

**MU120\_4M7   Open Mathematics**

**Geometry**

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## Introduction

This free course looks at various aspects of shape and space. It uses a lot of mathematical vocabulary, so you should make sure that you are clear about the precise meaning of words such as circumference, parallel, similar and cross-section. You may find it helpful to note down the meaning of each new word, perhaps illustrating it with a diagram.

This OpenLearn course provides a sample of level 1 study in [Mathematics](http://www.open.ac.uk/courses/find/mathematics?utm_source=openlearn&utm_campaign=ou&utm_medium=ebook).

## Learning outcomes

After studying this course, you should be able to:

* understand geometrical terminology for angles, triangles, quadrilaterals and circles
* measure angles using a protractor
* use geometrical results to determine unknown angles
* recognise line and rotational symmetries
* find the areas of triangles, quadrilaterals and circles and shapes based on these.

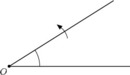
## 1 Angles

## 1.1 Angles, notation and measurement

In everyday language, the word ‘angle’ is often used to mean the space between two lines (‘The two roads met at a sharp angle’) or a rotation (‘Turn the wheel through a large angle’). Both of these senses are used in mathematics, but it is probably easier to start by thinking of an angle in terms of the second of these – as a rotation.

The diagram below shows a fixed arm and a rotating arm (with the arrow), which are joined together at O, forming an angle between them. Imagine that the rotating arm, which is pivoted at O, initially rests on top of the fixed arm and that it then rotates in the direction of the arrow. Focus on the size of the marked angle between the arms.

Start of Figure



End of Figure

At first the angle is quite sharp, but it becomes less so. It then becomes a right angle, and subsequently gets much blunter until the two arms form a straight line. Then it starts to turn back upon itself, passing through a three-quarter turn and, when the rotating arm gets back to the start, it rests on top of the fixed arm again.

The most common unit for expressing angles is degrees, denoted by °, with a complete turn or revolution being equal to 360°. Angles can also be measured in radians, and you will meet this unit of measure if you study further maths, science or technology courses.

Start of Box

**Acute angle**

Any angle that is less than a quarter turn; that is, less than 90°. An example of an acute angle is the angle that a door makes with a doorframe when it is ajar.

Start of Figure

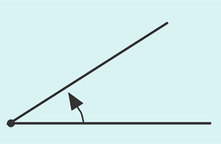


Figure ang1

[View description - Figure ang1](" \l "Session1_Description1)

[View description - Figure ang1](" \l "Session1_Alternative1)

End of Figure

End of Box

Start of Box

**Right angle**

The angle that corresponds to a quarter turn; it is exactly 90°. The angles at the corners of most doors, books and windows are right angles.

Start of Figure

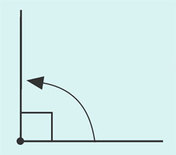


Figure ang2

[View description - Figure ang2](" \l "Session1_Description2)

[View description - Figure ang2](" \l "Session1_Alternative2)

End of Figure

End of Box

Start of Box

**Obtuse angle**

Any angle that is between a quarter turn and a half turn; that is, between 90° and 180°. An example is the angle between the blades of a pair of scissors when they are open as wide as possible.

Start of Figure

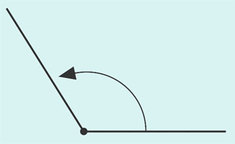


Figure ang3

[View description - Figure ang3](" \l "Session1_Description3)

[View description - Figure ang3](" \l "Session1_Alternative3)

End of Figure

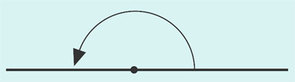
End of Box

Start of Box

**Half turn (Straight angle)**

This corresponds to a straight line; it is exactly 180°. The pages of an open book that is lying flat approximately describe a half turn.

Start of Figure



[View description - Uncaptioned Figure](" \l "Session1_Description4)

[View description - Uncaptioned Figure](" \l "Session1_Alternative4)

End of Figure

End of Box

Start of Box

**Reflex angle**

Any angle that is between a half turn and a complete turn; that is, between 180° and 360°. When a box is opened and the hinged lid falls back so as to rest on the surface on which the box is standing, the angle that the lid turns through is a reflex angle.

Start of Figure

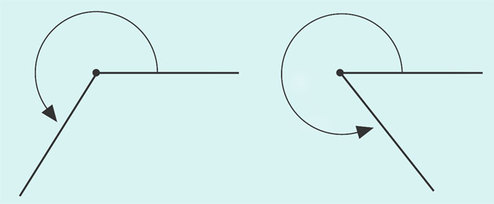


Figure ang5

[View description - Figure ang5](" \l "Session1_Description5)

[View description - Figure ang5](" \l "Session1_Alternative5)

End of Figure

End of Box

Start of Box

**Complete turn**

This corresponds to a complete turn, or one revolution; it is exactly 360°. This is the angle that the minute hand of a clock turns through in an hour.

Start of Figure

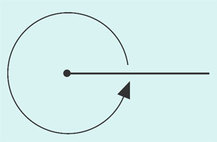


Figure ang6

[View description - Figure ang6](" \l "Session1_Description6)

[View description - Figure ang6](" \l "Session1_Alternative6)

End of Figure

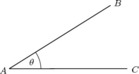
End of Box

Remember that if the angle between two straight lines is 90°, then the lines are said to be **perpendicular** to each other.

Sometimes it is necessary to refer to a turn that is more than one complete revolution, and so is greater than 360°. An example is the angle that the minute hand of a clock turns through in a period of 12 hours: each complete revolution of the minute hand amounts to 360°, so twelve revolutions amount to 12 × 360° = 4320°.

Several different notations are used for labelling angles. For example, the angle below can be referred to as ‘angle BAC’ and written as BD:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_580e07963ffaee5d82b01bcd3780ff3d4e391cf1_mu120_b_i041e.gifC or D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_fd5feead7472346759ae81357f8a42ff12c0a9f5_angle.gifBAC, or it can be referred to as the angle ‘theta’ and labelled θ.

Start of Figure



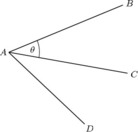
[View description - Uncaptioned Figure](" \l "Session1_Alternative7)

End of Figure

Alternatively, an angle may be denoted by the label on the vertex but with a hat on it. The vertex is another name for the ‘corner’ of an angle. For instance, the angle θ above may be denoted by D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_580e07963ffaee5d82b01bcd3780ff3d4e391cf1_mu120_b_i041e.gif, which is read as ‘angle A’.

This notation can be ambiguous if there is more than one angle at the vertex, as in the example below.

Start of Figure



End of Figure

In such cases, θ can be specified as D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_c2783d5a2ede9a11c50ef2daa232edac08138728_mu120_b_i029e.gif, D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_68f927d9276e3d60d005a8ef68dc0d4dbd2010d8_mu120_b_i028e.gif, D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_fd5feead7472346759ae81357f8a42ff12c0a9f5_angle.gifCAB or D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_fd5feead7472346759ae81357f8a42ff12c0a9f5_angle.gifBAC – the middle letter indicates the vertex and the two outer letters identify the ‘arms’ of the angle.

### Try some yourself

Start of Activity

**Question 1**

Start of Question

What angles do the hour hand and the minute hand of a clock turn through in five hours?

End of Question

[View answer - Question 1](" \l "Session1_Answer1)

End of Activity

Start of Activity

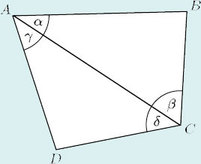
**Question 2**

Start of Question

Give an alternative notation for labelling each of these angles in the diagram below.

