Cambridge IGCSE · Mathematics 0580 · Notes

Constructions, scale drawings and bearings

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Read first: **Geometrical terms and symmetry**, **Ratio, proportion and rates**

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What you need to know

The Core and Extended syllabuses are the same for this topic. By the end of it you should be able to:

1. **Measure and draw lines and angles** accurately with a ruler and a protractor: lengths in centimetres or millimetres, angles in degrees, and lines parallel or perpendicular to a given line.
2. **Construct a triangle from the lengths of its three sides** using only a ruler and a pair of compasses, leaving the construction arcs in. The same method builds shapes made of triangles, such as a rhombus or a parallelogram drawn as two triangles. (Constructing perpendicular bisectors and angle bisectors is **not** needed.)
3. **Draw, use and interpret nets** of cubes, cuboids, prisms and pyramids, and use the measurements on a net to find a volume or a surface area.
4. **Draw and interpret scale drawings**: turn a length on a drawing or map into a real distance and back, using a scale written as "1 cm to 5 km" or as a ratio $1 : n$. Use a ruler for every straight line.
5. **Use and interpret three-figure bearings**: measured clockwise from north, from 000° to 360°; the directions north, east, south and west ("due east of"); measuring and drawing bearings; and finding the bearing of A from B when you know the bearing of B from A.

Understand it

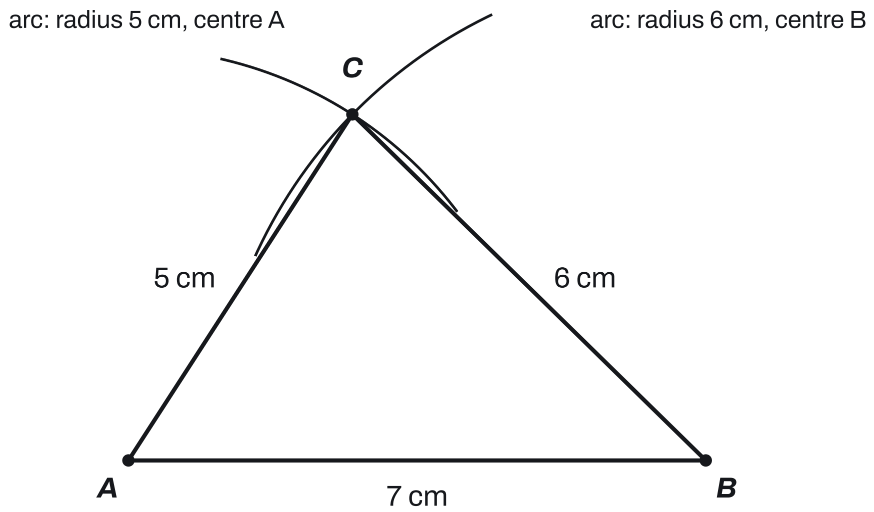
Measuring and drawing lines and angles

- **Lengths.** Put the 0 of the ruler (not the end of the ruler) on one end of the line and read the other end. 1 cm $= 10$ mm, so a line of 5.6 cm is 56 mm. Answers are usually accepted within 1 or 2 mm.
- **Angles.** Put the centre of the protractor exactly on the vertex and its zero line along one arm. A protractor has two scales; use the one that starts at 0 on the arm you lined up. Then estimate first: an obtuse angle cannot be 64°, and an acute one cannot be 116°. A reflex angle is 360° minus the angle on the other side.
- **Perpendicular** means at right angles (90°). To draw a perpendicular line through a point P, put the 90° line of the protractor (or the corner of a set square) on the line at P and rule along it.

- **Parallel** lines stay the same distance apart. Rule one using the grid lines, or measure the same distance from the line at two places and join the two points.
- The **midpoint** of a line is halfway along: measure the line and halve the length.

Constructing a triangle from three sides

A pair of compasses marks every point that is a fixed distance from a centre. So if $AC = 5$ cm, C lies on the circle of radius 5 cm about A; if $BC = 6$ cm, it lies on the circle of radius 6 cm about B. The point where the two arcs cross is C.



