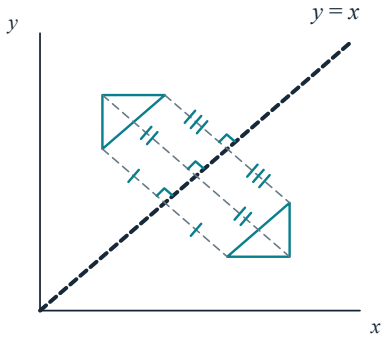
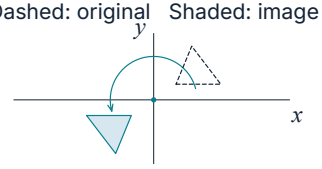
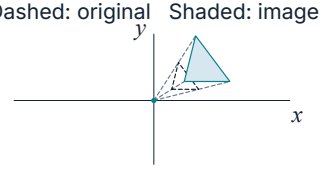
Transformations

H08.10 **Fractional enlargement**	A positive scale factor less than 1 makes the image smaller than the original. Dashed: original Shaded: image  Centre (0, 0); 0 < k < 1 E.g. centre (0,0), factor $\frac{1}{2}$: (6,4) maps to (3,2).
H08.11 **Congruent images**	Translations, reflections and rotations keep the shape and size the same. The original and image are congruent.
H08.12 **Combined transformations**	Their order can affect the final image. E.g. start at (1,2). Translate 1 right, then reflect in the y-axis: $(-2,2)$. Reverse the order: (0,2).
H08.13 **Reflection in the x axis**	(x,y) maps to $(x,-y)$. Dashed: original Shaded: image  Mirror line: y = 0 E.g. (2,3) maps to $(2,-3)$.

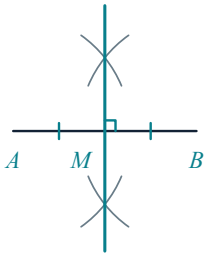
Transformations

H08.14 **Reflection in the y axis**	(x,y) maps to $(-x,y)$. Dashed: original Shaded: image  Mirror line: x = 0 E.g. (2,3) maps to $(-2,3)$.
H08.15 **Reflection in y = x**	(x,y) maps to (y,x).  Measure at right angles to the line E.g. (2,3) maps to (3,2).
H08.16 **Half turn about the origin**	(x,y) maps to $(-x,-y)$. Dashed: original Shaded: image  Centre (0, 0); 180° turn E.g. (2,3) maps to $(-2,-3)$.

Transformations

H08.17 **Enlargement at the origin**	With scale factor k, (x,y) maps to (kx,ky). Dashed: original Shaded: image  Centre (0, 0); k > 1 E.g. $k = 2$: (2,3) maps to (4,6).
H08.18 **Enlargement angles**	Enlargement preserves the sizes of corresponding angles.

Constructions

H08.19 **Bisect**	Divide into two equal parts.
H08.20 **Perpendicular bisector**	A line at 90° to a segment through its midpoint. From each endpoint, draw arcs of the same radius (more than half the segment). Join the two arc intersections.  Leave the compass arcs visible.

Matching ticks show equal lengths.

H08 | Transformations and constructions

MY RETRIEVAL PRACTICE

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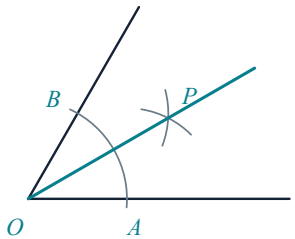
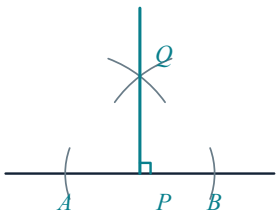
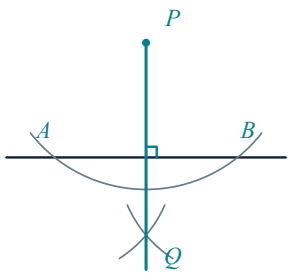
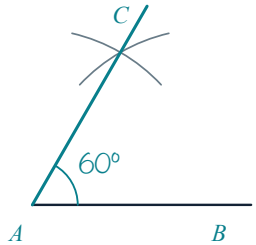
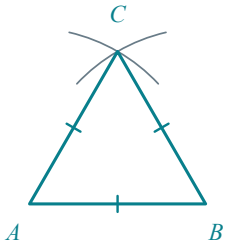
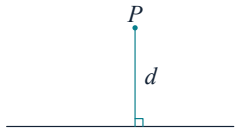
Constructions

H08.21 **Angle bisector**	A ray dividing an angle into two equal angles. From the vertex, mark equal distances on both arms. From those marks, draw equal-radius arcs; join their intersection to the vertex.  Leave the compass arcs visible. E.g. bisect 70°: Each angle = 70° ÷ 2 = 35°.
H08.22 **Perpendicular at a point on a line**	Centre the compass at the point and mark equal distances on the line. Draw equal-radius arcs from those marks. Join their intersection to the original point.  Leave the compass arcs visible.

Constructions

H08.23 **Perpendicular from a point to a line**	Centre the compass at the point and draw an arc cutting the line twice. From those intersections, draw equal-radius arcs meeting on the other side. Join that meeting point to the original point.  Leave the compass arcs visible.
H08.24 **Construct a 60° angle**	Draw a ray from A and mark B on it. Set the compass to AB. Draw arcs centred at A and B, meeting at C. Draw the ray AC: angle BAC is 60°.  Leave the compass arcs visible.

Constructions

H08.25 **Construct an equilateral triangle**	Draw a segment AB. Set the compass to AB. Draw equal-radius arcs centred at A and B, meeting at C. Join AC and BC. All three sides are equal and each angle is 60°.  Leave the compass arcs visible.
H08.26 **Shortest point to line distance**	The perpendicular distance. 
H08.27 **Triangle inequality**	The sum of any two side lengths of a triangle exceeds the third side. E.g. 2, 3 and 6 cm cannot form a triangle: 2 + 3 = 5 < 6.

Loci: constructions

H08.28 **Locus and loci**	A locus is the set of all points satisfying a condition. Loci is the plural. A locus can be a line, curve or region.

Matching ticks show equal lengths.

H08 | Transformations and constructions

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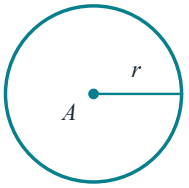
Loci: constructions

H08.29
Fixed distance from a point

All points exactly r from A form a circle, centre A, radius r. Set the compasses to r using the diagram scale and draw the full circle.

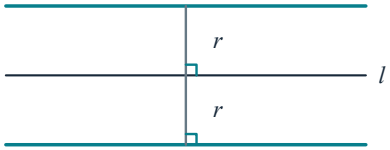


Compass radius r

H08.30
Fixed distance from a straight line

For a line extending in both directions, the locus is two parallel lines, one on each side. Mark the required distance r along perpendiculars to the given line; join the marks with a ruler.

Perpendicular distances



H08.31
Fixed distance from a line segment

The locus around finite segment AB has two parallel straight parts and a semicircle at each end. Construct offsets at distance r ; draw outward semicircles of radius r, centred at A and B, to join the ends.

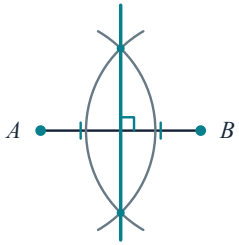
Parallel sides + semicircular ends

Loci: constructions

H08.32
Equidistant from two points

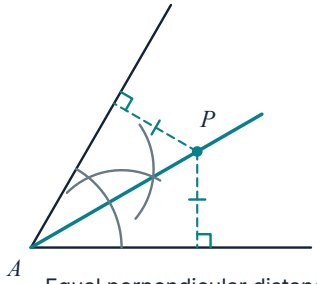
All points equally far from A and B lie on the perpendicular bisector of AB. Draw equal-radius arcs (radius greater than half AB) from both points, above and below AB; join the arc intersections.

Equal-radius compass arcs



H08.33
Equidistant from two sides of an angle

Inside an angle, the locus of points equally far from its two sides is the internal angle bisector. Construct it using equal-radius compass arcs. Measure the distances to the sides perpendicularly.



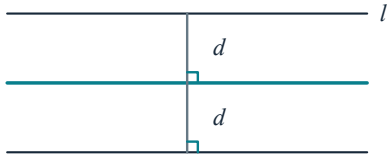
Equal perpendicular distances

Loci: constructions

H08.34
Equidistant from parallel lines

The locus is the parallel line halfway between them. Construct a perpendicular across the two lines; bisect the section between them, then draw the parallel through that midpoint.

Perpendicular distances

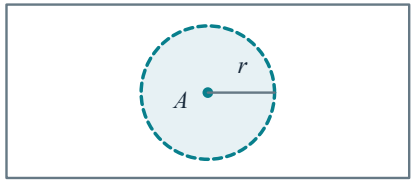


Loci: regions and conditions

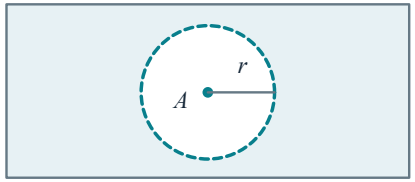
H08.35
Nearer to or further from a point

Construct the boundary circle, centre A, radius r. Shade inside for $PA < r$; shade outside for $PA > r$. Restrict the shading to the area given in the question.

PA < r: inside



PA > r: outside



H08 | Transformations and constructions

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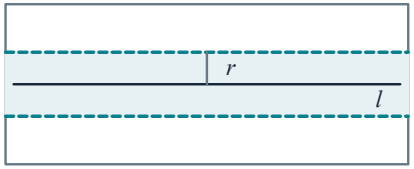
Loci: regions and conditions

H08.36

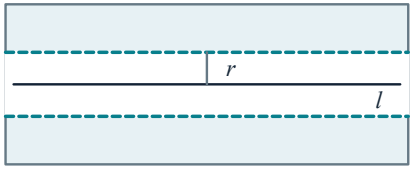
Nearer to or further from a line

Construct the two parallel boundaries at perpendicular distance r. Shade the strip between them for distance less than r; shade outside the strip for distance greater than r.

Distance < r



Distance > r

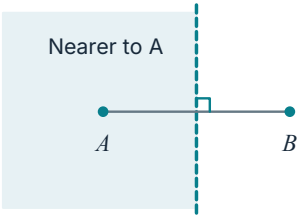


H08.37

Nearer to A than to B

Construct the perpendicular bisector of AB. Shade the side containing A. Points on the bisector are equally far from both points, so are not nearer to either.

Perpendicular bisector

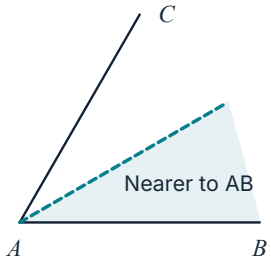


Loci: regions and conditions

H08.38

Nearer to one side of an angle

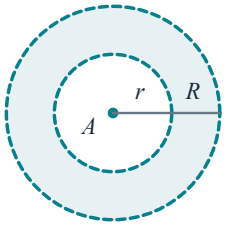
Construct the internal angle bisector. Inside the given angle, shade between the chosen side and the bisector. Check using perpendicular distances to the two sides.



H08.39

Between two distances from a point

Construct two circles with the same centre and the stated radii. Shade the ring between them. For $r < PA < R$, points on either circle are excluded.



r < PA < R

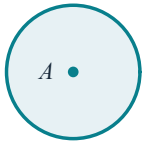
Loci: regions and conditions

H08.40

Included and excluded boundaries

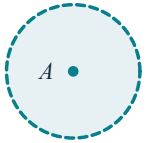
Exactly r means the boundary only. At most r means $\leq r$; at least r means $\geq r$: include the boundary. Less than / more than means $<$ / $>$: exclude it. A solid boundary shows inclusion; a dashed boundary shows exclusion.

$PA \leq r$



Boundary included

$PA < r$

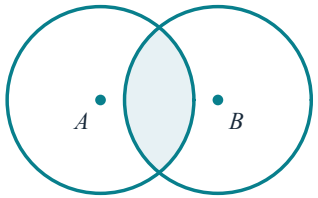


Boundary excluded

H08.41

Two conditions: AND

Construct each boundary separately. Shade only the overlap satisfying both conditions. For example, inside both circles means within the stated distance of both A and B. Keep the construction arcs visible.