* (a) α
* (b) β
* (c) D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_7ac24c1b251a6924d88e262ef3df36969ad3a3bc_mu120_b_i043e.gif
* (d) D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_fd5feead7472346759ae81357f8a42ff12c0a9f5_angle.gifACD

Start of Figure



End of Figure

End of Question

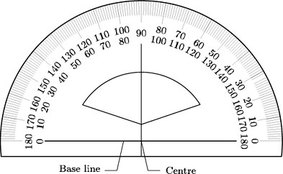
[View answer - Question 2](" \l "Session1_Answer2)

End of Activity

## 1.2 How to measure an angle

To measure an angle you need a protractor. The protractor shown here is a semicircle that is graduated to measure angles from 0° to 180°. It is also possible to buy circular protractors that measure angles from 0° to 360°.

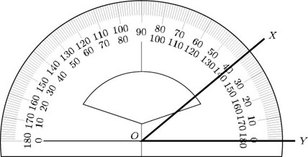
Start of Figure



End of Figure

The diagram below indicates how the protractor should be positioned in order to measure an angle. Place the base line of the protractor on one arm of the angle, with the centre O on the vertex. The angle can then be read straight from the scale. Here D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_fd5feead7472346759ae81357f8a42ff12c0a9f5_angle.gifD:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_b7751fe8d1496d557186872ea34aae2c17b007f3_mu120_b_i042e.gif= 40° (not 140°).

Start of Figure

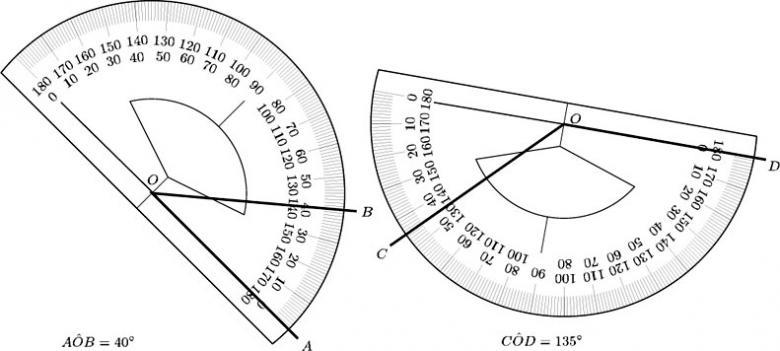


End of Figure

Be careful to use the correct scale. In this case the angle extends from the line OY up to the line OX, so use the scale that shows OY as 0° – the outer scale in this instance.

In the above example, one of the arms of the angle is horizontal. However, sometimes you may find that you need to position the protractor in an awkward position in order to measure an angle.

Start of Figure



End of Figure

You can also use a protractor to construct an angle accurately, but once you have drawn the angle, be on the safe side and measure it to check that it is correct.

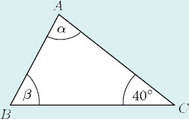
### Try some yourself

Start of Activity

**Question 1**

Start of Question

Start of Figure



End of Figure

* (a) How would you refer to angle α in this triangle by means of the letters A, B and C?
* (b) Measure α with a protractor , if you have one, or otherwise estimate it.
* (c) What type of angle is α?
* (d) Find β without using a protractor using the fact that the three angles of a triangle always add up to 180°.

End of Question

[View answer - Question 1](" \l "Session1_Answer3)

End of Activity

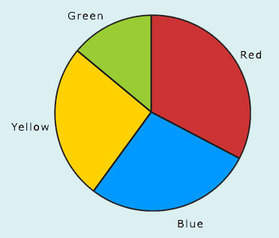
Start of Activity

**Question 2**

Start of Question

**2** This pie chart shows the proportions of people voting for four parties in a local election.

Start of Figure



End of Figure

* (a) Measure the angles of the four slices of the pie with your protractor or estimate them if you don't have a protractor.
* (b) Check your measurements by ensuring that the angles add up to 360°.
* (c) Work out the percentage of the total vote polled by each of the four parties.

End of Question

[View answer - Question 2](" \l "Session1_Answer4)

End of Activity

## 1.3 Angles, points and lines

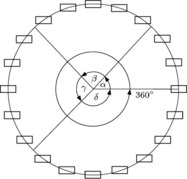
Very often, angles in a shape are determined by the geometric properties of that shape. For example, a square has four right angles. So, when you know a shape is a square, you do not need to measure its angles to know that they are 90°. The rest of this section will look at the properties of shapes that enable you to deduce and calculate angles rather than measure them. You may like to add these properties to your notes.

### 1.3.1 Angles at a point

Another useful property to remember is that one complete turn is 360°. This means that when there are several angles making up a complete turn, the sum of those angles must be 360°.

For instance, if the angles turned by a Big Wheel at a fairground as it picks up passengers were α, β, γ and δ as shown in the diagram below, then α + β + γ + δ = 360°.

Start of Figure



End of Figure

Start of Box

The sum of angles at a point is 360°.

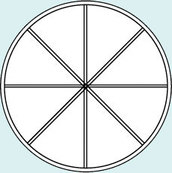
End of Box

Start of Example

**Example 1**

Calculate the angle between adjacent spokes of this wheel.

Start of Figure



End of Figure

[View answer - Example 1](" \l "Session1_Answer5)

End of Example

### Try some yourself

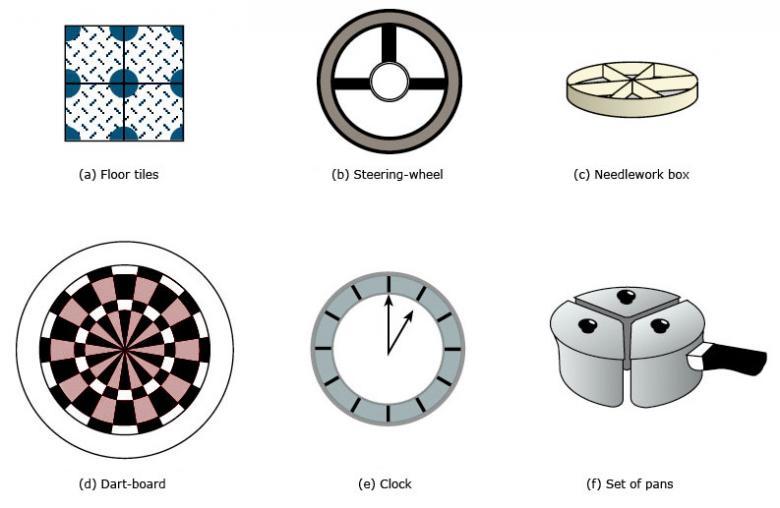
Start of Activity

**Question 1**

Start of Question

Calculate all the angles at the centres of these objects.

Start of Figure



End of Figure

End of Question

[View answer - Question 1](" \l "Session1_Answer6)

End of Activity

## 1.3.2 Angles on a line

If several angles make up a half turn, then the sum of those angles must be D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_74d272ff1236b721524b59ebe3a506eeab7ddd98_mu120_b_i044e.gif× 360° = 180°. Therefore, in the following diagram, α + β + γ + δ = 180°.

Start of Figure



End of Figure

Start of Box

The sum of angles on a line is 180°.

End of Box

(Note that different diagrams can be labelled with the same letters – α, β, γ, and δ in this case. The letters represent different angles here to those in the diagram in the preceding section.)

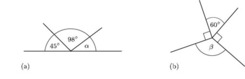
You can sometimes use these properties to determine unknown angles.

Start of Example

**Example 2**

Find α and β in the diagrams below. These are the types of diagram that might arise when plotting the course of a ship.