1. Rule one side (often it is already drawn for you) and label its ends.
2. Open the compasses to the length of the second side, measured on a ruler. Put the point on the correct end and draw an arc on the side where the triangle goes.
3. Do the same from the other end with the third length, so the arcs cross.
4. Rule from each end to the crossing point. **Leave the arcs in**: they are the evidence of the construction.

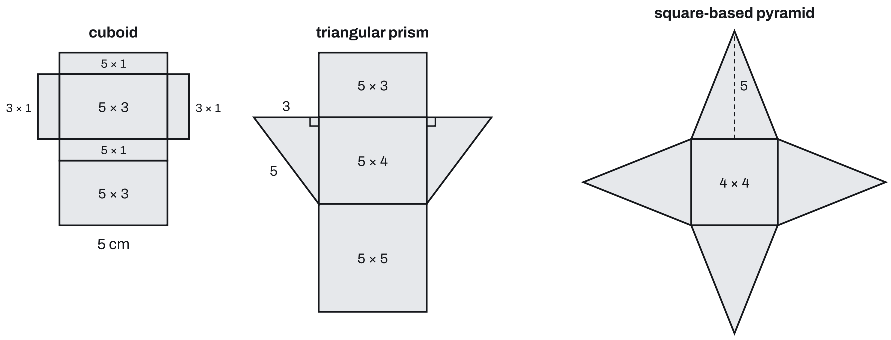
Two checks. The two shorter sides must add up to more than the longest, or the arcs never meet (you cannot draw a triangle with sides 3, 4 and 9 cm). And the length from A must go on the arc drawn from A: swapping them gives a triangle that is the mirror image, with AC and BC the wrong way round.

The same idea solves other problems:

- **A rhombus with side 5.8 cm on a given diagonal**: construct two triangles on the diagonal, one on each side, with every arc of radius 5.8 cm.
- **A parallelogram**: construct the triangle made by two sides and a diagonal, then the second triangle to finish it.
- **A point a given distance from two places**, such as a buoy 3.6 km from one boat and 2.7 km from another: turn both distances into centimetres with the scale, then draw an arc from each place. The point is where they cross (on the side the question says).

Nets

A **net** is a flat shape that folds up into a solid. Every face of the solid appears exactly once, and edges that meet when folded must be the same length.



- **Cuboid** (length l, width w, height h): 6 rectangles in three matching pairs, $l \times w$, $l \times h$ and $w \times h$. The usual layout is a column of four faces going round the cuboid with one face on each side of it. A **cube** is 6 equal squares.
- **Prism**: the two end faces are the cross-section; the rest are rectangles, all as long as the prism, one for each side of the cross-section. A triangular prism with cross-section sides 3, 4, 5 cm and length 5 cm has rectangles 5×3, 5×4 and 5×5 and two triangles. Each side of a triangle sits against the rectangle whose width is the same length: so the right angle goes at the corner where the 3 and 4 rectangles meet, and the 3 cm side lies along the 3 cm rectangle.
- **Pyramid**: the base, with one triangle on each edge of it, all meeting at the apex when folded.
- An **open box** has no lid, so its net has 5 faces, not 6.

Using a net: the **surface area** is the total area of the net. The **volume** comes from the dimensions you read off it: a cuboid's volume is $l \times w \times h$. For the $5 \times 3 \times 1$ cuboid, the surface area is $2(15 + 5 + 3) = 46$ cm² and the volume is 15 cm³.

To read the dimensions from a net, find one face whose sides you know, then match edges that fold together. On a grid, count squares.

Scale drawings and maps

A scale drawing is the real thing shrunk so that **every length is divided by the same number**. Angles are not changed, so bearings and angles can be measured straight off the drawing.

- **"1 cm to 4 km"** (or "1 cm represents 4 km"): multiply the drawing length in cm by 4 to get km. A line of 4.6 cm stands for $4.6 \times 4 = 18.4$ km. The other way, divide: 30 km is drawn as $30 \div 4 = 7.5$ cm.
- **A ratio scale** $1 : n$ means 1 cm on the map is n cm in real life (any unit, the same on both sides). To change units, use 100 cm $= 1$ m and 1000 m $= 1$ km, so 1 km $= 100\,000$ cm.