Inside both circles (AND)

H08 | Transformations and constructions

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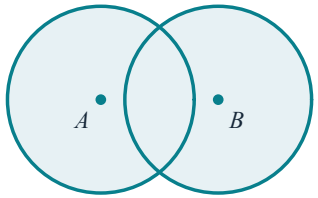
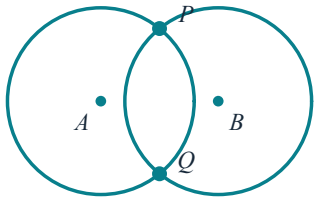
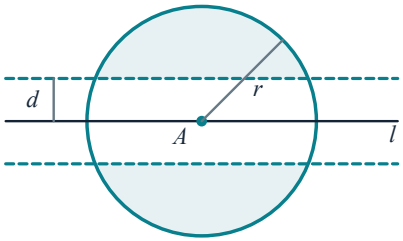
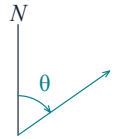
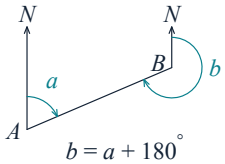
Loci: regions and conditions

H08.42 **Either condition: OR**	Shade all points satisfying at least one condition, including the overlap. For example, inside either circle means within the stated distance of A or B (or both). Only exclude the overlap if the question says exactly one.  Inside either circle (OR)
H08.43 **Two exact conditions**	Draw both loci and mark their intersection points. These are the possible positions, not a shaded area. There may be two, one or no possible positions; check any extra restriction in the question.  P and Q satisfy both exact distances

Loci: regions and conditions

H08.44 **Combining a circle and a line region**	For points within r of A and more than d from line l, construct the circle and both parallel offsets. Shade the parts inside the circle that lie outside the distance-d strip. Check every part against both conditions.  Inside circle AND outside strip
H08.45 **Solving a loci region problem**	Convert real distances using the scale. Construct every boundary with ruler and compasses. Decide which side of each boundary is allowed; use a test point if needed. Shade only the region meeting all conditions and lying within the given plan. Leave construction arcs visible.

Bearings and scale

H08.46 **Bearing**	An angle measured clockwise from north, written with three digits.  E.g. 45° clockwise from north is written as bearing 045°.
H08.47 **Reverse bearing**	Differs from the original bearing by 180°, expressed in the range 000° to less than 360°.  $b = a + 180^\circ$ E.g. A to B: 070°. B to A: 070° + 180° = 250°.
H08.48 **Scale 1 : n**	One unit on the drawing represents n of the same units in reality. **Map (cm) Real (cm)** 1 : 200 ×3 ×3 3 : 600 Scale 1 : 200. 3 cm represents 600 cm = 6 m.

H09 | Equations and inequalities

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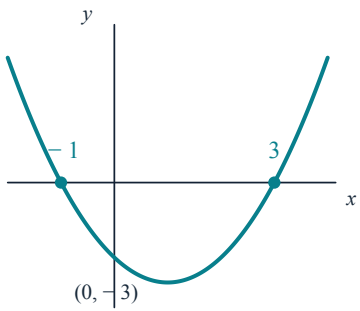
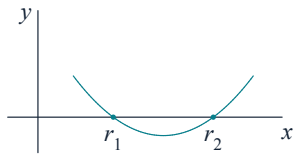
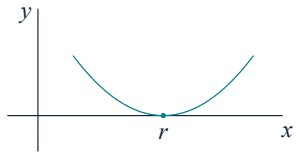
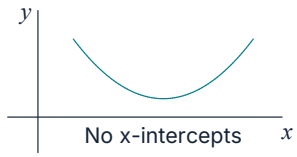
Quadratic equations

H09.01 **Quadratic expression**	An expression $ax^2 + bx + c$, with $a \neq 0$.
H09.02 **Factorising quadratics**	For $x^2 + bx + c$, find two numbers with product c and sum b. Put these numbers in the two brackets. $x^2 + x - 6$ Product -6, sum 1: use 3 and -2. $3 \times (-2) = -6$; $3 + (-2) = 1$. So $x^2 + x - 6 = (x + 3)(x - 2)$.
H09.03 **Factorising: coefficient of x^2**	For $ax^2 + bx + c$, find two numbers with product ac and sum b. Split the middle term, then factorise by grouping. $2x^2 + 11x + 12$ Product $2 \times 12 = 24$, sum 11: use 3 and 8. $= 2x^2 + 3x + 8x + 12$ $= x(2x + 3) + 4(2x + 3)$ $= (2x + 3)(x + 4)$
H09.04 **Solving factorised quadratics**	If two factors multiply to zero, at least one factor must be zero. Set each bracket equal to zero and solve each equation. E.g. $(x - 4)(x + 1) = 0$: $x - 4 = 0$ or $x + 1 = 0$. So $x = 4$ or $x = -1$.

Quadratic equations

H09.05 **Root**	A value of the unknown that makes an equation equal to zero. On a graph, a root is an x-intercept, where y = 0.  $y = (x - 3)(x + 1)$ At $y = 0$: $x = 3$ or $x = -1$. The roots are 3 and -1.
H09.06 **Quadratic formula**	For $ax^2 + bx + c = 0$: $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$, $a \neq 0$. E.g. $2x^2 + x - 3 = 0$: $x = \frac{-1 \pm \sqrt{1 + 24}}{4}$ $= \frac{-1 \pm 5}{4}$ So $x = 1$ or $x = -\frac{3}{2}$.
H09.07 **Discriminant**	For a quadratic, $D = b^2 - 4ac$. E.g. $x^2 - 4x + 3 = 0$: $D = (-4)^2 - 4(1)(3) = 4$ Two distinct real roots.

Quadratic equations

H09.08 **Positive discriminant**	Two distinct real roots.  E.g. $x^2 - 1 = 0$: $D = 4 > 0$. Roots $x = -1, 1$.
H09.09 **Zero discriminant**	One repeated real root.  E.g. $(x - 2)^2 = 0$: $D = 0$. Repeated root $x = 2$.
H09.10 **Negative discriminant**	No real roots.  E.g. $x^2 + 1 = 0$: $D = -4 < 0$. No real roots.

H09 | Equations and inequalities

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Quadratic equations

H09.11 **Quadratic factor coefficients**	$(px+q)(rx+s) = prx^2 + (ps+qr)x + qs.$ E.g. $(2x+3)(x-4)$ $= 2x^2 - 8x + 3x - 12$ $= 2x^2 - 5x - 12.$

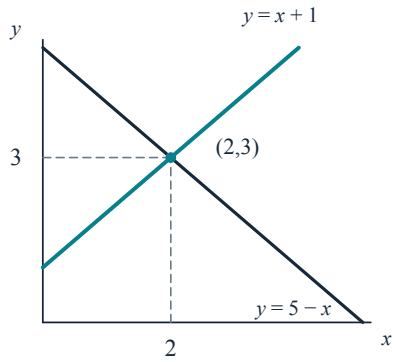
Simultaneous equations

H09.12 **Solution**	A value that makes an equation true. E.g. $x = 4$ solves $3x + 1 = 13$: $3(4) + 1 = 13.$
H09.13 **Equivalent equations**	Equations with the same solution set. E.g. $2x + 6 = 14$ and $x + 3 = 7$ both have solution $x = 4$.
H09.14 **Equality and balance**	Keep both sides balanced: do the same operation to both sides. Isolate the unknown, so it is on its own on one side. E.g. $3x + 5 = 17$ $3x = 12$ (subtract 5 from both sides). $x = 4$ (divide both sides by 3).
H09.15 **Inverse operations**	Inverse operations undo each other. Use them in reverse order to isolate the unknown. Addition undoes subtraction; multiplication undoes division. E.g. undo $\times 4$ with $\div 4$: $4x = 20$, so $x = 20 \div 4 = 5.$

Simultaneous equations

H09.16 **Linear equation**	An equation in which the highest power of the unknown is 1. If the unknown is on both sides, subtract the term with the smaller coefficient first. $5x - 7 = 2x + 8$ Subtract $2x$: $3x - 7 = 8.$ Add 7: $3x = 15.$ Divide by 3: $x = 5.$
H09.17 **Simultaneous solution**	Values satisfying all the equations at the same time. E.g. $x + y = 7$, $x - y = 1$: Add: $2x = 8$, so $x = 4$. Then $y = 7 - 4 = 3.$
H09.18 **Linear simultaneous equations: elimination**	Multiply one or both equations if needed to match the size of an x or y coefficient. Then use SSS: Same Signs Subtract; DSA: Different Signs Add. Solve the remaining equation, then substitute back to find the other unknown. Check both original equations. E.g. $2x + 3y = 13$ (1) $3x + 2y = 12$ (2). (1) $\times$ 3: $6x + 9y = 39.$ (2) $\times$ 2: $6x + 4y = 24.$ Subtract: $5y = 15$, so $y = 3.$ $3x + 2(3) = 12$, so $3x = 6.$ $x = 2.$ Check: $2(2) + 3(3) = 13$; $3(2) + 2(3) = 12.$

Simultaneous equations

H09.19 **Linear and quadratic: substitution**	Make one variable the subject of the linear equation and substitute into the quadratic. If both are written as $y = \ldots$, set the expressions equal. Solve the resulting quadratic. Substitute each root back to find its paired value. Check both pairs. E.g. $y = x + 2$, $y = x^2 - 4.$ $x^2 - 4 = x + 2$ $x^2 - x - 6 = 0$ $(x-3)(x+2) = 0$ $x = 3$ or $x = -2.$ If $x = 3$, $y = 3 + 2 = 5.$ If $x = -2$, $y = -2 + 2 = 0.$ Solutions: (3,5) and (−2,0).
H09.20 **Intersection of graphs**	Its coordinates satisfy both graph equations.  Intersection (2,3): $x = 2$, $y = 3.$

H09 | Equations and inequalities

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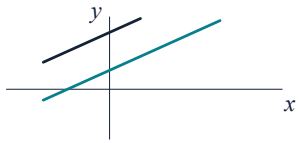
Simultaneous equations

H09.21 Parallel lines: no solution

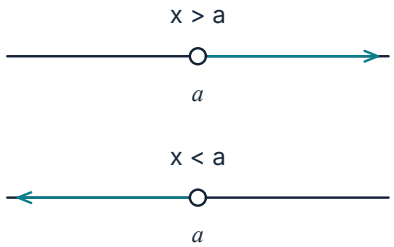
Different parallel straight lines never meet, so their equations have no simultaneous solution.



Inequalities and regions

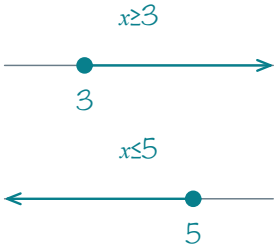
H09.22 Strict inequalities

$x < a$ or $x > a$: the endpoint is not included. Show it with an open circle on a number line.



H09.23 Inclusive inequalities

$x \leq a$ or $x \geq a$: the endpoint is included. Show it with a closed circle on a number line.



Inequalities and regions

H09.24 Solving linear inequalities

Use inverse operations as for a linear equation. Multiplying or dividing by a negative number reverses the inequality sign. Show an excluded endpoint with an open circle and an included endpoint with a closed circle.

E.g. $3x - 2 < 10$ gives $3x < 12$, so $x < 4$.
With a negative x term: $7 - 2x < 1$.
Add $2x$ to both sides: $7 < 1 + 2x$.
Subtract 1: $6 < 2x$, so $x > 3$.

H09.25 Multiplication by a negative

Multiplying or dividing an inequality by a negative number reverses its direction.

E.g. $-2x < 6$
Divide by -2: $x > -3$.

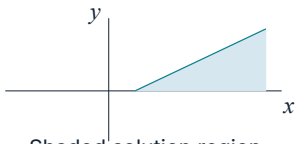
H09.26 Strict boundary line

A dashed boundary represents $<$ or $>$ and is not included.

Shaded solution region

H09.27 Inclusive boundary line

A solid boundary represents $\leq$ or $\geq$ and is included.

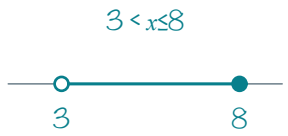


Shaded solution region

Inequalities and regions

H09.28 Combined inequalities

All stated conditions must hold. On a number line, show the interval between the endpoints and whether each endpoint is included.

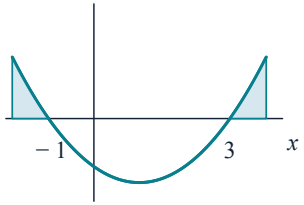


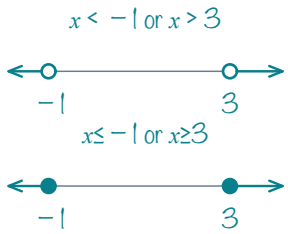
H09.29 Solving quadratic inequalities

Rearrange to $f(x) > 0$, $f(x) \geq 0$, $f(x) < 0$ or $f(x) \leq 0$. Solve $f(x) = 0$. Sketch the curve with its roots and opening direction. Select the required regions; include roots only for $\leq$ or $\geq$.