Start of Figure



End of Figure

[View answer - Example 2](" \l "Session1_Answer7)

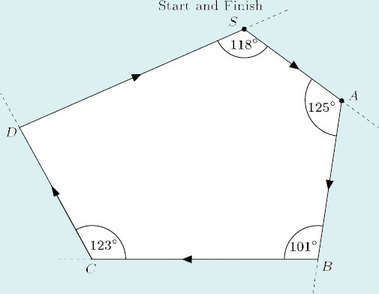
End of Example

Start of Example

**Example 3**

Students at an orienteering event follow a route round a set course in a clockwise direction. (Assume that the students run in straight lines and keep to the track.)

Start of Figure



End of Figure

* (a) Through what angle do the students turn at A?
* (b) When they arrive at D, what is the total angle that they have turned through relative to their starting direction?
* (c) When they return to S, through what angle must they turn in order to face in the direction in which they started?
* (d) When they reach D, through what angle must they turn in order to return to the start?

[View answer - Example 3](" \l "Session1_Answer8)

End of Example

### Try some yourself

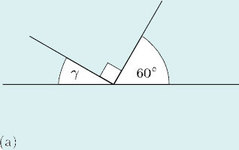
Start of Activity

**Question 1**

Start of Question

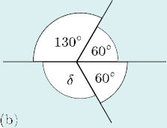
Find γ and δ in the following diagrams produced by a ship's navigator.

Start of Figure



End of Figure

Start of Figure



End of Figure

End of Question

[View answer - Question 1](" \l "Session1_Answer9)

End of Activity

## 1.3.3 Drawing a pie chart

You can use the fact that the sum of angles at a point is 360° to draw a pie chart.

Start of Example

**Example 4**

Over a five-year period a mathematics tutor found that 16 of her students gained distinctions, 32 gained pass grades and 12 failed to complete the course. Draw a pie chart to represent these data.

[View answer - Example 4](" \l "Session1_Answer10)

End of Example

### Try some yourself

Start of Activity

**Question 1**

Start of Question

A company carried out a survey, recording how staff in a particular office spent their working time. The table shows the average number of minutes spent in each hour on various activities.

Start of Table

|  |  |
| --- | --- |
| **Activity** | **Time taken on average in one hour/mins** |
| Keyboarding | 35 |
| Answering telephone | 12 |
| Talking with colleagues | 10 |
| Other | 3 |

End of Table

The data is to be displayed as a pie chart. Work out the angle at the centre for each slice.

End of Question

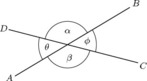
[View answer - Question 1](" \l "Session1_Answer11)

End of Activity

## 1.3.4 Vertically opposite angles

When two straight lines cross, they form four angles. In the diagram below, these angles are labelled α, β, θ and φ and referred to as alpha, beta, theta and phi. The angles opposite each other are equal. They are called **vertically opposite** angles. Here α and β are a pair of vertically opposite angles, as are θ and φ. Although such angles are called ‘vertically opposite’, they do not need to be vertically above and below each other!

Start of Figure



[View description - Uncaptioned Figure](" \l "Session1_Alternative9)

End of Figure

Start of Box

For two intersecting straight lines, vertically opposite angles are equal.

End of Box

We can show that vertically opposite angles are equal as follows:

Start of Quote

α and θ lie on a line.

So, α + θ = 180°

and α = 180° – θ

but β and θ also lie on a line.

So, β + θ = 180°

and β = 180° – θ.

Hence, α = β because they are both equal to 180° – θ.

End of Quote

### Try Some Yourself

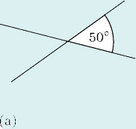
Start of Activity

**Question 1**

Start of Question

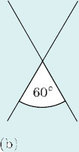
Find all the remaining angles in each of the diagrams below.

Start of Figure



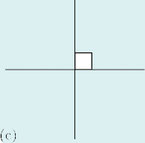
End of Figure

Start of Figure



End of Figure

Start of Figure



End of Figure

End of Question

[View answer - Question 1](" \l "Session1_Answer12)

End of Activity

## 1.4 Parallel lines

Two straight lines that do not intersect, no matter how far they are extended, are said to be **parallel**. Arrows are used to indicate parallel lines.

Start of Figure

Parallel lines

[View description - Uncaptioned Figure](" \l "Session1_Alternative10)

End of Figure

## 1.4.1 Corresponding angles

Look at the line l, which cuts two parallel lines m and n.

Start of Figure



[View description - Uncaptioned Figure](" \l "Session1_Alternative11)

End of Figure

If you trace the lines at one of the intersections in the diagram below and place them over the lines at the other intersection, you will find that the two sets of lines coincide exactly. The four angles at each intersection also coincide exactly: thus α = a, β = b, γ = c and δ = d.

Start of Figure



End of Figure

The pairs of angles that correspond to each other at such intersections are called **corresponding angles**.

In the diagram below, α and a are corresponding angles: they are equal because m and n are parallel.

Start of Figure



End of Figure

Start of Box

When a line intersects two parallel lines, corresponding angles are equal.

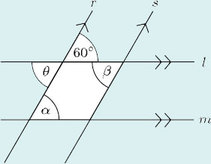
End of Box

Start of Example

**Example 5**

This diagram represents the type of arrangement that occurs in a garden trellis or a wine rack (r and s are parallel lines, indicated by the single arrowheads; l and m are also parallel, indicated by the double arrowheads). Calculate the angles α and β.

Start of Figure



End of Figure

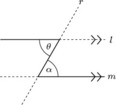
[View answer - Example 5](" \l "Session1_Answer13)

End of Example

## 1.4.2 Alternate angles

Other pairs of equal angles can be identified in [Example 5](#exa001_005). These pairs of angles occur in a Z-shape, as indicated by the solid line in the diagram below. Such angles are called **alternate angles**.

Start of Figure



[View description - Uncaptioned Figure](" \l "Session1_Alternative12)

End of Figure

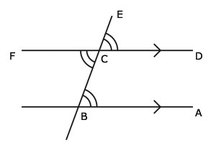
Start of Box

When a line intersects two parallel lines, alternate angles are equal.

End of Box

To prove this result consider the diagram below:

Start of Figure



End of Figure

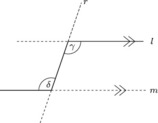
D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_fd5feead7472346759ae81357f8a42ff12c0a9f5_angle.gifABC = D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_fd5feead7472346759ae81357f8a42ff12c0a9f5_angle.gifDCE (corresponding angles)

and D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_fd5feead7472346759ae81357f8a42ff12c0a9f5_angle.gifDCE = D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_fd5feead7472346759ae81357f8a42ff12c0a9f5_angle.gifFCB (vertically opposed angles)

So, D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_fd5feead7472346759ae81357f8a42ff12c0a9f5_angle.gifABC = D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_fd5feead7472346759ae81357f8a42ff12c0a9f5_angle.gifFCB (both equal to D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_fd5feead7472346759ae81357f8a42ff12c0a9f5_angle.gifDCE).

The other two angles are also equal and are also called alternate angles.

Start of Figure



End of Figure

It is important to realise that you can find the sizes of unknown angles in many shapes by using a combination of the angle properties that have been outlined. To recap:

Start of Box

* Vertically opposite angles are equal.
* Angles at a point add up to 360°.
* Angles on a straight line add up to 180°.
* Corresponding angles on parallel lines are equal.
* Alternate angles on parallel lines are equal.

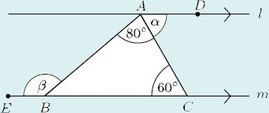
End of Box

Start of Example

**Example 6**

Find α and β in the following diagram.

Start of Figure



End of Figure

[View answer - Example 6](" \l "Session1_Answer14)

End of Example

These properties of corresponding and alternate angles mean that the opposite angles in a parallelogram are also equal.