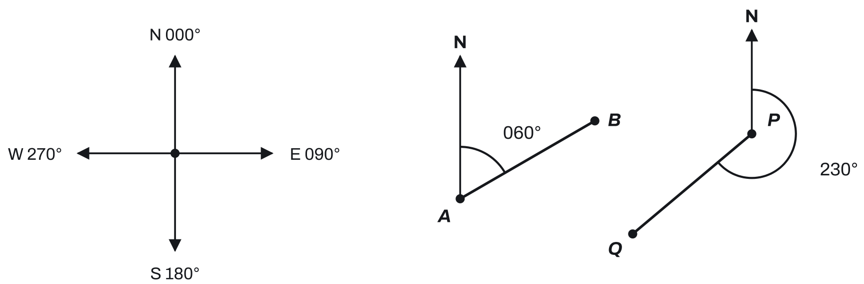
$$1 : 250\,000 \;\text{ means }\; 1 \text{ cm} \to 250\,000 \text{ cm} = 2500 \text{ m} = 2.5 \text{ km}.$$

- To write "1 cm to 4 km" as $1 : n$, change 4 km into cm: $4 \times 100\,000 = 400\,000$, so $1 : 400\,000$. Both sides must be in the same unit before you drop the units.

- **Areas on a map.** An area is length times length, so it is scaled by the length scale **squared**. At 1 cm to 4 km, each 1 cm $\times$ 1 cm square on the map stands for $4 \times 4 = 16$ km². The easy way: find what 1 cm stands for, square it, then multiply by the map area.
- **A different scale.** If you redraw a map at a new scale, the bearings stay the same and only the lengths change.

Bearings

A **bearing** gives a direction as an angle measured **clockwise from north**, written with **three figures**: 060°, not 60°. North is 000°, east 090°, south 180° and west 270°. "Due east of C" means on a bearing of exactly 090° from C.

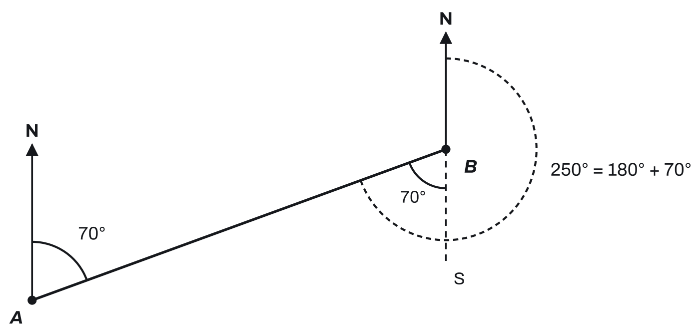


"The bearing of B from A" is measured **at** A: stand at A, face north, and turn clockwise until you face B. The word after "from" tells you where to put the protractor.

To measure a bearing more than 180° with a semicircular protractor, measure the angle anticlockwise from north to the line and take it from 360°: an anticlockwise angle of 130° gives $360 - 130 = 230^\circ$. Or measure from south and add 180°.

Back bearings

North lines at two places are parallel. So if B is on a bearing of 070° from A, then at B the angle between south and the line back to A is also 70° (alternate angles). Going clockwise from north at B to A is $180^\circ + 70^\circ = 250^\circ$.



The bearing of A from B always differs from the bearing of B from A by exactly 180°:

- bearing **less than** 180°: **add** 180° ($070^\circ \to 250^\circ$);

- bearing **more than** 180°: **subtract** 180° $(230^\circ \to 050^\circ)$.

Working out bearings from angle facts

When a diagram is **not to scale** you calculate bearings instead of measuring them. Draw a north line at every point you need a bearing from, then use angle facts: angles on a straight line add to 180°, angles round a point to 360°, co-interior angles between the parallel north lines add to 180°, alternate angles are equal, and the angles of a triangle add to 180°. On Extended papers the angle inside the triangle is sometimes found with trigonometry first; the bearing is then found the same way.

Key facts and formulas

"Given" means it is on the List of formulas printed on page 2 of the exam paper. Everything else, learn.