H09.30 Quadratic inequalities: positive

For $f(x) > 0$, select where the curve is above the x-axis. For $f(x) \geq 0$, include the roots too. Shown: $f(x) = (x + 1)(x - 3)$.





Shading identifies the relevant region.

H09 | Equations and inequalities

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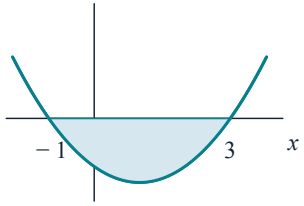
Inequalities and regions

H09.31

Quadratic inequalities: negative

For $f(x) < 0$, select where the curve is below the x-axis. For $f(x) \leq 0$, include the roots too. Shown: $f(x) = (x+1)(x-3)$.



$-1 < x < 3$

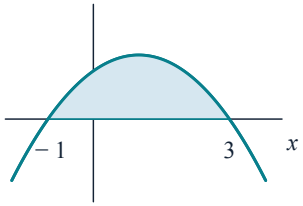
$-1 \leq x \leq 3$

Inequalities and regions

H09.32

Downward opening quadratic

A negative x^2 coefficient gives a downward-opening curve. With two distinct roots, it is above the axis between them and below the axis outside them.



$-(x+1)(x-3) > 0$

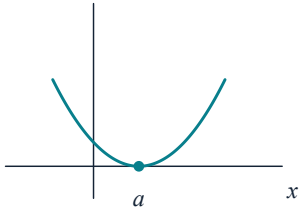
$-1 < x < 3$

Inequalities and regions

H09.33

Repeated root inequality

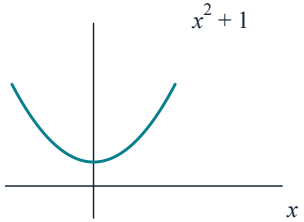
For $f(x) = (x-a)^2$:
$f(x) \geq 0$: all real x.
$f(x) > 0$: all x except a.
$f(x) \leq 0$: only x = a.
$f(x) < 0$: no solutions.



H09.34

Quadratic with no real roots

The curve never meets the x-axis. A positive leading coefficient puts it entirely above the axis; a negative one puts it entirely below.



Shading identifies the relevant region.

H10 | Probability

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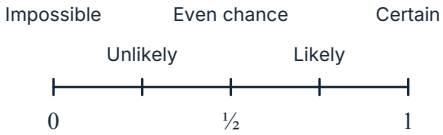
Probability foundations

H10.01 Probability scale

From 0 (impossible) to 1 (certain), inclusive.



H10.02 Outcome

A possible result of a trial.

H10.03 Event

A set of outcomes.

E.g. 'even score' on a six-sided die is the event {2,4,6}.

H10.04 Sample space

The set of all possible outcomes.

A coin and a six-sided die

Die	1	2	3	4	5	6
H	H1	H2	H3	H4	H5	H6
T	T1	T2	T3	T4	T5	T6

12 possible outcomes

H10.05 Equally likely outcomes

$$P(A) = \frac{\text{favourable outcomes}}{\text{total outcomes}}.$$

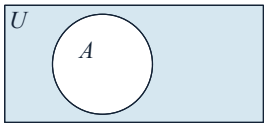
E.g. fair six-sided die:

$P(\text{even}) = \frac{3}{6} = \frac{1}{2}$.

Probability foundations

H10.06 Complement

$$P(\text{not } A) = 1 - P(A).$$



E.g. $P(\text{rain}) = 0.3$:

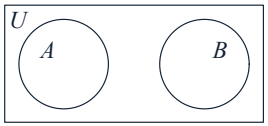
$P(\text{no rain}) = 1 - 0.3 = 0.7$.

H10.07 Exhaustive outcomes

They cover every possible outcome.

H10.08 Mutually exclusive events

They cannot happen at the same time.



H10.09 Exclusive and exhaustive outcomes

Their probabilities sum to 1.

E.g. fair die: odd or even.

$P(\text{odd}) + P(\text{even})$

$= \frac{1}{2} + \frac{1}{2} = 1$.

H10.10 Mutually exclusive addition

For mutually exclusive A and B: $P(A \text{ or } B) = P(A) + P(B)$.

E.g. fair die: score 1 or 2:

$\frac{1}{6} + \frac{1}{6} = \frac{1}{3}$.

H10.11 Relative frequency

Observed event frequency divided by the number of trials.

E.g. 18 successes in 60 trials:

$18 \div 60 = 0.3$.

Probability foundations

H10.12 Expected frequency

Probability multiplied by the number of trials.

E.g. probability 0.2, 150 trials:

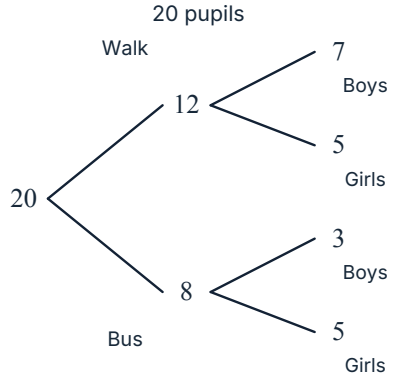
Expected successes $= 0.2 \times 150 = 30$.

H10.13 Experimental estimates

Larger numbers of representative trials generally give more reliable probability estimates.

H10.14 Frequency tree

A branching diagram showing counts rather than probabilities.



12 + 8 = 20; 7 + 5 = 12

Combined and conditional events

H10.15 Independent events

The occurrence of one does not change the probability of the other.

H10.16 Independent multiplication

For independent A and B: $P(A \text{ and } B) = P(A)P(B)$.

E.g. two independent fair coin tosses:

$P(\text{two heads}) = \frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$.

Shading identifies the relevant region.

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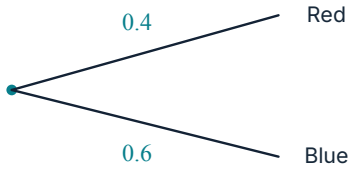
☐	☐	☐	☐	☐		☐	☐	☐	☐	☐	

Combined and conditional events

H10.17
Tree branches at a node

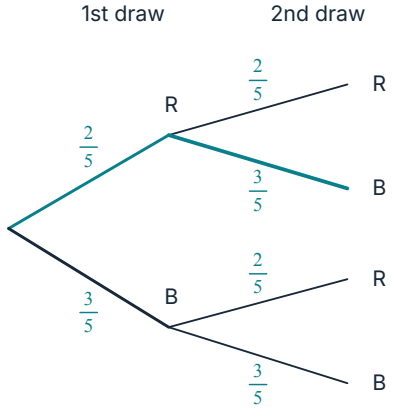
Probabilities of all possible branches from the same node sum to 1.



$0.4 + 0.6 = 1.$

H10.18
Tree path probability

The product of the probabilities along that complete path.



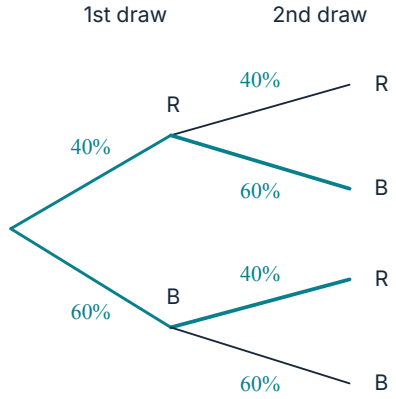
Draw twice with replacement.

$P(RB) = \frac{2}{5} \times \frac{3}{5} = \frac{6}{25}.$

Combined and conditional events

H10.19
Alternative tree paths

Probabilities of mutually exclusive successful paths are added.

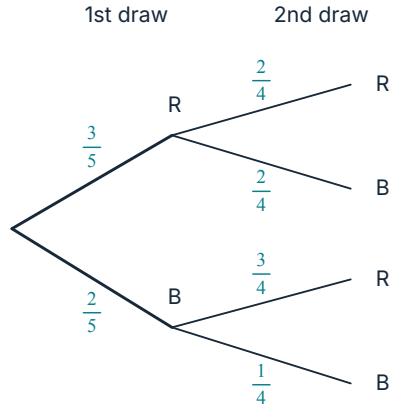


With replacement, $P(R) = 40\%$.
Convert to decimals to calculate:
$P(RB) + P(BR)$
$= 0.4 \times 0.6 + 0.6 \times 0.4$
$= 0.48 = 48\%.$

Combined and conditional events

H10.20
Sampling without replacement

The population size changes and the selections are generally dependent.



E.g. 3 red and 2 blue counters, no replacement:
$P(\text{two red}) = \frac{3}{5} \times \frac{2}{4} = \frac{3}{10}.$

H10 | Probability

MY RETRIEVAL PRACTICE

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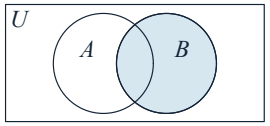
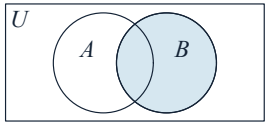
☐	☐	☐	☐	☐	_____	☐	☐	☐	☐	☐	_____

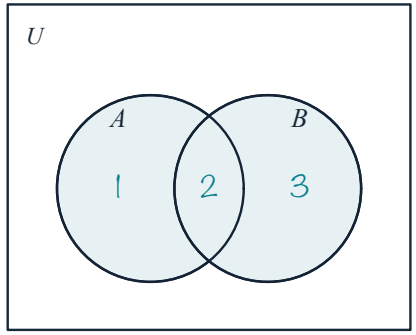
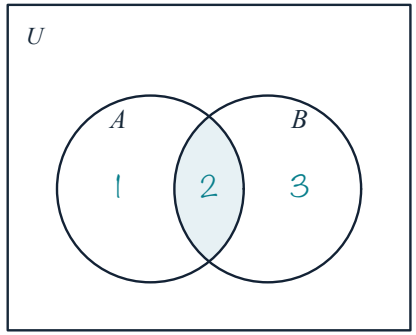
Combined and conditional events

H10.21 **Conditional probability**	The probability of an event given that another event has occurred.  Given B: consider only B
H10.22 **Conditional probability formula**	$P(A\|B) = \frac{P(A\cap B)}{P(B)}$, for $P(B) > 0$.  Given B: consider only B E.g. $P(A\cap B) = 0.2$, $P(B) = 0.5$: $P(A\|B) = 0.2 \div 0.5 = 0.4$.
H10.23 **General addition rule**	$P(A\cup B) = P(A) + P(B) - P(A\cap B)$. E.g. $P(A) = 0.4$, $P(B) = 0.5$, overlap 0.2: $P(A\cup B) = 0.4 + 0.5 - 0.2 = 0.7$.

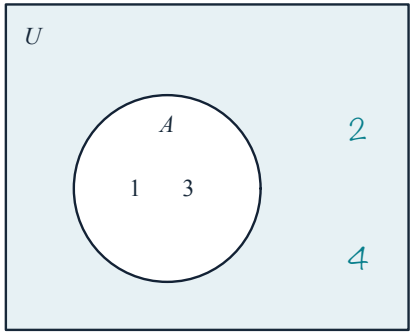
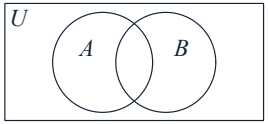
Set facts

H10.24 **Universal set**	All the elements under consideration.
H10.25 **Set member**	$x \in A$ means x belongs to set A.

Set facts

H10.26 **Union**	$A\cup B$: elements in A or B or both. Example sets  E.g. $A = \{1,2\}$, $B = \{2,3\}$: $A\cup B = \{1,2,3\}$.
H10.27 **Intersection**	$A\cap B$: elements in both A and B. Example sets  E.g. $A = \{1,2\}$, $B = \{2,3\}$: $A\cap B = \{2\}$.

Set facts

H10.28 **Set complement**	A': elements in the universal set but not in A. Example sets  E.g. universal set $\{1,2,3,4\}$, $A = \{1,3\}$: $A' = \{2,4\}$.
H10.29 **Empty set**	A set with no elements, written ∅.
H10.30 **Number in a set**	$n(A)$ is the number of elements in A. E.g. $A = \{2,4,6\}$: $n(A) = 3$.
H10.31 **Venn diagram**	Overlapping regions represent membership of sets. 

Shading identifies the relevant region.