### Try some yourself

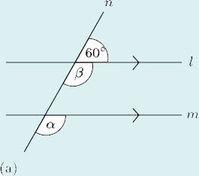
Start of Activity

**Question 1**

Start of Question

Find α and β in each of the diagrams below.

Start of Figure



End of Figure

End of Question

[View answer - Question 1](" \l "Session1_Answer15)

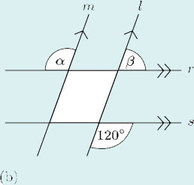
End of Activity

Start of Activity

**Question 2**

Start of Question

Start of Figure



End of Figure

End of Question

[View answer - Question 2](" \l "Session1_Answer16)

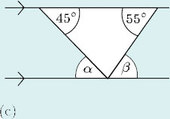
End of Activity

Start of Activity

**Question 3**

Start of Question

Start of Figure



End of Figure

End of Question

[View answer - Question 3](" \l "Session1_Answer17)

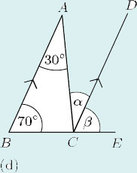
End of Activity

Start of Activity

**Question 4**

Start of Question

Start of Figure



End of Figure

End of Question

[View answer - Question 4](" \l "Session1_Answer18)

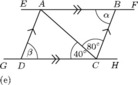
End of Activity

Start of Activity

**Question 5**

Start of Question

Start of Figure



End of Figure

End of Question

[View answer - Question 5](" \l "Session1_Answer19)

End of Activity

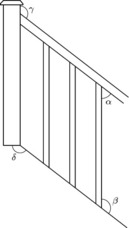
Start of Activity

**Question 6**

Start of Question

**2** This diagram shows part of some bannister rails. The handrail makes an angle of 40° with the horizontal. Calculate angles α, β, γ and δ.

Start of Figure



End of Figure

End of Question

[View answer - Question 6](" \l "Session1_Answer20)

End of Activity

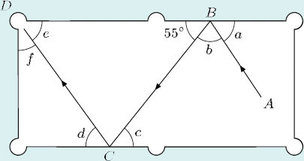
Start of Activity

**Question 7**

Start of Question

**3** The arrows on the diagram below indicate the idealised path (ABCD) of a snooker ball on a snooker table. Assume that the angles between the cushion (the edge of the snooker table) and the path of the ball before and after it impacts with the cushion are equal. Calculate the sizes of the angles marked a, b, c, d, e and f.

Start of Figure



End of Figure

End of Question

[View answer - Question 7](" \l "Session1_Answer21)

End of Activity

## 2 Shapes and symmetry

## 2.1 Geometric shapes – triangles

This section deals with the simplest geometric shapes and their symmetries. All of the shapes are two-dimensional – hence they can be drawn accurately on paper.

Simple geometric shapes are studied in mathematics partly because they are used in thousands of practical applications. For instance, triangles occur in bridges, pylons and, more mundanely, in folding chairs; rectangles occur in windows, cinema screens and sheets of paper; while circles are an essential part of wheels, gears and plates.

By definition, triangles are shapes with three straight sides. However, there are various types of triangle:

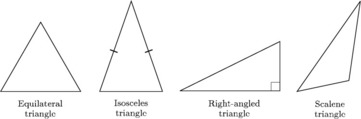
An **equilateral triangle** is a triangle with all three sides of equal length. The three angles are also all equal.

An **isosceles triangle** is a triangle with two sides of equal length. The two angles opposite the equal sides are also equal to one another.

A **right-angled triangle** is a triangle with one angle that is a right angle.

A **scalene triangle** is a triangle with all the sides of different lengths. The angles are also all different.

Start of Figure



End of Figure

It is a general convention that equal sides are marked by drawing a short line, /, through them, and a right angle is marked by a square between the arms of the angle. If sides and angles are not marked, do not assume that they are equal, just because they look equal!

## 2.2 Geometric shapes – quadrilaterals

Start of Figure

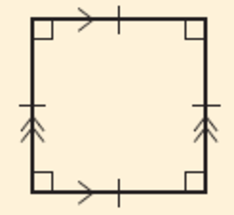


A **quadrilateral** is a shape with four straight sides.

[View description - A quadrilateral is a shape with four straight sides.](" \l "Session2_Alternative1)

End of Figure

Start of Figure

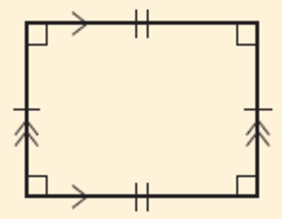


A **square** has four equal sides and four right angles. Opposite sides are parallel.

[View description - A square has four equal sides and four right angles. Opposite sides are parallel ...](" \l "Session2_Alternative2)

End of Figure

Start of Figure

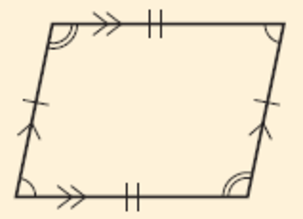


A **rectangle** has four right angles and opposite sides are equal and parallel.

[View description - A rectangle has four right angles and opposite sides are equal and parallel.](" \l "Session2_Alternative3)

End of Figure

Start of Figure

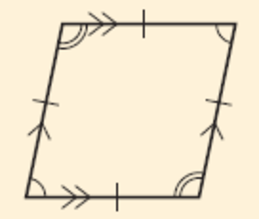


A **parallelogram** has opposite sides equal and parallel. Opposite angles are equal.

[View description - A parallelogram has opposite sides equal and parallel. Opposite angles are equal ...](" \l "Session2_Alternative4)

End of Figure

Start of Figure



A **rhombus** has four equal sides. Opposite sides are parallel and opposite angles are equal.

[View description - A rhombus has four equal sides. Opposite sides are parallel and opposite angles are ...](" \l "Session2_Alternative5)

End of Figure

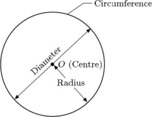
From the descriptions above, you can see that squares, rectangles and rhombuses are all special types of parallelogram.

## 2.3 Geometric shapes – circles

All circles are the same shape – they can only have different sizes.

In a circle, all the points are the same distance from a point called the centre. The centre is often labelled with the letter O.

Start of Figure



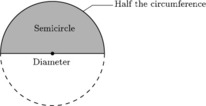
[View description - Uncaptioned Figure](" \l "Session2_Alternative6)

End of Figure

The outside edge of a circle is called the **circumference**. A straight line from the centre to a point on the circumference is called a **radius** of the circle (the plural of radius is radii).

A line with both ends on the circumference and passing through the centre is called a **diameter**. Any diameter cuts the circle into two halves called **semicircles**.

Start of Figure

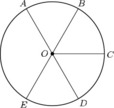


[View description - Uncaptioned Figure](" \l "Session2_Alternative7)

End of Figure

In the circle below, the lines labelled OA, OB, OC, OD and OE are all radii, and AD and BE are diameters. The points A, B, C, D and E all lie on the circumference.

Start of Figure



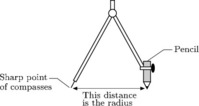
End of Figure

Although the terms ‘radius’, ‘diameter’ and ‘circumference’ each denote a certain line, these words are also employed to mean the lengths of those lines. So it is common to say, for example, ‘Mark a point on the circumference’ and ‘The circumference of this circle is 7.3 cm’. It is obvious from the context whether the line itself or the length is being referred to.

## 2.4 Drawing circles

Drawing circles freehand often produces very uncircle-like shapes! If you need a reasonable circle, you could draw round a circular object, but if you need to draw an accurate circle with a particular radius, you will need a pair of compasses and a ruler. Using the ruler, set the distance between the point of the compasses and the tip of the pencil at the desired radius; place the point on the paper at the position where you want the centre of the circle to be and carefully rotate the compasses on the point so that the pencil marks out the required circle.