Formula	Status
Bearing: clockwise from north, three figures; N 000°, E 090°, S 180°, W 270°	Learn it
Back bearing $=$ bearing $+180^\circ$ (if under 180°) or bearing -180° (if over 180°)	Learn it
Scale "1 cm to k": real length $=$ drawing length $\times k$; drawing length $=$ real length $\div k$	Learn it
$1 : n$ means 1 cm stands for n cm; 1 m $= 100$ cm, 1 km $= 100\,000$ cm	Learn it
Map areas: if 1 cm stands for k, then 1 cm² stands for k^2	Learn it
Construction: arcs of the two side lengths from the two ends of the base cross at the third vertex	Learn it
Cuboid: surface area $= 2(lw + lh + wh)$, volume $V = lwh$	Learn it
Area of a triangle $A = \frac{1}{2}bh$	Given
Volume of a prism $V = Al$ (A = area of cross-section)	Given

How to do it

In the questions we have tagged for this topic (106 questions, 2021–2025; five of them were printed on two papers), the types came up this often. 28 of the 106 questions have parts of more than one type, so the counts add up to more than 106.

Question type	Questions
Scales: real distances, scales as $1 : n$, and map areas	29
Nets: draw, complete or use	24
Measuring and drawing lines and angles	22
Measuring a bearing on a scale drawing	17
Marking a point from a bearing and a distance	16

Question type	Questions
Constructing a triangle with ruler and compasses	15
Back bearings: the bearing of A from B	14
Working out bearings from angle facts	11

1. Scales: real distances, scales as 1 : n, and map areas (29 questions)

1. **Measure** the line on the drawing carefully, in cm, to the nearest mm. Write the measurement down: it earns a mark on its own.
2. **Apply the scale**: "1 cm to k km" means multiply by k. For $1 : n$, multiply by n to get cm, then divide by $100\,000$ for km (or by 100 for m).
3. **Give the units** asked for.

Variations you will meet:

- **Map to real with a ratio**: 4.2 cm on a $1 : 300\,000$ map is $4.2 \times 300\,000 = 1\,260\,000$ cm $= 12.6$ km.
- **Write a scale as** $1 : n$: change the real length into cm. "1 cm to 7 km" is $1 : 700\,000$; "2 cm to 150 m" is $2 : 15\,000$, so $1 : 7500$.
- **Find the scale from a drawing**: a real length and its drawing length give the scale. A 9 m mast drawn 12 cm tall: $900 \div 12 = 75$, so $1 : 75$.
- **Real length to drawing length**: divide by the scale, then mark it with a ruler.
- **Areas**: find what 1 cm stands for (in km or m), square it, and multiply by the map area. Going backwards, the area ratio gives k^2; take the square root to get the length scale.
- **Is the scale suitable?** Work out how big the drawing would be and compare it with the paper: a route 3 km across at $1 : 600\,000$ is only 0.5 cm, far too small.

2. Nets: draw, complete or use (24 questions)

1. **List the faces** with their sizes first: for a cuboid, three pairs $l \times w$, $l \times h$, $w \times h$; for a prism, two cross-sections and one rectangle per side.
2. **Match every edge**: faces that meet along an edge must have that edge the same length. For a prism, each side of the end triangle sits against the rectangle of the same width.
3. **Start from the face already drawn** and add faces edge to edge, so every shared edge has the same length. For a cuboid, a column of four faces round the middle, plus one on each side, always works.
4. **Rule** the net on the grid (count squares for each length) and check that it would fold: no two faces on top of each other, and every face used once.

Variations you will meet:

- **Triangular prism**: the rectangles are all as long as the prism, and their widths are the three sides of the triangle. Put one triangle on each side of the rectangles, both joined to the same rectangle. For a right-angled 3, 4, 5 triangle joined to the 4 rectangle, the right angle goes at the corner where the 3 and 4

rectangles meet, with the 3 cm side along the edge of the 3 rectangle; the 5 cm side then ends at the 5 rectangle. Draw the 3 and 4 sides along grid lines.