H11 | Multiplicative change and rates

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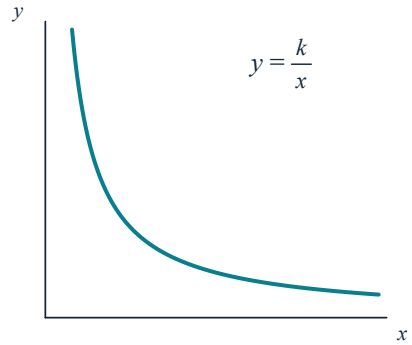
Growth and decay

H11.01 **Successive changes**	The overall multiplier is the product of the individual multipliers. E.g. 10% up, then 10% down: $1.1 \times 0.9 = 0.99$ An overall 1% decrease.
H11.02 **Compound growth**	Initial value P, after n periods at rate r%: $V = P(1+\frac{r}{100})^n$. E.g. £200 at 5% growth for 2 years: $200 \times 1.05^2 = 220.50$, so £220.50.
H11.03 **Compound decay**	Initial value P, after n periods at rate r%: $V = P(1-\frac{r}{100})^n$. E.g. £500 loses 20% yearly for 2 years: $500 \times 0.8^2 = 320$, so £320.
H11.04 **Simple interest**	For principal P, rate r% per period and t periods: $I = \frac{Prt}{100}$. Interest is on the original principal only. E.g. £300 at 4% simple interest for 3 years: $I = \frac{300 \times 4 \times 3}{100} = 36$, so £36 interest.

Growth and decay

H11.05 **Repeated multiplier**	For constant multiplier k: $u_{n+1} = ku_n$. E.g. $u_1 = 80$, $u_{n+1} = 0.5u_n$: 80, 40, 20, 10, ...

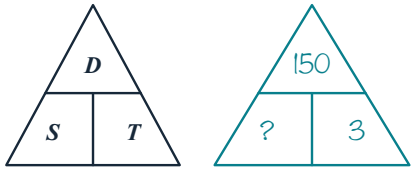
Ratio and proportion

H11.06 **Inverse proportion**	$y \propto \frac{1}{x}$ means y is inversely proportional to x: $y = \frac{k}{x}$, for $x \neq 0$. For positive quantities, as one doubles the other halves.  Positive x and y; k > 0 E.g. $y = \frac{24}{x}$. When $x = 6$: $y = 24 \div 6 = 4$.

Ratio and proportion

H11.07 **Inverse proportion invariant**	$xy = k$ is constant. E.g. $x = 6$, $y = 4$: $xy = 6 \times 4 = 24$.

Rates and units

H11.08 **Speed**	$\text{speed} = \frac{\text{distance}}{\text{time}}$. 150 km travelled in 3 hours.  150 ÷ 3 = 50 km/h Substitute the values, then divide

H11 | Multiplicative change and rates

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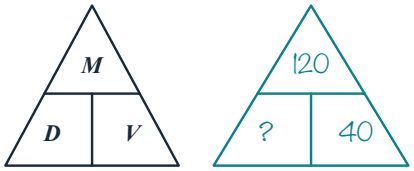
Rates and units

H11.09 Density

$$\text{density} = \frac{\text{mass}}{\text{volume}}.$$

120 g occupies 40 cm³.



120 ÷ 40 = 3 g/cm³

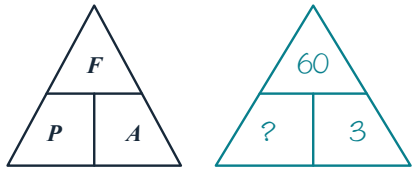
Substitute the values, then divide

Rates and units

H11.10 Pressure

$$\text{pressure} = \frac{\text{force}}{\text{area}}.$$

A force of 60 N acts on 3 m².



60 ÷ 3 = 20 N/m²

Substitute the values, then divide

H11.11 Unit price

The price for one item (or one unit of measure). Calculate cost divided by quantity, using comparable units.

Cost (£)	Number of items
3.60	8
÷ 8	÷ 8
0.45	1

45p per item

Rates and units

H11.12 Average speed

Total distance divided by total time.

E.g. 60 km in 1 h, then 60 km in 2 h:

$$\frac{60+60}{1+2} = 40 \text{ km/h}.$$

H11.13 Hours and minutes

1 hour = 60 minutes.

E.g. 1 h 45 min:

$$1 + \frac{45}{60} = 1.75 \text{ hours}.$$

H11.14 Minutes and seconds

1 minute = 60 seconds.

Acceleration

H11.15 Acceleration

Change in velocity divided by elapsed time.

E.g. velocity rises from 4 to 16 m/s in 3 s:

$$a = \frac{16-4}{3} = 4 \text{ m/s}^2.$$

H12 | Congruence and similarity

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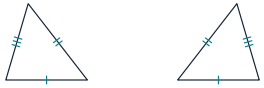
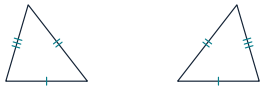
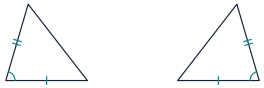
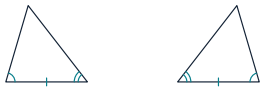
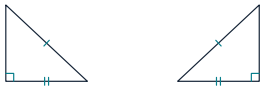
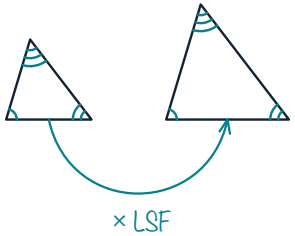
Congruence conditions

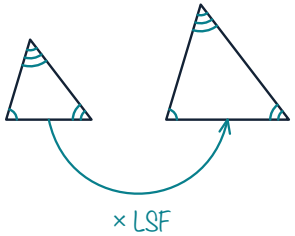
H12.01 **Congruent shapes**	Shapes with the same size and shape; corresponding lengths and angles are equal.  Matching marks: equal parts
H12.02 **SSS congruence**	Side-Side-Side. Three pairs of corresponding sides are equal.  Matching marks: equal parts
H12.03 **SAS congruence**	Side-Angle-Side. Two pairs of corresponding sides and the included angles are equal.  Matching marks: equal parts
H12.04 **ASA congruence**	Angle-Side-Angle. Two pairs of corresponding angles and a corresponding side are equal.  Matching marks: equal parts
H12.05 **RHS congruence**	Right angle-Hypotenuse-Side. Right angles, hypotenuses and one other pair of corresponding sides are equal.  Matching marks: equal parts

Matching ticks show equal lengths.

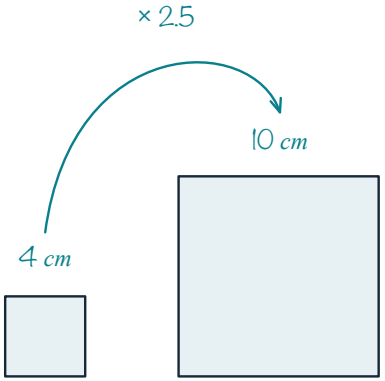
Congruence conditions

H12.06 **AAA is not congruence**	Equal corresponding angles establish triangle similarity, not necessarily equal size. Equal corresponding angles  Corresponding sides

Similarity in 2D and 3D

H12.07 **Similar shapes**	Corresponding angles are equal and corresponding lengths are in a constant ratio. Equal corresponding angles  Corresponding sides

Similarity in 2D and 3D

H12.08 **Length scale factor**	$\text{LSF} = \frac{\text{image length}}{\text{original length}}$. LSF is the positive length scale factor.  Corresponding sides Length: ×2.5; Area: ×6.25; Volume: ×15.625 E.g. corresponding sides 4 cm and 10 cm: LSF = 10 ÷ 4 = 2.5.

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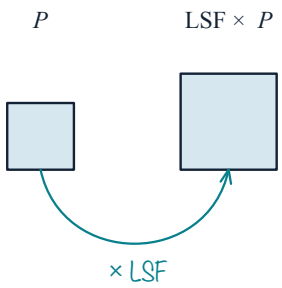
Similarity in 2D and 3D

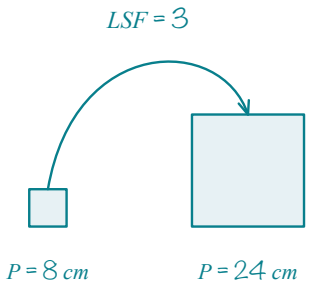
H12.09

Perimeter scale factor

For similar shapes, the perimeter scale factor (PSF) equals the length scale factor: PSF = LSF.



Corresponding sides



Length	Area	Volume
×3	×9	×27

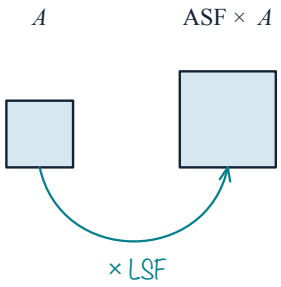
E.g. length factor 3, perimeter 8 cm:
New perimeter = 3 × 8 = 24 cm.

Similarity in 2D and 3D

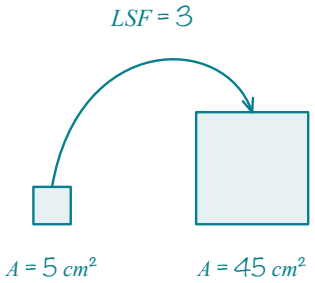
H12.10

Area scale factor

For similar shapes:
$ASF = LSF^2$.
ASF = area scale factor; LSF = length scale factor.



Corresponding sides



Length	Area	Volume
×3	×9	×27

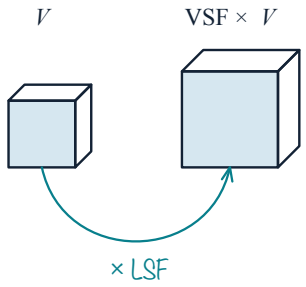
E.g. LSF 3:
ASF = 3^2 = 9.
5 cm² maps to 45 cm².

Similarity in 2D and 3D

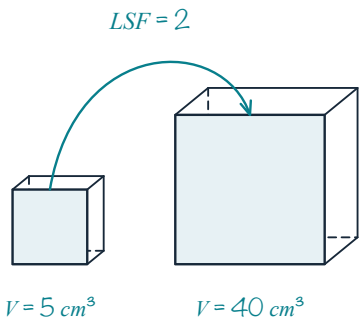
H12.11

Volume scale factor

For similar solids:
$VSF = LSF^3$.
VSF = volume scale factor; LSF = length scale factor.



Corresponding sides



Length	Area	Volume
×2	×4	×8

E.g. LSF 2:
VSF = 2^3 = 8.
5 cm³ maps to 40 cm³.

H12 | Congruence and similarity

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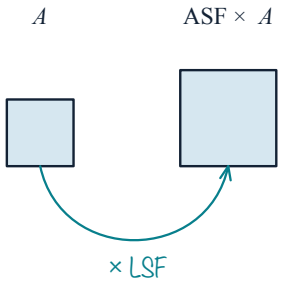
Similarity in 2D and 3D

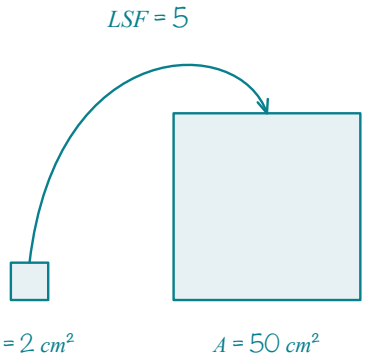
H12.12

Length from area factor

For similar shapes:
$\text{LSF} = \sqrt{\text{ASF}}$.
LSF = length scale factor; ASF = area scale factor.



Corresponding sides



Length	Area	Volume
×5	×25	×125

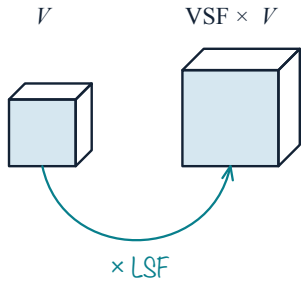
E.g. ASF 25:
LSF $= \sqrt{25} = 5$.

Similarity in 2D and 3D

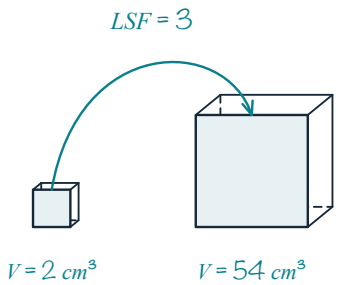
H12.13

Length from volume factor

For similar solids:
$\text{LSF} = \sqrt[3]{\text{VSF}}$.
LSF = length scale factor; VSF = volume scale factor.



Corresponding sides



Length	Area	Volume
×3	×9	×27

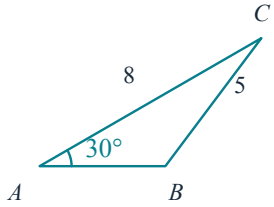
E.g. VSF 27:
LSF $= \sqrt[3]{27} = 3$.