Start of Figure



End of Figure

To draw a large circle, perhaps to create a circular flower bed, a similar set-up is needed. The essentials are a fixed central point (possibly a stake) and a means of ensuring a constant radius (possibly a string). To draw a circle on a computer or calculator screen, you may also need to fix the centre (maybe using coordinates) and the radius.

It is often necessary to label diagrams of geometric figures, such as circles or triangles, in order to make it easier to refer to specific parts of the figure. Usually points are labelled as A, B, C, … and lines as AB, BC, …, or a, b, c, … and using combinations of the letters, such as ‘triangle ABC’ (‘Triangle ABC’ is often written as ‘ΔABC’.). It is rather laborious to read, but unfortunately is unavoidable.

Note that, as in the case of words like ‘radius’ and ‘circumference’, AB may be used to mean the line from A to B or the length of the line itself.

## 2.5 Symmetry

Symmetry is a feature that has been used in the design of objects and patterns in many cultures throughout recorded history. From Greek vases and medieval windows to Victorian tiles and Native American decorations, symmetry has been seen as a way of achieving balance and beauty.

Start of Figure



End of Figure

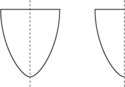
Symmetry can be described mathematically, and is a useful concept when dealing with shapes.

## 2.6 Line symmetry

Look at the shapes below. The symmetry of the shape on the left and its relationship to the shape on the right can be thought of in two ways:

* Fold the left-hand shape along the central line. Then one side lies exactly on top of the other, and gives the shape on the right.
* Imagine a mirror placed along the central dotted line. The reflection in the mirror gives the other half of the shape.

Start of Figure



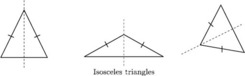
[View description - Uncaptioned Figure](" \l "Session2_Alternative8)

End of Figure

This type of symmetry is called **line symmetry**.

Any isosceles triangle has line symmetry.

Start of Figure

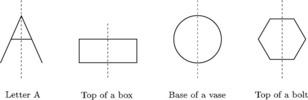


End of Figure

The dashed lines represent lines of symmetry, and each shape is said to be **symmetrical** about this line.

The following all have line symmetry:

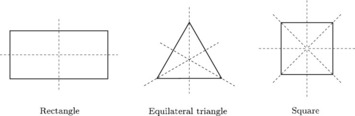
Start of Figure



End of Figure

A shape can have more than one line of symmetry. Thus a rectangle has two lines of symmetry, an equilateral triangle has three lines of symmetry, and a square has four.

Start of Figure



End of Figure

A circle has an infinite number of lines of symmetry since it can be folded about any diameter. Only eight of the possible lines of symmetry are indicated below.

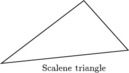
Start of Figure



End of Figure

Some shapes, such as a scalene triangle, have no lines of symmetry – it is not possible to fold the shape about a line so that the two halves fit exactly on top of one another.

Start of Figure



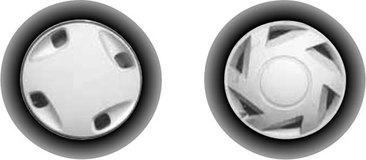
[View description - Uncaptioned Figure](" \l "Session2_Alternative9)

End of Figure

## 2.7 Rotational symmetry

There is another kind of symmetry which is often used in designs. It can be seen, for instance, in a car wheel trim.

Start of Figure



[View description - Uncaptioned Figure](" \l "Session2_Alternative10)

End of Figure

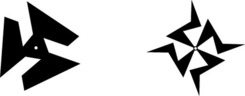
Look at the trim on the left. It does not have line symmetry but it has **rotational symmetry**. If the wheel is rotated through a quarter of a full turn, it will look exactly the same; likewise, if it is rotated through half a complete turn, or through three-quarters of a turn. There are four positions in which the wheel looks the same: hence the wheel is said to have **rotational symmetry of order 4** or **four-fold rotational symmetry**.

The wheel trim on the right has rotational symmetry of order 6. In this case there are six positions in which the trim will look exactly the same. These occur when the wheel is rotated through one-sixth of a complete turn, two-sixths of a turn, and so on, to five-sixths of a turn and finally a complete turn (when, of course, the wheel is back in its original position).

The centre of the shape is the point about which the shape is rotated; it is called **the centre of rotation**.

A shape does not have to be round to have rotational symmetry. The following shapes have rotational symmetry of orders 3 and 4, respectively.

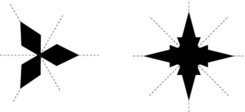
Start of Figure



End of Figure

It is not difficult to create shapes with both line symmetry and rotational symmetry. The two designs below are examples.

Start of Figure



End of Figure

The design on the left has three lines of symmetry and rotational symmetry of order 3. The one on the right has four lines of symmetry and rotational symmetry of order 4.

A shape with no rotational symmetry, like the one below, is sometimes said to have ‘rotational symmetry of order 1’. This is because it will only fit on top of itself in one position – after a complete turn.

Start of Figure



[View description - Uncaptioned Figure](" \l "Session2_Alternative11)

End of Figure

### Try some yourself

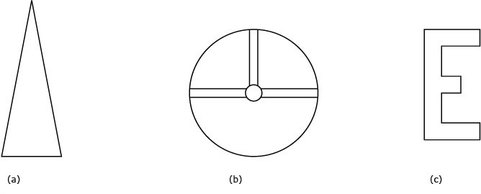
Start of Activity

**Question 1**

Start of Question

Draw a line of symmetry on each of the shapes below.

Start of Figure



End of Figure

End of Question

[View answer - Question 1](" \l "Session2_Answer1)

End of Activity

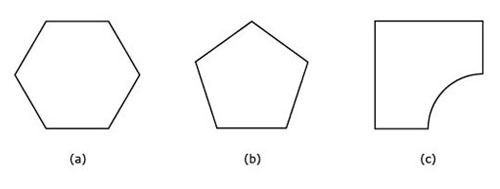
Start of Activity

**Question 2**

Start of Question

Mark all of the lines of symmetry on these shapes. For each shape, state the total number of lines of symmetry.

Start of Figure



End of Figure

End of Question

[View answer - Question 2](" \l "Session2_Answer2)

End of Activity

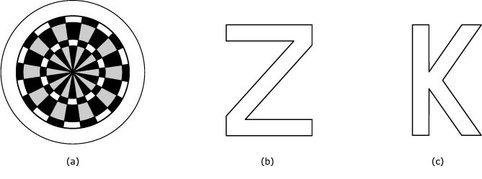
Start of Activity

**Question 3**

Start of Question

Which of these have rotational symmetry?

Start of Figure



End of Figure

End of Question

[View answer - Question 3](" \l "Session2_Answer3)

End of Activity

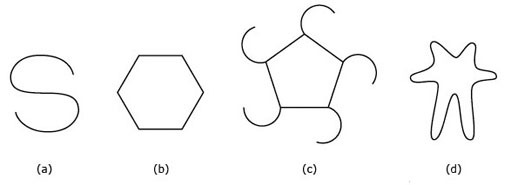
Start of Activity

**Question 4**

Start of Question

Mark the centre of rotation on each of the shapes below. For each, state the order of rotational symmetry.

Start of Figure



End of Figure

End of Question

[View answer - Question 4](" \l "Session2_Answer4)

End of Activity

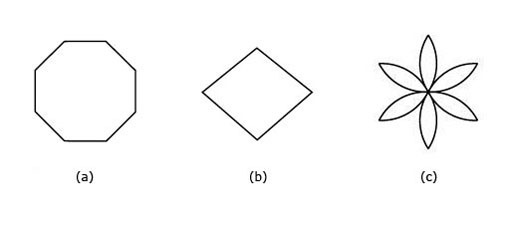
Start of Activity

**Question 5**

Start of Question

Describe the symmetry of each of these shapes. Mark all the lines of symmetry in each case. Also mark the centre of rotation, and state the order of rotational symmetry.