- **Square-based pyramid**: the square with a triangle on each side. You may first need the height of the triangle (Pythagoras).
- **Open box**: leave out the lid, 5 faces.
- **Only the volume given**: find the missing edge from $V = lwh$ (a volume of 40 cm³ on a 5 by 2 base means a height of 4 cm), then draw.
- **Read a net**: write down the dimensions, which points meet when it is folded, the name of the solid, or the number on the opposite face of a dice (opposite faces are never next to each other on the net, and on a dice they add up to 7).
- **Surface area and volume from the net**: add the areas of all the faces; multiply the three dimensions.

3. Measuring and drawing lines and angles (22 questions)

1. **Lines**: 0 on the ruler at one end; read to the nearest mm; give the unit asked for (cm or mm).
2. **Angles**: centre on the vertex, zero line on one arm, read the scale that starts from 0 on that arm, and check against your estimate.
3. **Perpendicular through a point**: 90° from the line at that point, ruled right across. **Parallel**: rule at the same distance all along.

Variations you will meet:

- **Measure an angle, then name its type** (acute, obtuse, reflex).
- **Mark the midpoint** and draw the perpendicular through it.
- **Measure an angle on a triangle you have just constructed**, such as the angle opposite the longest side.

4. Measuring a bearing on a scale drawing (17 questions)

1. Find the point after "from": that is where you measure. If there is no north line there, draw one parallel to the others (straight up the page).
2. Put the protractor centre on the point and its zero on the north line.
3. Read the angle **clockwise** from north to the line. If the line is to the left of north, the bearing is more than 180°: take the anticlockwise angle from 360°.
4. Write three figures: 047°, not 47°.

5. Marking a point from a bearing and a distance (16 questions)

1. **Change the distance** into cm with the scale: 36 km at 1 cm to 8 km is 4.5 cm.
2. At the starting point, measure the bearing clockwise from north and mark it lightly.
3. **Rule a line** from the point through your mark, measure the length along it, and mark and label the new point.

Variations you will meet:

- **Two bearings**: a point on a bearing of 052° from K and 301° from L. Draw both bearing lines, long enough to cross; the point is where they meet.
- **A point due east of another**: rule a line at right angles to the north line.
- **Redraw on a map with a different scale**: the bearing is the same; only the length changes.
- **Speed and time first**: a cyclist travels at 18 km/h for 1 h 20 min, so $18 \times \frac{4}{3} = 24$ km along the road, then use the scale.

6. Constructing a triangle with ruler and compasses (15 questions)

1. Set the compasses against a ruler to the first length and draw an arc **from the correct end** of the given side.
2. Set the second length and draw an arc from the other end so they cross.
3. Rule both sides to the crossing point, and **leave the arcs**.

Variations you will meet:

- **Lengths in metres or km with a scale**: convert first. 26 m at 1 cm to 4 m is 6.5 cm.
- **A rhombus or a parallelogram** from two triangles on a diagonal or on two given sides.
- **A point at given distances from two places** (a boat, a lighthouse): arcs from both, crossing on the side the question describes ("to the east of").

7. Back bearings: the bearing of A from B (14 questions)

1. Check the question gives the bearing of B from A and asks for A from B (or the other way round).
2. Under 180°: add 180°. Over 180°: subtract 180°.
3. Sketch the two north lines if you are unsure; the answer must point roughly back the other way.

Variations you will meet:

- **"Due east"**: B due east of A means the bearing of A from B is 270°.
- **A ratio of the two bearings**, such as $x : y = 1 : 4$: the larger is 180° more than the smaller, so the 3 parts in between are 180°. One part is 60°, $x = 060^\circ$ and $y = 240^\circ$.
- **In a story** (a boat and a harbour, a hotel and a town): pick out the "from" point carefully.

8. Working out bearings from angle facts (11 questions)

1. Draw a north line at each point you need.
2. Mark every bearing you are given as an angle clockwise from its north line.
3. Use angle facts (co-interior 180° and alternate angles between north lines, angles in a triangle, isosceles and equilateral triangles, regular polygons) to find the angle you need at the new point.
4. Add or subtract to turn that angle into a clockwise angle from north.