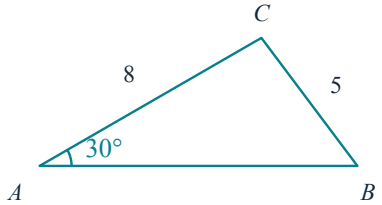
Further course facts

H12.14

SSA information

Two sides and a non-included angle do not always determine a unique triangle.





H13 | Further trigonometry

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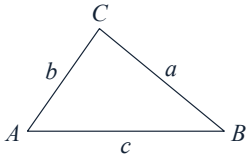
Triangle relationships

H13.01

Triangle side angle convention

Side a is opposite angle A, side b opposite B, side c opposite C.

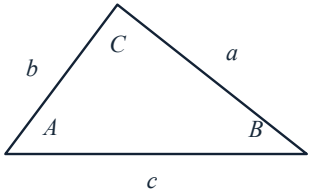


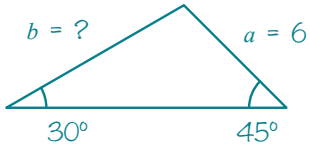
Triangle relationships

H13.02

Sine rule: missing side

Put sides on top: $\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$. Use a known opposite side-angle pair.





E.g. $A = 30°$, $B = 45°$, $a = 6$ cm:

$\frac{6}{\sin 30°} = \frac{b}{\sin 45°}$

$b = \frac{6\sin 45°}{\sin 30°}$

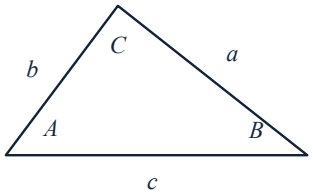
$b = 8.485... \approx 8.49$ cm (2 d.p.).

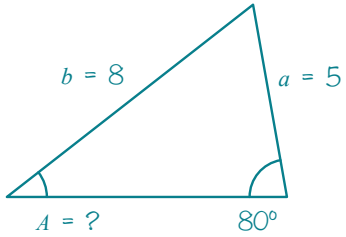
Triangle relationships

H13.03

Sine rule: missing angle

Put sines on top: $\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$. Find the sine, then use inverse sine. Check whether the supplementary angle also fits.





E.g. $a = 5$ cm, $b = 8$ cm, $B = 80°$:

$\frac{\sin A}{5} = \frac{\sin 80°}{8}$

$\sin A = \frac{5\sin 80°}{8}$

$A = \sin^{-1}(0.61550...)$

$A \approx 37.99°$ (2 d.p.).

The other angle, 142.01°, is impossible: with 80° it exceeds 180°.

H13 | Further trigonometry

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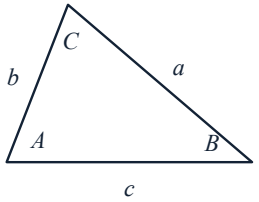
Triangle relationships

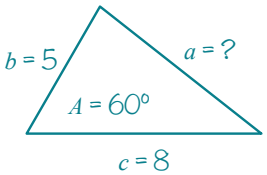
H13.04

Cosine rule

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



Example triangle



E.g. $b = 5$, $c = 8$, $A = 60°$:

$a^2 = 5^2 + 8^2 - 2 \times 5 \times 8\cos 60°$

$a^2 = 25 + 64 - 80\cos 60°$

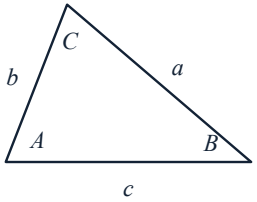
$= 49$, so $a = 7$.

Triangle relationships

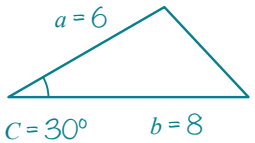
H13.05

Triangle area using sine

area $= \frac{1}{2}ab\sin C$, where C is the included angle.



Example triangle



E.g. $a = 6$ cm, $b = 8$ cm, $C = 30°$:

Area $= \frac{1}{2}(6)(8)\sin 30°$

$= 12$ cm^2.

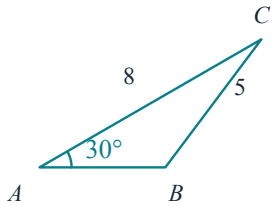
Triangle relationships

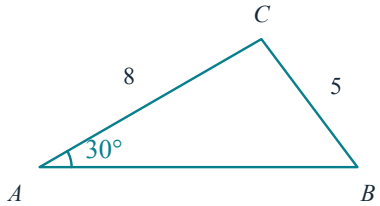
H13.06

Sine ambiguity

Two sides and a non-included angle (SSA) can give two different triangles.

For $0° < \theta < 180°$, $\sin\theta = \sin(180° - \theta)$.





E.g. $\sin 30° = \sin 150° = \frac{1}{2}$.

Check the triangle to choose a valid angle.

H13 | Further trigonometry

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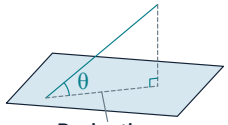
Triangle relationships

H13.07
Angle between line and plane

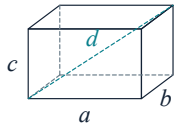
The angle between the line and its perpendicular projection onto the plane.



Triangle relationships

H13.08
Cuboid space diagonal

For perpendicular edge lengths a, b, c: $d = \sqrt{a^2 + b^2 + c^2}$.

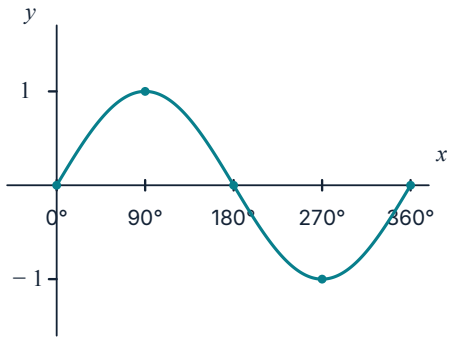


E.g. edges 3, 4 and 12 cm:
$d = \sqrt{9 + 16 + 144}$
$= 13$ cm.

Trigonometric graphs

H13.09
Sine graph

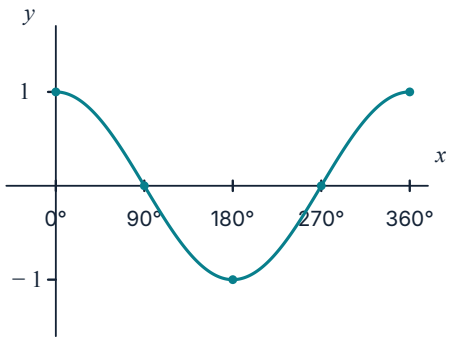
$y = \sin x$ has period 360° and range $-1 \le y \le 1$.



Trigonometric graphs

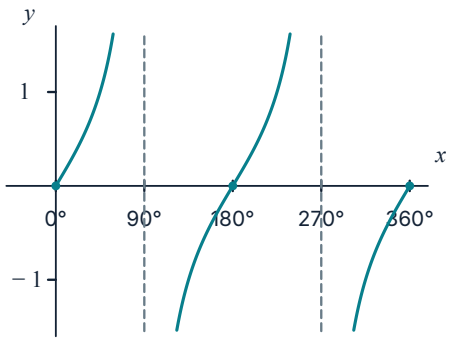
H13.10
Cosine graph

$y = \cos x$ has period 360° and range $-1 \le y \le 1$.



H13.11
Tangent graph

$y = \tan x$ has period 180°. It is undefined at $90° + 180°n$ for integer n.



Shading identifies the relevant region.

H14 | Sampling and distributions

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Collecting data

H14.01 **Population**	The whole group being studied.
H14.02 **Sample**	A subset of the population used to collect data.
H14.03 **Primary data**	Data collected first-hand for the investigation. E.g. questionnaires, interviews, observations or measurements you collect.
H14.04 **Secondary data**	Data collected previously by someone else or for another purpose. E.g. published census data, existing school records or data from a research report.
H14.05 **Random sample**	A sample selected by chance; in simple random sampling every member has equal selection probability. E.g. mix all names in a hat and draw without looking. Or number every member and use a random-number generator, without repeats.
H14.06 **Bias**	A systematic tendency to favour some outcomes or groups over others.
H14.07 **Representative sample**	A sample reflecting relevant characteristics of its population.

Collecting data

H14.08 **Stratified sample**	A sample selected from population subgroups, usually in proportion to their sizes.
H14.09 **Proportional stratum allocation**	$\frac{\text{stratum size}}{\text{population size}} \times \text{sample size.}$ E.g. subgroup 60 of 240 people, sample size 40: $\frac{60}{240} \times 40 = 10$ people.
H14.10 **Census**	Data collected from every member of the population.

Cumulative frequency and box plots

H14.11 **Cumulative frequency**

The running total of frequencies.

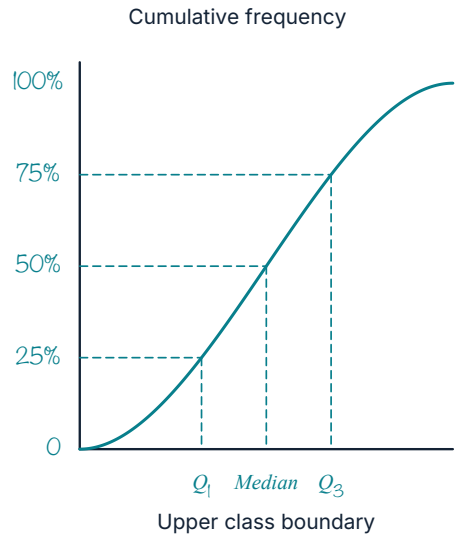
Score x	Frequency	Cumulative
$0 \le x < 10$	3	3
$10 \le x < 20$	5	8
$20 \le x < 30$	2	10

Running totals: 3, 3 + 5 = 8, 8 + 2 = 10.

Cumulative frequency and box plots

H14.12 **Cumulative frequency plot**

Plot cumulative frequency against upper class boundaries and draw a smooth increasing curve. Read across from 25%, 50% and 75% of the total frequency, then down to find Q_1, the median and Q_3.



H14 | Sampling and distributions

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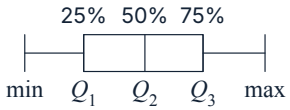
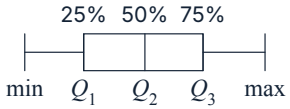
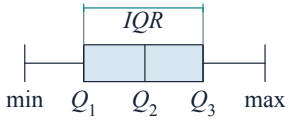
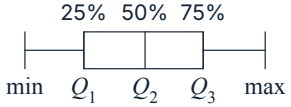
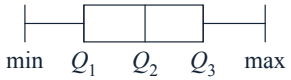
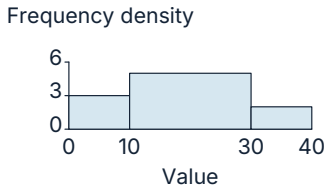
Cumulative frequency and box plots

H14.13 **Lower quartile**	The value at the 25th percentile, written Q_1. 
H14.14 **Upper quartile**	The value at the 75th percentile, written Q_3. 
H14.15 **Interquartile range**	$IQR = Q_3 - Q_1$. It measures the spread of the middle 50% of the data.  E.g. $Q_1 = 12$, $Q_3 = 20$: $IQR = 20 - 12 = 8$.

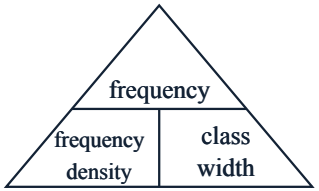
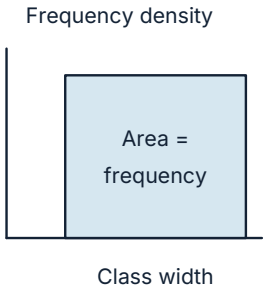
Cumulative frequency and box plots

H14.16 **Median percentile**	The 50th percentile, also called the second quartile, Q_2. 
H14.17 **Box plot**	Displays minimum, lower quartile, median, upper quartile and maximum (unless separately marked outliers are used). 

Histograms

H14.18 **Histogram**	Bar area represents frequency; bars join at class boundaries. 

Histograms

H14.19 **Frequency density**	$\text{frequency density} = \dfrac{\text{frequency}}{\text{class width}}$.  E.g. frequency 24, class $10 < x \leq 18$: Width $= 18 - 10 = 8$. Density $= 24 \div 8 = 3$.
H14.20 **Histogram frequency**	Class width multiplied by frequency density.  E.g. width 5, frequency density 4: Frequency $= 5 \times 4 = 20$.

Shading identifies the relevant region.