Start of Figure



End of Figure

End of Question

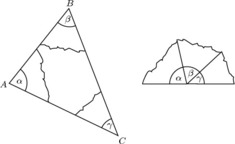
[View answer - Question 5](" \l "Session2_Answer5)

End of Activity

## 2.8 The angles of a triangle

The sum of the angles of any triangle is 180°. This property can be demonstrated in several ways. One way is to draw a triangle on a piece of paper, mark each angle with a different symbol, and then cut out the angles and arrange them side by side, touching one another as illustrated.

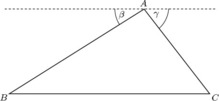
Start of Figure



End of Figure

You can see why it is that the angles fit together in this way by looking at the triangle below. An extra line has been added parallel to the base. The angle of the triangle, D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_e879eb0574cae34e866f9abea1e4e6df433c7869_mu120_b_i049e.gif, is equal to the angle β at the top (they are alternate angles), and similarly the angle of the triangle, D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_70b6d68295477a4e916aa65c8bcf7eaa3338223d_mu120_b_i050e.gif, is equal to the angle γ at the top (they are also alternate angles). The three angles at the top (β, γ and the angle of the triangle, D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_580e07963ffaee5d82b01bcd3780ff3d4e391cf1_mu120_b_i041e.gif) form a straight line of total angle 180°, and so the angles of the triangle must also add up to 180°.

Start of Figure



End of Figure

Start of Box

The sum of the angles of a triangle is 180°.

End of Box

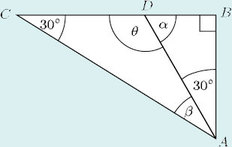
The fact that the angles of a triangle add up to 180° is another angle property that enables you to find unknown angles.

Start of Example

**Example 7**

Find α, β and θ in the diagram below.

Start of Figure



End of Figure

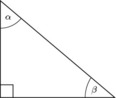
[View answer - Example 7](" \l "Session2_Answer6)

End of Example

It is possible to deduce more information about the angles in certain special kinds of triangles.

In a right-angled triangle, since one angle is a right angle (90°), the other two angles must add up to 90°. Thus, in the example below, α + β = 90°.

Start of Figure



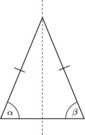
End of Figure

In an equilateral triangle, all the angles are the same size. So each angle of an equilateral triangle must be 180° ÷ 3 = 60°.

In an isosceles triangle, two sides are of equal length and the angles opposite those sides are equal. Therefore, α = β in the triangle below.

Such angles are often called **base angles**.

Start of Figure



[View description - Uncaptioned Figure](" \l "Session2_Alternative12)

End of Figure

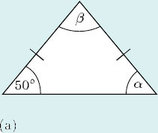
This means that there are only two different sizes of angle in an isosceles triangle: if the size of one angle is known, the sizes of the other two angles can easily be found. The next example shows how this is done.

Start of Example

**Example 8**

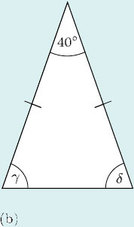
Find the unknown angles in these isosceles triangles, which represent parts of the roof supports of a house.

Start of Figure



End of Figure

Start of Figure



End of Figure

[View answer - Example 8](" \l "Session2_Answer7)

End of Example

The various angle properties can also be used to find the sum of the angles of a quadrilateral.

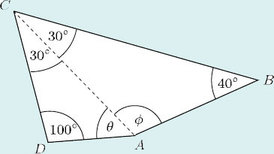
Start of Example

**Example 9**

The diagram below represents the four stages of a walk drawn on an Ordnance Survey map.

The figure ABCD is a quadrilateral. Find θ and φ, and thus the sum of all the angles of the quadrilateral.

Start of Figure



End of Figure

[View answer - Example 9](" \l "Session2_Answer8)

End of Example

In fact, you can find the sum of the four angles of a quadrilateral without calculating each angle as in [Example 9](#exa001_009). Look again at the quadrilateral: the dotted line splits it into two triangles, and the angles of these triangles together make up the angles of the quadrilateral. Each triangle has an angle sum of 180°, so the angle sum of the quadrilateral is 2 × 180° = 360°. This is true for any quadrilateral.

Start of Box

The sum of the angles of a quadrilateral is 360°.

End of Box

Similarly, other polygons (that is, other shapes with straight sides) can be divided into triangles to find the sum of their angles.

### Try some yourself

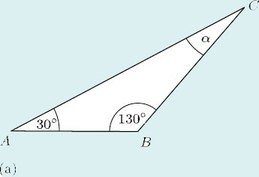
Start of Activity

**Question 1**

Start of Question

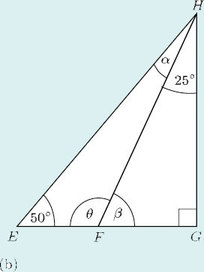
Find the unknown angles in each of these diagrams, which represent part of the bracing structure supporting a marquee.

Start of Figure



End of Figure

Start of Figure



End of Figure

End of Question

[View answer - Question 1](" \l "Session2_Answer9)

End of Activity

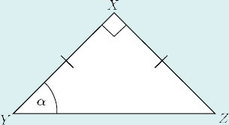
Start of Activity

**Question 2**

Start of Question

Deduce the value of α in the triangle below.

Start of Figure



End of Figure

End of Question

[View answer - Question 2](" \l "Session2_Answer10)

End of Activity

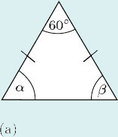
Start of Activity

**Question 3**

Start of Question

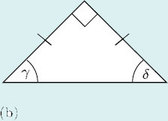
Find the unknown angles in the following isosceles triangles, which represent roof rafters.

Start of Figure



End of Figure

Start of Figure



End of Figure

End of Question

[View answer - Question 3](" \l "Session2_Answer11)

End of Activity

## 2.9 Similar and congruent shapes

Two shapes are said to be **similar** if they are the same shape but not necessarily the same size. In other words, one may be an enlargement of the other. They may also have different orientations, as in the drawing below.

Start of Figure



End of Figure

When a photograph is enlarged, the two images are similar.

Start of Figure



End of Figure

But if a photograph is stretched in only one direction, the resulting shape is not similar to the original.

Start of Figure



End of Figure

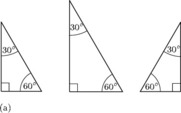
In effect, when two shapes are similar, one is a scaled up (or down) version of the other. Thus an accurate model and its original will be similar in this mathematical sense. If you measure the sides of the model, you will find that to produce the original, each side must be scaled up by the same amount. However, the angles remain the same in each version.

The simplest scaled shapes are similar triangles. In two similar triangles, angles in equivalent positions must be the same size. This provides a way of identifying similar triangles.

It is not necessary to calculate all the angles in two similar triangles. If two angles in one triangle match two angles in the other, then the third angle must also be the same in both, because in each case it will be 180° minus the sum of the other two angles.

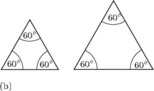
Examples of similar triangles are set out below.

Start of Figure



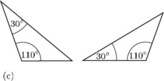
End of Figure

Start of Figure



End of Figure

Start of Figure



End of Figure

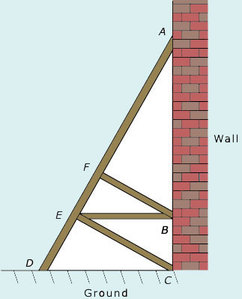
If two figures are the same shape and the same size, they are said to be **congruent**.