Variations you will meet:

- **Angle between two bearings from one point**: the bearings of B and C from A are 035° and 158°, so angle $BAC = 158 - 35 = 123^\circ$.
- **Show that an angle is** 90° from two bearings: 305° and 035° from Y differ by $360 - 305 + 35 = 90^\circ$.
- **Extended:** a triangle with sides or angles found by the sine or cosine rule, then turned into a bearing. The bearing work is the same; the trigonometry is in its own topics.

Worked examples

The bold codes show where marks are earned, as in Cambridge mark schemes. The number is how many marks.

- **M1** method mark: for a correct method, even if the numbers slip.
- **A1** accuracy mark: for a correct answer; it needs the M mark before it.
- **B1** mark for a correct result on its own, with no method needed.

Example 1

A map has a scale of $1 : 250\,000$.

(a) On the map, town P is 6.2 cm from town Q. Work out the actual distance between the towns in kilometres. **[2]**

(b) Complete the statement: 1 cm on the map represents .... km. **[1]**

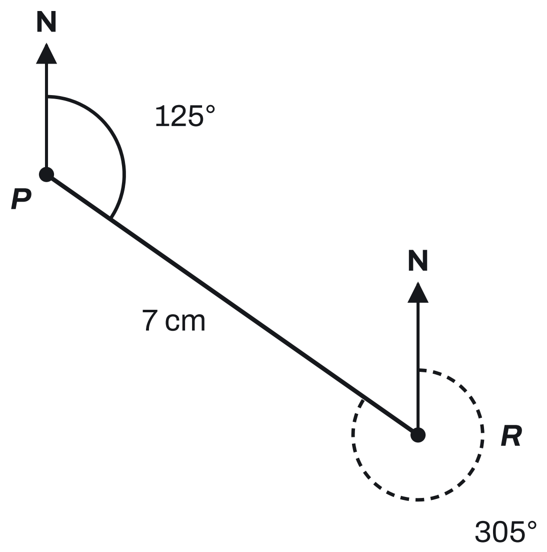
(c) Town R is 17.5 km from P on a bearing of 125°. Describe how to mark R on the map. **[2]**

(d) Work out the bearing of P from R. **[2]**

(a) $6.2 \times 250\,000 = 1\,550\,000$ cm **M1**; $\div 100\,000$: 15.5 km **A1**.

(b) $250\,000$ cm $= 2.5$ km. **B1**

(c) Map distance $17.5 \div 2.5 = 7$ cm. **B1** At P, measure 125° clockwise from north, rule a line and mark R 7 cm along it. **B1** (One mark each: the right bearing and the right length.)



(d) $125 + 180$ **M1** $= 305^\circ$ **A1**.

Example 2

A field is a triangle PQR with $PQ = 180$ m, $PR = 120$ m and $QR = 150$ m.

(a) Using a scale of 1 cm to 20 m, and a ruler and compasses only, construct a scale drawing of the field. Side PQ has already been drawn. **[3]**

(b) Measure angle PRQ. **[1]**

(c) Write the scale in the form $1 : n$. **[1]**

(a) Scale lengths: $PQ = 180 \div 20 = 9$ cm, $PR = 120 \div 20 = 6$ cm, $QR = 150 \div 20 = 7.5$ cm. **B1** Arc of radius 6 cm centred on P and arc of radius 7.5 cm centred on Q, crossing at R; rule PR and QR and leave the arcs. **B2** ($6 + 7.5 > 9$, so the arcs do meet.)

(b) About 83° (the angle opposite the longest side, PQ). **B1** (An accurate drawing gives 82.8°; about 2° either way is accepted, and it follows your own drawing.)

(c) 20 m $= 2000$ cm, so $1 : 2000$. **B1**

Example 3

A closed box is a cuboid measuring 6 cm by 4 cm by 3 cm.