H15 | Further quadratics and functions

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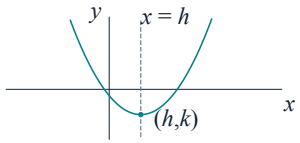
Algebra and quadratics

H15.01 Completed square form

$a(x-h)^2+k$ has turning point (h,k), for $a \neq 0$.



E.g. $y = 2(x-3)^2+5$:
Turning point (3,5), a minimum.

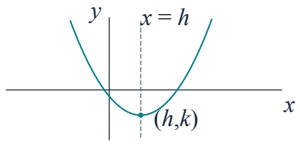
H15.02 Completing the square

$$x^2+bx=(x+\frac{b}{2})^2-\frac{b^2}{4}.$$

E.g. x^2+6x+2
$=(x+3)^2-9+2$
$=(x+3)^2-7.$

H15.03 Quadratic symmetry line

For $y=ax^2+bx+c$: $x=-\frac{b}{2a}$.

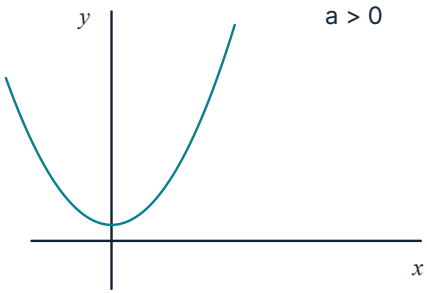


E.g. $y=2x^2-8x+1$:
Symmetry line $x=\frac{8}{2(2)}=2.$

Algebra and quadratics

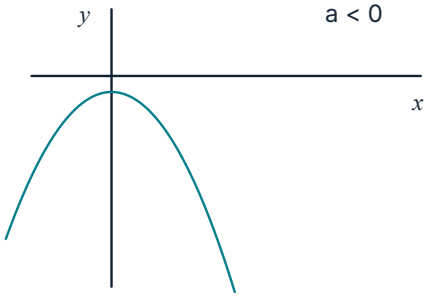
H15.04 Positive quadratic coefficient

For $y=ax^2+bx+c$ with $a>0$, the parabola opens upwards and its turning point is a minimum.



H15.05 Negative quadratic coefficient

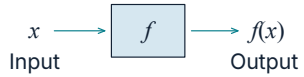
For $y=ax^2+bx+c$ with $a<0$, the parabola opens downwards and its turning point is a maximum.



Functions

H15.06 Function

A rule assigning exactly one output to each permitted input.



H15.07 Function notation

$f(x)$ is the output of function f at input x.

E.g. $f(x)=2x+3$:
$f(4)=2(4)+3=11.$

H15.08 Composite function

$fg(x)$ means $f(g(x))$: the output of g is the input to f.

f(x) = 2x + 1; g(x) = x²

fg(3) = f(g(3))

gf(3) = g(f(3))

E.g. $f(x)=2x+1$, $g(x)=x^2$:
$fg(3)=f(9)=19.$
$gf(3)=g(7)=49$: order matters.

H15 | Further quadratics and functions

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Functions

H15.09 Inverse function

f^{-1} reverses a one-to-one function, on the stated domain.

$$x \underset{f^{-1}}{\overset{f}{\rightleftarrows}} f(x)$$

E.g. $f(x) = 3x - 2$:
$y = 3x - 2$
$y + 2 = 3x$
$x = \frac{y+2}{3}$
Replace y by the inverse input x:
$f^{-1}(x) = \frac{x+2}{3}$.

Functions

H15.10 Inverse composition

$f^{-1}(f(x)) = x$ for permitted inputs.

$$x \underset{f^{-1}}{\overset{f}{\rightleftarrows}} f(x)$$

E.g. $f(x) = 2x + 1$:
$f^{-1}(x) = \frac{x-1}{2}$
$f(3) = 2(3) + 1 = 7$
$f^{-1}(7) = \frac{7-1}{2} = 3$.

H15.11 Iteration

Repeated use of a rule, often written $x_{n+1} = f(x_n)$.

E.g. $x_{n+1} = \frac{x_n + 6}{2}$, $x_0 = 2$:
$x_1 = \frac{2+6}{2} = 4$
$x_2 = \frac{4+6}{2} = 5$
$x_3 = \frac{5+6}{2} = 5.5$.

H15.12 Rearranging for iteration

Rearrange the equation into $x = g(x)$. Replace the x on the left by x_{n+1} and each x on the right by x_n.

$x^2 + x - 3 = 0$
$x^2 = 3 - x$
$x = \sqrt{3 - x}$ (for the positive root).
$x_{n+1} = \sqrt{3 - x_n}$.
Start $x_0 = 1$: $x_1 = 1.414...$, $x_2 = 1.259...$

Functions

H15.13 Locating a root by a sign change

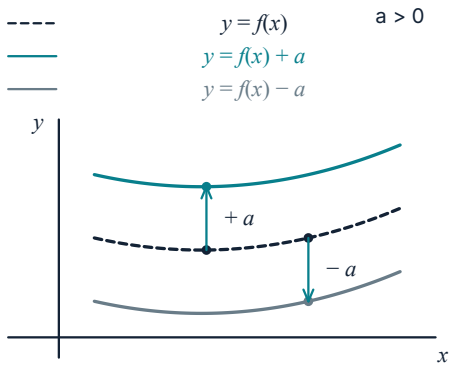
For a continuous function, opposite signs at two inputs show that a root lies between them. Test closer inputs to narrow the interval.

$f(x) = x^2 + x - 3$
$f(1) = 1 + 1 - 3 = -1$
$f(2) = 4 + 2 - 3 = 3$
The sign changes, so a root lies between 1 and 2.
$f(1.3) = -0.01$, $f(1.4) = 0.36$: a root lies between 1.3 and 1.4.

Graph transformations

H15.14 Vertical graph translation

For $a > 0$: $y = f(x) + a$ moves up by a; $y = f(x) - a$ moves down by a.
Up: $\begin{pmatrix} 0 \\ a \end{pmatrix}$; down: $\begin{pmatrix} 0 \\ -a \end{pmatrix}$.



H15 | Further quadratics and functions

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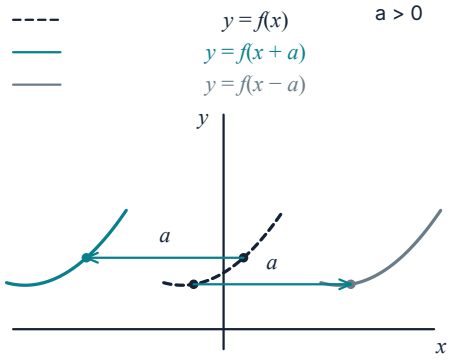
Graph transformations

H15.15 Horizontal graph translation

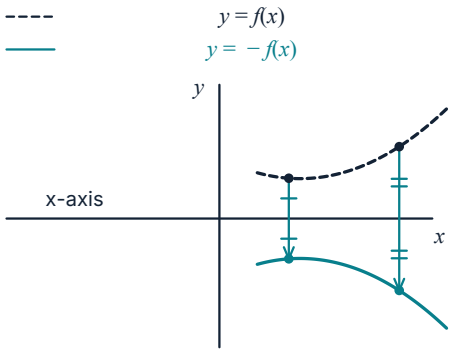
For $a > 0$: $y = f(x + a)$ moves left by a; $y = f(x - a)$ moves right by a.

Left: $\begin{pmatrix} -a \\ 0 \end{pmatrix}$; right: $\begin{pmatrix} a \\ 0 \end{pmatrix}$.



H15.16 Reflection in the x axis

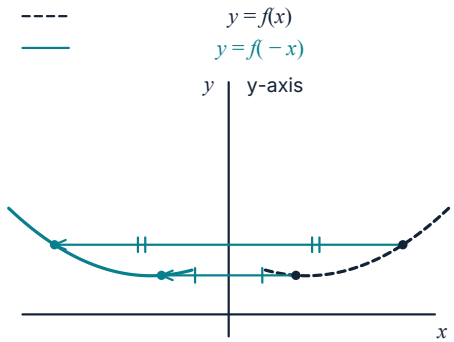
$y = -f(x)$ reflects the graph in the x-axis. $(x,y) \mapsto (x, -y)$.



Graph transformations

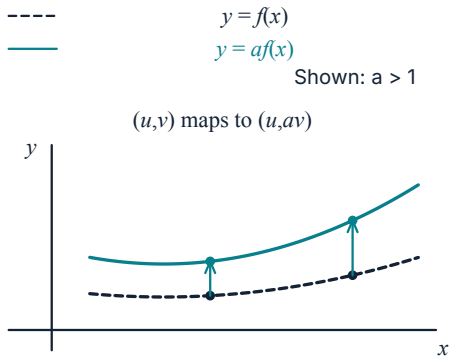
H15.17 Reflection in the y axis

$y = f(-x)$ reflects the graph in the y-axis. $(x,y) \mapsto (-x,y)$.



H15.18 Vertical graph stretch

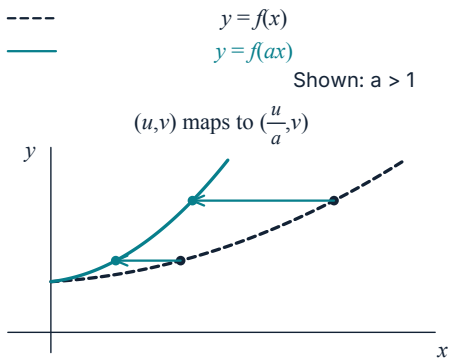
$y = af(x)$ multiplies y-coordinates by a; x-coordinates stay fixed. For $a > 1$, stretch vertically; for $0 < a < 1$, compress vertically. Negative a also reflects in the x-axis; $a = 0$ gives $y = 0$.



Graph transformations

H15.19 Horizontal graph stretch

$y = f(ax)$ multiplies x-coordinates by $\frac{1}{a}$; y-coordinates stay fixed ($a \neq 0$). For $a > 1$, compress horizontally; for $0 < a < 1$, stretch horizontally. Negative a also reflects in the y-axis.



Domain and range

H15.20 Domain

The set of permitted inputs of a function.

E.g. for $f(x) = \sqrt{x - 2}$ over real numbers, $x \geq 2$.

H15.21 Range

The set of outputs a function takes on its stated domain.

E.g. $f(x) = x^2$, with real inputs:
Range: $f(x) \geq 0$.

H15.22 One to one function

Different permitted inputs give different outputs.

E.g. $f(x) = x^2$ is not one-to-one on all real numbers:
$f(2) = f(-2) = 4$.

Matching ticks show equal lengths.

H16 | Circle reasoning

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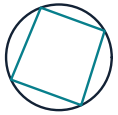
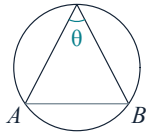
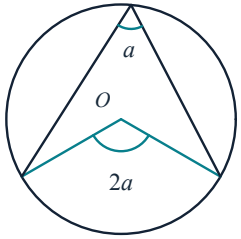
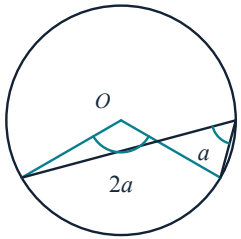
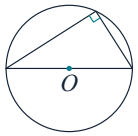
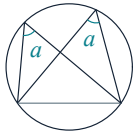
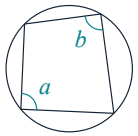
Circle vocabulary

H16.01 **Cyclic quadrilateral**	A quadrilateral with all four vertices on one circle. 
H16.02 **Equal radii**	All radii of one circle are equal in length.
H16.03 **Subtended angle**	The angle made by joining each end of a chord or arc to a point. 

Circle theorems

H16.04 **Angle at the centre**	The angle at the centre is twice the angle at the circumference.  

Circle theorems

H16.05 **Angle in a semicircle**	Angles in a semicircle are 90°. 
H16.06 **Same segment angles**	Angles in the same segment are equal. 
H16.07 **Cyclic opposite angles**	Opposite angles in a cyclic quadrilateral add up to 180°. 

Matching ticks show equal lengths.

H16 | Circle reasoning

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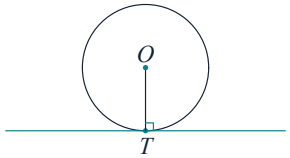
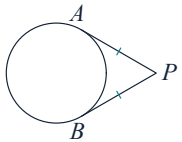
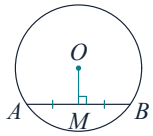
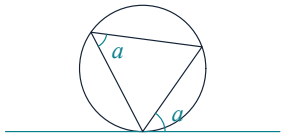
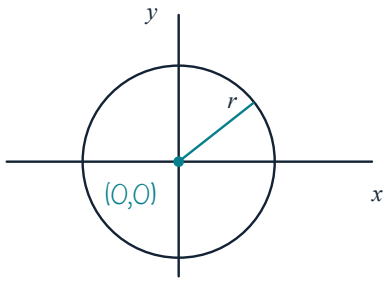
Circle theorems

H16.08 **Radius and tangent**	The angle between a tangent and a radius is 90°. 
H16.09 **Two tangents**	Tangents from a fixed point outside a circle are equal in length. 
H16.10 **Centre to chord**	The perpendicular from the centre to the chord bisects the chord. 