Start of Example

**Example 10**

This diagram shows, in simplified form, a wooden buttress supporting the wall of a medieval church.

Start of Figure



[View description - Uncaptioned Figure](" \l "Session2_Alternative13)

End of Figure

The angle between the ground and the buttress, D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_155ecc7cb1c5f90d442d928570608a50fa3fee42_mu120_b_i055e.gif, is 65°. By making appropriate assumptions, identify which triangles are similar. Calculate all the angles in the structure.

[View answer - Example 10](" \l "Session2_Answer12)

End of Example

You may have met other examples of similar shapes, for example, when using scale diagrams. The scale plan of a house is similar to the actual layout of the house.

### Try some yourself

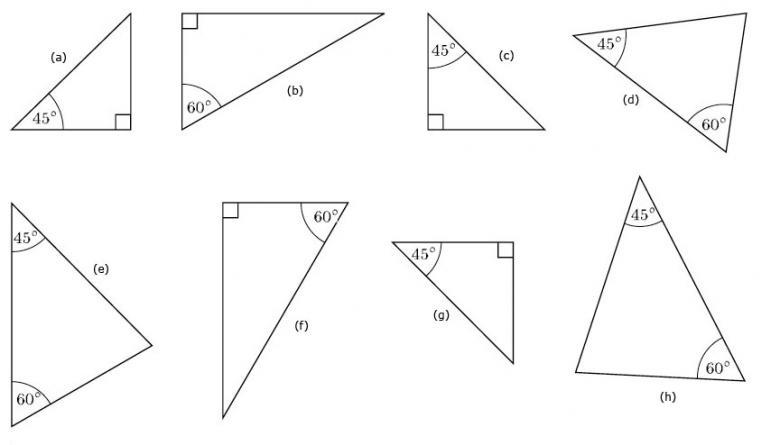
Start of Activity

**Question 1**

Start of Question

Which of these triangles are similar?

Start of Figure



End of Figure

End of Question

[View answer - Question 1](" \l "Session2_Answer13)

End of Activity

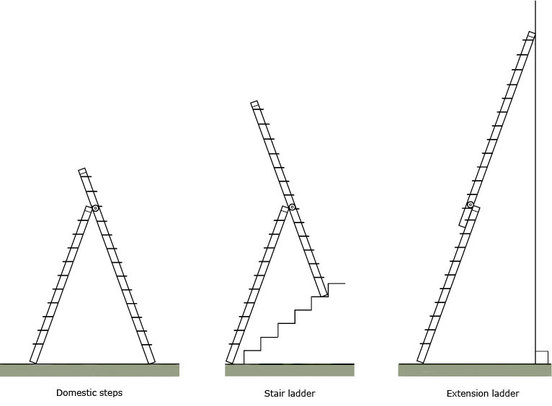
Start of Activity

**Question 2**

Start of Question

An aluminium ladder can be used in three different ways:

Start of Figure



End of Figure

The manufacturer says that in use, each segment of the ladder should make an angle of 20° with the vertical.

For each diagram, add construction lines and labels so as to identify two similar triangles. Are any of the similar triangles also congruent?

End of Question

[View answer - Question 2](" \l "Session2_Answer14)

End of Activity

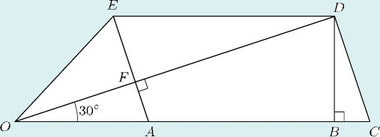
Start of Activity

**Question 3**

Start of Question

This diagram shows the arrangement of the struts in a wall of a shed.

Start of Figure



[View description - Uncaptioned Figure](" \l "Session2_Alternative14)

End of Figure

The lines OABC and DE are each horizontal. The struts EA and DC are parallel.

* (a) Which of these are right angles?
* D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_cbe3198e5439a615bfb8cd8dd492be07def5722e_mu120_b_u040e.gif
* (b) Write down two angles that are equal to D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_60b7ec1a33ca590ea61a6a8565c8ed2d42bf9d87_mu120_b_i026e.gif
* (c) Several of the triangles formed by the struts are similar (that is, they are the same shape). Write down all the triangles that are similar to ΔOAF.

End of Question

[View answer - Question 3](" \l "Session2_Answer15)

End of Activity

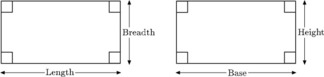
## 3 Areas and volumes

## 3.1 Areas of quadrilaterals and triangles

You may like to add the area formulas in this section to your notes for future reference.

The simplest areas to find are those of rectangles. The area of a rectangle is its length multiplied by its breadth. Sometimes the dimensions of a rectangle are referred to as the base and the height, instead of the length and the breadth. The area is then expressed as the base multiplied by the height.

Start of Figure



End of Figure

Start of Box

Area of a rectangle = length × breadth = base × height

End of Box

A square is a special kind of rectangle in which the length is equal to the breadth. Hence its area is the length of one side multiplied by itself, or the length of one side squared.

Start of Box

Area of a square = length × length = length2

End of Box

For example, the area of a square mirror with sides 50 cm long is 50 cm × 50 cm = 2500 cm2.

Now consider parallelograms.

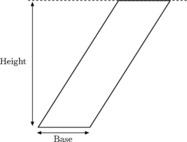
Start of Box

Area of a parallelogram = base × height

End of Box

In the formula for the area of a parallelogram, the height is the perpendicular distance from the base to the opposite side. In order to avoid ambiguity it is sometimes called the perpendicular height rather than just the height. The height is not the length of the sloping side.

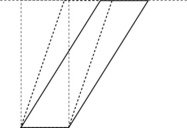
Start of Figure



End of Figure

At first sight, the formula for a parallelogram is quite surprising: it is the same formula as that for a rectangle. Imagine the bottom side of the parallelogram is fixed, but the top side slides along a line, as in the diagram below. The top and bottom of the parallelogram remain the same length and the same distance apart, while the other two sides lengthen or shrink. The shape always remains a parallelogram. (Notice that in one position, the parallelogram will become a rectangle – its sides will be at right angles to the base.)

Start of Figure



End of Figure

The area of the parallelogram stays the same as the parallelogram shifts: it is equal to the area of the rectangle (which, of course, is given by base × height). This is easy to see by looking at the next diagram. In this, the first figure consists of two identical triangles and a parallelogram. Imagine the left-hand triangle slides to the right: it will fit above the other triangle and leave a rectangle to the left. The second figure shows the same two triangles and the rectangle. Therefore the area of the parallelogram must be the same as the area of the rectangle.

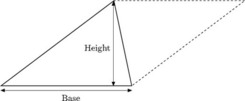
Start of Figure



End of Figure

Next think about the areas of triangles. Any triangle can be seen as half of a parallelogram.

Start of Figure



End of Figure

So the area of a triangle is half the area of a parallelogram.

Start of Box

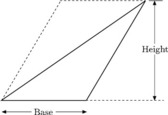
D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_d16c9d2d3b2f30ef4aac2f8b86dbfcf37df336a4_mu120_b_i065e.gif

End of Box

Again, the height is the perpendicular height, which is now the distance from the base to the opposite corner, or vertex, of the triangle.

This formula is true for any triangle, because any triangle will be half of a parallelogram even when the perpendicular height lies outside the triangle, as below.

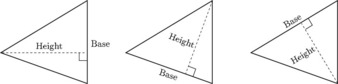
Start of Figure



End of Figure

If a triangle does not have a side that is horizontal, it is not clear which side is ‘the base’. The beauty of the formula for the area is that it works no matter which side is called ‘the base’. Thus the area of the following triangle can be evaluated in three ways.

Start of Figure



End of Figure

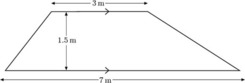
You can often use what you know about the areas of rectangles and triangles to find the areas of more complex shapes.