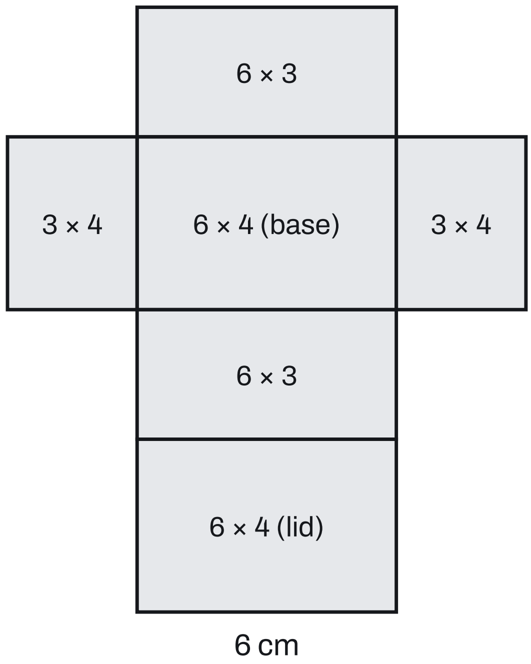
(a) Draw a net of the box on a 1 cm grid. **[3]**

(b) Work out the total surface area of the box. **[2]**

(c) A second box is the same size but has **no lid**. Work out the area of card in its net. **[1]**

(d) Work out the volume of the box. **[2]**

(a) Faces: two 6×4, two 6×3, two 4×3. A column of four (6×3, 6×4, 6×3, 6×4) with a 3×4 face on each side of one of the 6×4 faces. **B3** (**B2** for all but one face right, **B1** for one extra correct face.)



(b) $2(6 \times 4 + 6 \times 3 + 4 \times 3) = 2(24 + 18 + 12)$ **M1** $= 108$ cm² **A1**.

(c) Leave out one 6×4 face: $108 - 24 = 84$ cm². **B1**

(d) $6 \times 4 \times 3$ **M1** $= 72$ cm³ **A1**.

Example 4

Three towns L, M and T form an equilateral triangle. M is due east of L, and T is south of the line LM.

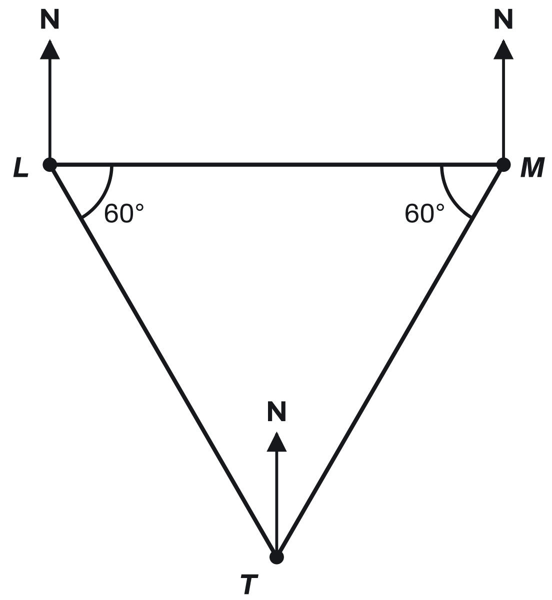
(a) Write down the bearing of M from L. **[1]**

(b) Find the bearing of T from L. **[1]**

(c) Find the bearing of T from M. **[2]**

(d) Find the bearing of L from T and the bearing of M from T. **[2]**

(e) The bearing of Y from X is x° and the bearing of X from Y is y°, where $x : y = 1 : 5$. Find x and y. **[3]**



(a) Due east: 090°. **B1**

(b) Every angle is 60°; T is 60° clockwise past east: $90 + 60 = 150^\circ$. **B1**

(c) At M, west (270°) points to L, and T is 60° anticlockwise from that: $270 - 60$ **M1** $= 210^\circ$ **A1**.

(d) Back bearings: L from T is $150 + 180 = 330^\circ$ **B1**; M from T is $210 - 180 = 030^\circ$ **B1**.

(e) y is five times x, so $y > x$ and $y = x + 180$. **M1** Then $5x = x + 180$, $4x = 180$ **M1**, $x = 45$, $y = 225$ **A1**.