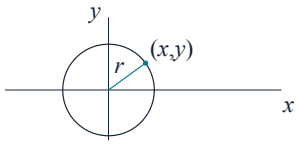
Circle theorems

H16.11 **Alternate segment theorem**	Angles in alternate segments are equal. 

Circle and line equations

H16.12 **Circle at the origin**	Centre $(0,0)$ and radius r: $x^2 + y^2 = r^2$.  E.g. centre (0,0), radius 5: $x^2 + y^2 = 25$.

Circle and line equations

H16.13 **Radius gradient**	From the origin to (x,y): $m = \frac{y}{x}$, for $x \neq 0$.  E.g. radius to (3,4): $m = \frac{4}{3}$; tangent gradient $= -\frac{3}{4}$.

Matching ticks show equal lengths.

H16 | Circle reasoning

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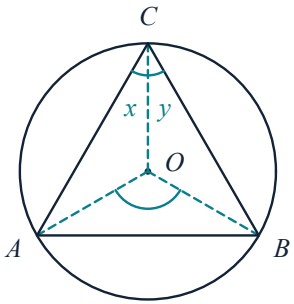
Circle Theorem Proofs

H16.14

Prove: angle at the centre



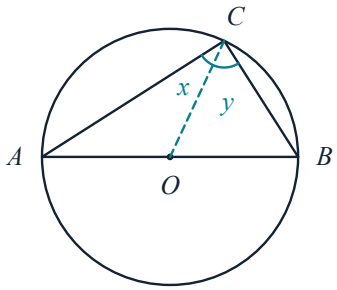
Join the centre O to A, B and C. Use the two isosceles triangles, then angles around O.

Let $\angle ACO = x$ and $\angle OCB = y$.
$OA = OC$ and $OB = OC$ (radii).
So $\angle OAC = x$ and $\angle OBC = y$ (base angles).
$\angle AOC = 180° - 2x$.
$\angle BOC = 180° - 2y$.
The remaining angle at O is
$\angle AOB = 360° - (180° - 2x) - (180° - 2y)$
$= 2x + 2y = 2(x + y)$.
But $\angle ACB = x + y$.
So $\angle AOB = 2\angle ACB$.

Circle Theorem Proofs

H16.15

Prove: angle in a semicircle



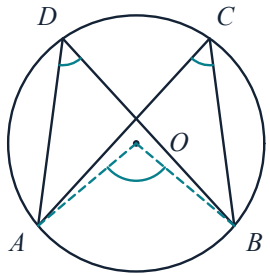
Join O to C to form two isosceles triangles. Use equal base angles and the angle sum of triangle ABC.

Let $\angle ACO = x$ and $\angle OCB = y$.
$OA = OC$, so $\angle OAC = x$ (isosceles triangle).
$OB = OC$, so $\angle OBC = y$ (isosceles triangle).
In triangle ABC:
$x + y + (x + y) = 180°$.
$2(x + y) = 180°$.
$x + y = 90°$.
But $\angle ACB = x + y$.
Therefore $\angle ACB = 90°$.

Circle Theorem Proofs

H16.16

Prove: angles in the same segment



Join O to the ends of chord AB. Compare the angles at C and D with the same central angle.

C and D lie in the same segment of the circle.
Both angles stand on the same arc AB.
$\angle ACB = \frac{1}{2}\angle AOB$.
$\angle ADB = \frac{1}{2}\angle AOB$.
Each is half the same angle at the centre.
Therefore $\angle ACB = \angle ADB$.

H16 | Circle reasoning

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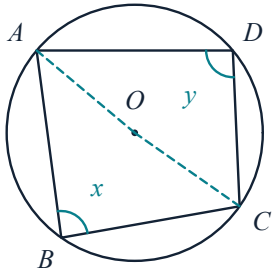
Circle Theorem Proofs

H16.17

Prove: cyclic opposite angles



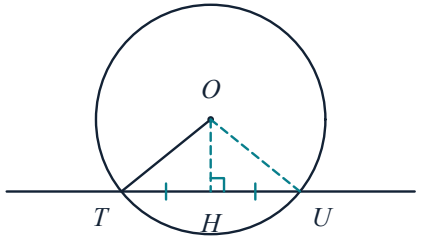
Join O to opposite vertices A and C. The two angles around O correspond to the two opposite angles.

Let $\angle ABC = x$ and $\angle ADC = y$.
The central angle standing on arc ADC is $2x$.
The other central angle, standing on arc ABC, is $2y$.
Together they make a full turn:
$2x + 2y = 360°$.
Divide by 2: $x + y = 180°$.
So $\angle ABC + \angle ADC = 180°$.
The same argument gives $\angle BAD + \angle BCD = 180°$.

Circle Theorem Proofs

H16.18

Prove: radius and tangent



Contradiction sketch

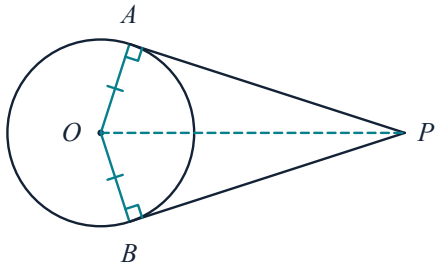
Use contradiction: assume the tangent at T is not perpendicular to OT. Drop perpendicular OH and reflect T in H to make U.

Suppose $H \neq T$. Choose U on the line so $TH = HU$, on opposite sides of H.
OH is common and $\angle OHT = \angle OHU = 90°$.
Triangles OHT and OHU are congruent (SAS).
Therefore $OU = OT$.
Since OT is a radius, U is also on the circle.
The line now meets the circle at two distinct points, T and U.
This contradicts the definition of a tangent.
So $H = T$ and OT is perpendicular to the tangent.

Circle Theorem Proofs

H16.19

Prove: two tangents



Join O to both points of contact and to the external point P. Prove the two right-angled triangles congruent.

$OA = OB$ (radii).
OP is a common hypotenuse.
$\angle OAP = \angle OBP = 90°$ (radius and tangent).
Triangles OAP and OBP are congruent by RHS.
Corresponding sides are equal:
$AP = BP$.
Therefore tangents from the same external point are equal in length.

H16 | Circle reasoning

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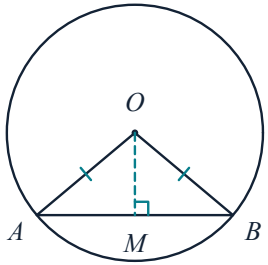
Circle Theorem Proofs

H16.20

Prove: centre to chord



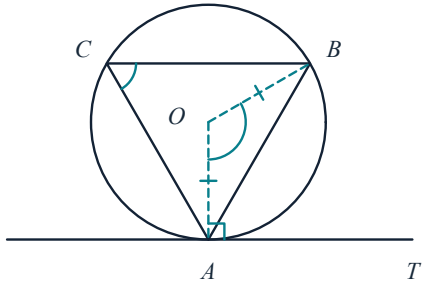
Join O to both ends of chord AB. Use RHS congruence on the two triangles made by perpendicular OM.

$OA = OB$ (radii).
OM is a common side.
$\angle OMA = \angle OMB = 90°$.
Triangles OMA and OMB are congruent by RHS.
So $AM = MB$ (corresponding sides).
Therefore OM bisects chord AB.
If AB is a diameter, $M = O$ and $AM = MB$ because both are radii.

Circle Theorem Proofs

H16.21

Prove: alternate segment theorem



OA = OB; angle AOB = 2α

Join radii OA and OB. Use the centre-angle theorem, equal base angles in isosceles triangle AOB, and the radius-tangent right angle.

Let $\angle ACB = \alpha$. Then $\angle AOB = 2\alpha$ (centre angle).
As $OA = OB$, $\angle OAB = \frac{180° - 2\alpha}{2} = 90° - \alpha$.
OA meets the tangent at $90°$, so $\angle TAB = 90° - (90° - \alpha) = \alpha$.
Therefore $\angle TAB = \angle ACB$, as required.

H17 | Further algebra and proof

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Algebraic fractions

H17.01 **Algebraic fractions: cancellation**	Only common factors of numerator and denominator can be cancelled. $\frac{x^2-9}{x-3}$ $=$ $\frac{\cancel{(x-3)}(x+3)}{\cancel{(x-3)}}$ $= x+3$
H17.02 **Algebraic fraction restrictions**	Values making any original denominator zero are excluded. E.g. $\frac{x+2}{x-5}$ is undefined at $x = 5$ because its denominator is zero.
H17.03 **Repeated subject and factoring**	$ax + bx = (a+b)x$ allows repeated occurrences of a subject to be collected as one factor. E.g. $y = ax + bx$ $y = x(a+b)$ $x = \frac{y}{a+b}$, for $a + b \neq 0$.

Surds and conjugates

H17.04 **Rationalise: one term denominator**	Multiply numerator and denominator by the surd that makes the denominator rational. E.g. $\frac{3}{\sqrt{2}} \times \frac{\sqrt{2}}{\sqrt{2}}$ $= \frac{3\sqrt{2}}{2}$.
H17.05 **Conjugates**	$a + \sqrt{b}$ and $a - \sqrt{b}$ are conjugates. Their product is $a^2 - b$. E.g. $(3+\sqrt{2})(3-\sqrt{2})$ $= 9 - 2 = 7$.
H17.06 **Rationalise: two term denominator**	For an integer plus or minus a surd, multiply numerator and denominator by the conjugate. Expand and simplify: the denominator becomes rational. E.g. $\frac{1}{3+\sqrt{2}} \times \frac{3-\sqrt{2}}{3-\sqrt{2}}$ $= \frac{3-\sqrt{2}}{9-2} = \frac{3-\sqrt{2}}{7}$.

Algebraic proof

H17.07 **Even integer**	An integer of the form $2n$, where n is an integer.

Algebraic proof

H17.08 **Odd integer**	An integer of the form $2n + 1$, where n is an integer.
H17.09 **Consecutive integers**	Integers of the form n, $n + 1$, $n + 2$, and so on.
H17.10 **Multiple of an integer**	A multiple of k has form kn for an integer n.
H17.11 **Counterexample**	One valid example that disproves a general claim. E.g. the claim 'all primes are odd' is disproved by 2.
H17.12 **Proof**	A logically justified argument establishing a result for every permitted case. E.g. the sum of any two even integers: $2m + 2n = 2(m + n)$. This is even because $m + n$ is an integer.

Consecutive parity

H17.13 **Consecutive even integers**	Integers $2n$, $2n + 2$, $2n + 4$, and so on.
H17.14 **Consecutive odd integers**	Integers $2n + 1$, $2n + 3$, $2n + 5$, and so on.

H18 | Vectors and geometry proofs

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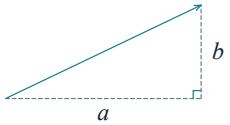
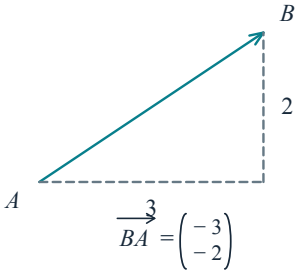
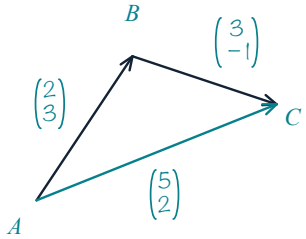
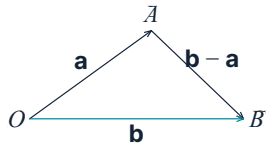
Vector facts

H18.01 **Vector**	A quantity with magnitude and direction. Direction follows the arrow E.g. displacement 5 m east, velocity 3 m/s north, or a force of 10 N downwards.
H18.02 **Scalar**	A quantity with magnitude only. E.g. mass 5 kg, time 10 s, distance 20 m or speed 3 m/s. No direction is given.
H18.03 **Column vector**	$\begin{pmatrix} a \\ b \end{pmatrix}$ means horizontal movement a, vertical movement b. 