Common mistakes

- **Forgetting the scale.** Examiners often see the measured length (such as 7 cm) given as the distance, or the scale used the wrong way (dividing instead of multiplying). Write the measurement, then the scale step.
- **Reading the wrong protractor scale.** Answers like 150° for 30°, or 64° for 116°, come from reading the other ring. Estimate first: acute or obtuse?
- **Measuring bearings from the wrong point or anticlockwise.** The bearing of B from A is measured at A, clockwise from north. Common wrong answers are 360° minus the right bearing, or the bearing measured from the other town.
- **Two-figure bearings.** Write 047°, not 47°.
- **Back bearings.** Common wrong answers are the given bearing itself, or 360° minus it (63° instead of 117° for the reverse of 297°). Add or subtract 180°.
- **Erasing construction arcs**, drawing them freehand or too small to see, or only drawing the triangle by measuring. Without arcs the construction loses a mark.
- **Arcs from the wrong ends.** Putting the length for AC on B gives a mirror-image triangle and loses marks.

- **Drawing a 3D picture instead of a net**, or a closed box when the question says the box is open (the word is in bold for a reason).
- **Nets that do not fold**: two faces covering the same edge, or edges that meet but are different lengths.
- **Areas scaled like lengths.** Multiplying a map area by the scale number gives an answer far too small; square what 1 cm stands for.
- **Unit slips in $1 : n$**: answers like $1 : 3$ or $1 : 3000$ for "1 cm to 3 km" (it is $1 : 300\,000$). Put both sides in cm.
- **Parallel for perpendicular**, or a "perpendicular" line drawn by eye that is not at 90°. Use the protractor or a set square.
- **Marking a point on the right bearing but at the edge of the protractor**, not at the right distance. Measure the length along the line.

How to get the marks

- **Scale drawing questions** usually give a mark for the measured length (usually within 1 or 2 mm) and one for applying the scale to it, even if the measurement is a little out. Show the measurement.
- **Marking a point** is usually **B1** for the right bearing and **B1** for the right distance, so do both carefully, and label the point.
- **Bearings measured** are accepted within about 2°; write three figures.
- **Constructions**: full marks need an accurate triangle (sides within about 2 mm) **and** both construction arcs visible. "Using a ruler and compasses only" means no protractor.
- **Nets** on a grid: marks for each correct face in a correct place; the whole net must fold into the solid. Rule it.
- **"Work out" or "calculate" a bearing**: show the angle sum, such as $125 + 180$; a sketch with north lines can earn the method mark. When a diagram says **NOT TO SCALE**, calculate: never measure it.
- **Give units** where asked ("give your answer in kilometres").

Quick check

1. On a map with scale $1 : 50\,000$, a path is 7.3 cm long. Find its real length in km.
2. (a) The bearing of Q from P is 295°. Find the bearing of P from Q. (b) B is due south of A. Write down the bearing of A from B.
3. Two towns are 42 km apart. How far apart are they on a map with scale 1 cm to 6 km? Write this scale in the form $1 : n$.
4. On a map with scale $1 : 20\,000$, a lake has an area of 6 cm². Find its real area in km².
5. A cuboid measures 7 cm by 2 cm by 3 cm. List the faces in its net, then find its surface area and volume.

Answers

1. $7.3 \times 50\,000 = 365\,000$ cm $= 3.65$ km.
2. (a) $295 - 180 = 115^\circ$. (b) A is due north of B: 000°.
3. $42 \div 6 = 7$ cm. 6 km $= 600\,000$ cm, so $1 : 600\,000$.
4. 1 cm stands for $20\,000$ cm $= 200$ m, so 1 cm² stands for $200^2 = 40\,000$ m². The lake: $6 \times 40\,000 = 240\,000$ m² $= 0.24$ km² (1 km² $= 1\,000\,000$ m²).
5. Two 7×2, two 7×3, two 2×3. Surface area $2(14 + 21 + 6) = 82$ cm²; volume $7 \times 2 \times 3 = 42$ cm³.

Past questions to try

- **0580/33/M/J/25 Q16**: a real distance from a scale drawing, measuring a bearing and marking a point.
- **0580/42/F/M/25 Q8**: a scale drawing, then a point at two given distances with compasses.
- **0580/13/M/J/25 Q8**: reading the dimensions from part of a net, completing it and finding the volume.
- **0580/22/F/M/21 Q10**: bearings in an equilateral triangle of towns.