Vector facts

H18.04 **Equal vectors**	They have the same magnitude and direction, regardless of position.
H18.05 **Reverse vector**	$\overrightarrow{BA} = -\overrightarrow{AB}$. $\overrightarrow{AB} = \begin{pmatrix} 3 \\ 2 \end{pmatrix}$  $\overrightarrow{BA} = \begin{pmatrix} -3 \\ -2 \end{pmatrix}$ E.g. $\overrightarrow{AB} = \begin{pmatrix} 3 \\ 2 \end{pmatrix}$ $\overrightarrow{BA} = \begin{pmatrix} -3 \\ -2 \end{pmatrix}$

Vector facts

H18.06 **Vector addition**	$\overrightarrow{AB} + \overrightarrow{BC} = \overrightarrow{AC}$. Add matching column-vector components: $\begin{pmatrix} a \\ b \end{pmatrix} + \begin{pmatrix} c \\ d \end{pmatrix} = \begin{pmatrix} a+c \\ b+d \end{pmatrix}$.  E.g. $\begin{pmatrix} 2 \\ 3 \end{pmatrix} + \begin{pmatrix} 3 \\ -1 \end{pmatrix} = \begin{pmatrix} 5 \\ 2 \end{pmatrix}$.
H18.07 **Position vector difference**	If A and B have position vectors **a**,**b**, then $\overrightarrow{AB}$ = **b** − **a**.  E.g. **a** = $\begin{pmatrix} 1 \\ 2 \end{pmatrix}$, **b** = $\begin{pmatrix} 4 \\ 6 \end{pmatrix}$. $\overrightarrow{AB} = \begin{pmatrix} 4-1 \\ 6-2 \end{pmatrix} = \begin{pmatrix} 3 \\ 4 \end{pmatrix}$.

H18 | Vectors and geometry proofs

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Vector facts

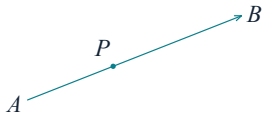
H18.08 Parallel vectors

Non-zero scalar multiples of the same non-zero vector are parallel.

E.g. $\begin{pmatrix}6\\-4\end{pmatrix}=2\begin{pmatrix}3\\-2\end{pmatrix}$.
The vectors are parallel.

H18.09 Collinear points

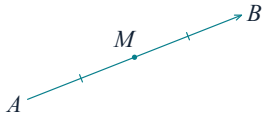
Points on the same straight line. Parallel displacement vectors with a common point establish collinearity.



E.g. $\overrightarrow{AB}=2\mathbf{a}+4\mathbf{b}$ and $\overrightarrow{BC}=\mathbf{a}+2\mathbf{b}$.
Then $\overrightarrow{AB}=2\overrightarrow{BC}$. The vectors are parallel and share B, so A, B and C are collinear.

H18.10 Midpoint position vector

For endpoint position vectors **a**,**b**: $\frac{1}{2}(\mathbf{a}+\mathbf{b})$.

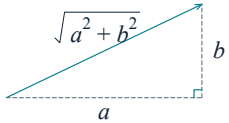


E.g. endpoint vectors $\begin{pmatrix}2\\4\end{pmatrix}, \begin{pmatrix}6\\8\end{pmatrix}$.
Midpoint $=\frac{1}{2}\begin{pmatrix}8\\12\end{pmatrix}=\begin{pmatrix}4\\6\end{pmatrix}$.

Vector facts

H18.11 Vector magnitude

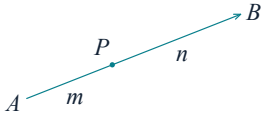
For $\begin{pmatrix}a\\b\end{pmatrix}$: magnitude $\sqrt{a^2+b^2}$.



E.g. magnitude of $\begin{pmatrix}3\\4\end{pmatrix}$:
$\sqrt{3^2+4^2}=5$.

H18.12 Internal division of a segment

If $AP:PB=m:n$, then $\overrightarrow{AP}=\frac{m}{m+n}\overrightarrow{AB}$.



E.g. $AP:PB=2:3$:
$\overrightarrow{AP}=\frac{2}{5}\overrightarrow{AB}$.

Column vector arithmetic

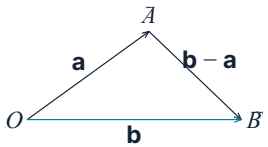
H18.13 Scalar multiplication

$$k\begin{pmatrix}a\\b\end{pmatrix}=\begin{pmatrix}ka\\kb\end{pmatrix}.$$

$a=\begin{pmatrix}2\\1\end{pmatrix}, b=\begin{pmatrix}3\\-2\end{pmatrix}$.
$2a+b=2\begin{pmatrix}2\\1\end{pmatrix}+\begin{pmatrix}3\\-2\end{pmatrix}$
$=\begin{pmatrix}4\\2\end{pmatrix}+\begin{pmatrix}3\\-2\end{pmatrix}=\begin{pmatrix}7\\0\end{pmatrix}$.

H18.14 Column vector subtraction

$$\begin{pmatrix}a\\b\end{pmatrix}-\begin{pmatrix}c\\d\end{pmatrix}=\begin{pmatrix}a-c\\b-d\end{pmatrix}.$$



E.g. $\begin{pmatrix}2\\3\end{pmatrix}-\begin{pmatrix}-1\\4\end{pmatrix}=\begin{pmatrix}3\\-1\end{pmatrix}$.

Matching ticks show equal lengths.

H19 | Non-linear graphs and proportion

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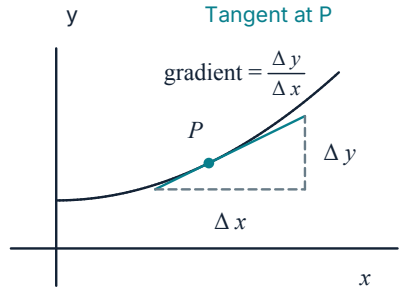
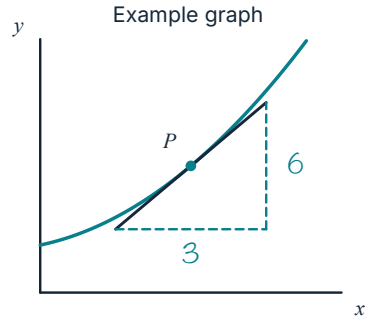
Proportion

H19.01 **Proportion to a power**	$y \propto x^n$ means $y = kx^n$. E.g. $y = kx^2$; $y = 20$ when $x = 2$: $20 = k(2^2)$ $20 = 4k$ $k = 20 \div 4 = 5$ Substitute $k = 5$: $y = 5x^2$.

Proportion

H19.02 **Inverse proportion to a power**	$y \propto \frac{1}{x^n}$ means $y = \frac{k}{x^n}$. E.g. $y = \frac{k}{x^2}$; $y = 3$ when $x = 2$: $3 = \frac{k}{2^2} = \frac{k}{4}$ $k = 3 \times 4 = 12$ Substitute $k = 12$: $y = \frac{12}{x^2}$.
H19.03 **Proportion to a square root**	$y \propto \sqrt{x}$ means $y = k\sqrt{x}$. E.g. $y = k\sqrt{x}$; $y = 12$ when $x = 9$: $12 = k\sqrt{9} = 3k$ $k = 12 \div 3 = 4$ Substitute $k = 4$: $y = 4\sqrt{x}$.

Rates and areas

H19.04 **Instantaneous rate**	The gradient of the tangent to a curve gives its rate of change at that point.   E.g. a tangent rises 6 units over a run of 3: Instantaneous rate $= 6 \div 3 = 2$.

H19 | Non-linear graphs and proportion

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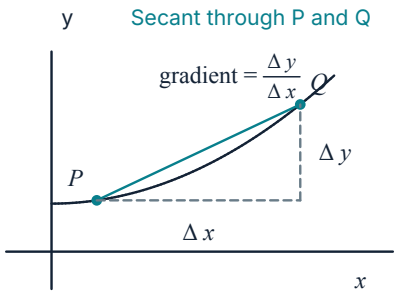
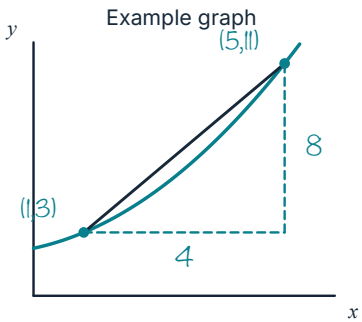
Rates and areas

H19.05

Average rate

The gradient of the chord joining two graph points gives the average rate over that interval.





E.g. points (1,3) and (5,11):

Average rate $= \frac{11-3}{5-1} = 2.$

Rates and areas

H19.06

Area under a graph: equal strips

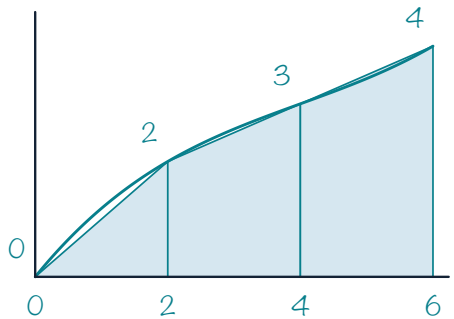
Divide the interval into equal-width strips. Look at the shape of each strip.

Triangle: $A = \frac{\text{base} \times \text{height}}{2}$.

Trapezium: $A = \frac{1}{2}(a+b)h$, where a,b are the parallel sides and h is their perpendicular separation.

Add all strip areas.

Equal strips: h = 2



Triangle + trapezium + trapezium

E.g. strip width 2; heights 0,2,3,4.

Triangle: $\frac{2 \times 2}{2} = 2.$

First trapezium: $\frac{1}{2}(2+3) \times 2 = 5.$

Second trapezium: $\frac{1}{2}(3+4) \times 2 = 7.$

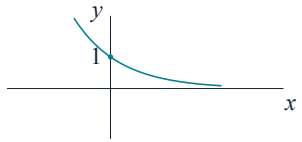
Total area $\approx 2 + 5 + 7 = 14$ square units.

Growth and decay

H19.07

Exponential decay graph

For $0 < a < 1$, $y = a^x$ decreases and passes through $(0,1)$.



Shading identifies the relevant region.

The thinking behind the guidance.

Research informing the study routines in this book. Follow the links to explore the original work.

1 **Cowan (2014)**
Working memory, learning and education.
https://pubmed.ncbi.nlm.nih.gov/25346585/

2 **Dunlosky et al. (2013)**
Improving Students' Learning With Effective Learning Techniques.
https://doi.org/10.1177/1529100612453266

3 **Roediger & Karpicke (2006)**
Retrieval practice and longer-term retention.
https://doi.org/10.1111/j.1467-9280.2006.01693.x

4 **Agarwal, Bain & Chamberlain (2012)**
Retrieval practice in school classrooms.
https://doi.org/10.1007/s10648-012-9210-2

5 **Cepeda et al. (2008)**
Spacing, review intervals and retention.
https://doi.org/10.1111/j.1467-9280.2008.02209.x

6 **Karpicke & Roediger (2007)**
Repeated retrieval and long-term retention.
https://doi.org/10.1016/j.jml.2006.09.004

7 **Bjork Learning & Forgetting Lab**
Desirable difficulties: useful, manageable challenges.
https://bjorklab.psych.ucla.edu/research/

8 **Rohrer et al. (2020)**
Randomised classroom study of interleaved maths practice.
https://doi.org/10.1037/edu0000367

9 **Pan & Rickard (2018)**
Transfer of test-enhanced learning: meta-analytic review.
https://doi.org/10.1037/bul0000151

10 **Rohrer & Taylor (2007)**
The shuffling of mathematics problems improves learning.
https://doi.org/10.1007/s11251-007-9015-8

11 **Emeny, W. G., Hartwig, M. K., & Rohrer, D. (2021)**
Spaced mathematics practice improves test scores and reduces overconfidence.
Applied Cognitive Psychology, 35(4), 1082–1089.
https://doi.org/10.1002/acp.3814

Judge learning by what you can recall later.

Use retrieval and spaced returns, then apply your knowledge. Your RAG judgement should follow an honest attempt, not just familiarity with the page.

YOUR EVERYDAY ROUTINE

A little today. Stronger tomorrow.

1. **Choose**

   A few items from your current topic and learning focus.

2. **Retrieve**

   Cover the answer. Say it, write it or draw it.

3. **Check**

   Find what is accurate and correct the gaps.

4. **Return**

   Schedule several return dates, then adapt them to recall.

THINK deeply. GROW in confidence. CARE for each other.

Ready to learn.

PACK. CHECK. GO.

Lay out your equipment and check the spaces before you pack your bag.

Also pack: your timetable in its wallet, this organiser, and the exercise books or folders for your lessons.

Equipment check spaces are not drawn to scale. This is the whole-school equipment list; follow your Maths teacher's instructions.