Start of Example

**Example 11**

The lawn shown below is trapezium-shaped. Find its area.

Start of Figure



[View description - Uncaptioned Figure](" \l "Session3_Alternative1)

End of Figure

[View answer - Example 11](" \l "Session3_Answer1)

End of Example

Start of Example

**Example 12**

Suppose a friend of yours decides to lay crazy paving in his garden which measures 7 m by 5 m, but he wants to leave two rectangular areas, each 2 m by 1 m, for flowerbeds. What area of crazy paving will be needed?

[View answer - Example 12](" \l "Session3_Answer2)

End of Example

### Try some yourself

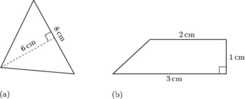
Start of Activity

**Question 1**

Start of Question

Find the area of each of these shapes.

Start of Figure



End of Figure

End of Question

[View answer - Question 1](" \l "Session3_Answer3)

End of Activity

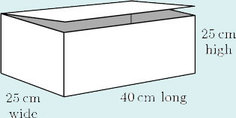
Start of Activity

**Question 2**

Start of Question

A girl is decorating a box by glueing wrapping paper on each face. She wants to put paper on the sides, the top and the bottom, and intends to cut out six pieces of paper and stick them on. Assuming no wastage, calculate what area of paper she will need.

Start of Figure



End of Figure

End of Question

[View answer - Question 2](" \l "Session3_Answer4)

End of Activity

Start of Activity

**Question 3**

Start of Question

A rug measures 3 m by 2 m. It is to be laid on a wooden floor that is 5 m long and 4 m wide. The floorboards not covered by the rug are to be varnished.

* (a) What area of floor will need to be varnished?
* (b) A tin of varnish covers 2.5 m2. How many tins will be required?

End of Question

[View answer - Question 3](" \l "Session3_Answer5)

End of Activity

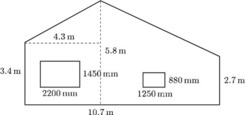
Start of Activity

**Question 4**

Start of Question

This diagram represents the end wall of a bungalow; the wall contains two windows. The wall is to be treated with a special protective paint. In order to decide how much paint is required, the owner wants to know the area of the wall. Divide the wall up into simple shapes and then find the total area.

Start of Figure



End of Figure

End of Question

[View answer - Question 4](" \l "Session3_Answer6)

End of Activity

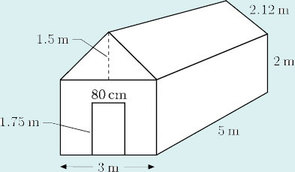
Start of Activity

**Question 5**

Start of Question

The diagram below shows the dimensions of a frame tent. Calculate the amount of canvas needed to make the tent, ignoring the door which is made of different material.

Start of Figure



[View description - Uncaptioned Figure](" \l "Session3_Alternative2)

End of Figure

End of Question

[View answer - Question 5](" \l "Session3_Answer7)

End of Activity

## 3.2 Areas of circles

There are two very famous formulas for circles:

Start of Box

circumference of a circle = D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_e4b5a438fc7dfc49ade4787a0c6fc5b58644abd7_pi.png × diameter

and

area of a circle = D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_e4b5a438fc7dfc49ade4787a0c6fc5b58644abd7_pi.png × radius2.

End of Box

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_e4b5a438fc7dfc49ade4787a0c6fc5b58644abd7_pi.pngis the Greek letter for ‘p’ and it has the name ‘pi’. Its value is approximately 3.14. Most calculators have a key for D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_e4b5a438fc7dfc49ade4787a0c6fc5b58644abd7_pi.png which you can use when carrying out calculations.

Try measuring the circumference and diameter of some circular objects such as tins, bottles or bowls. For each object, divide the circumference by the diameter. You should find that your answer is always just over 3. In fact the ratio is the constant D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_e4b5a438fc7dfc49ade4787a0c6fc5b58644abd7_pi.png. Therefore:

Start of Box

Circumference of a circle = D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_e4b5a438fc7dfc49ade4787a0c6fc5b58644abd7_pi.png × diameter

End of Box

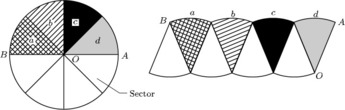
Since the diameter is twice the radius, this formula can be written as

circumference = D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_e4b5a438fc7dfc49ade4787a0c6fc5b58644abd7_pi.png × 2 × radius = 2D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_e4b5a438fc7dfc49ade4787a0c6fc5b58644abd7_pi.png × radius.

The formula for the area of a circle can be explained, as outlined below.

The circle here has been divided into equal ‘slices’ or **sectors**. The eight sectors can then be cut out and rearranged into the shape shown: this shape has the same area as the circle.

Start of Figure



End of Figure

You can see that the total distance from A to B along the ‘bumps’ is the same as half the circumference of the circle, that is:

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_8825148c447d62e1caca6da770de48ab5ac7d57a_mu120_b_i067e.gif× 2D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_e4b5a438fc7dfc49ade4787a0c6fc5b58644abd7_pi.png × radius = D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_e4b5a438fc7dfc49ade4787a0c6fc5b58644abd7_pi.png × radius. Also the length OA is the same as the radius of the circle.

Imagine dividing the circle into more and more sectors and rearranging them as described above. For example, dividing the circle into 16 equal sectors gives the following shape, whose area is still the same as that of the circle.

Start of Figure

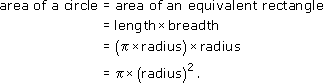
D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_401afece54e0d4dcd41ae55c6f595a03f940b9fc_mu120_b_i195i.jpg

End of Figure

Again the total distance from A to B along the bumps is D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_e4b5a438fc7dfc49ade4787a0c6fc5b58644abd7_pi.png × radius, and the length of OA is the same as the radius.

Notice how the rearranged shape is beginning to look more like a rectangle. The more sectors, the straighter AB will become and the more perpendicular OA will be. Eventually it will not be possible to distinguish the rearranged shape from a rectangle. The area of this rectangle will be the same as that of the circle, and its sides will have the lengths D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_e4b5a438fc7dfc49ade4787a0c6fc5b58644abd7_pi.png × radius (for AB) and radius (for OA). So the following formula can be deduced:

Start of $1



End of $1

Start of Box

Area of a circle = D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_e4b5a438fc7dfc49ade4787a0c6fc5b58644abd7_pi.png × (radius)2

End of Box

Start of Example

**Example 13**

A circular flowerbed is situated in the centre of a traffic roundabout. The radius of the flowerbed is 10 m. Find its circumference and its area.

[View answer - Example 13](" \l "Session3_Answer8)

End of Example

Start of Example

**Example 14**

A circular pond has a diameter of 7 m. A 1 m wide gravel path is to be laid around the pond. What is the area of the path?

[View answer - Example 14](" \l "Session3_Answer9)

End of Example

### Try some yourself

Start of Activity

**Question 1**

Start of Question

Find the area of a circle of (a) radius 8 cm, and (b) radius 15 m.

End of Question

[View answer - Question 1](" \l "Session3_Answer10)

End of Activity

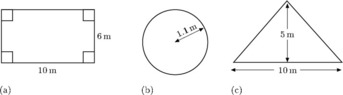
Start of Activity

**Question 2**

Start of Question

Calculate the areas of the following shapes:

Start of Figure



End of Figure

End of Question

[View answer - Question 2](" \l "Session3_Answer11)

End of Activity

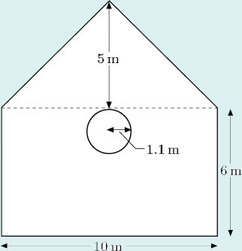
Start of Activity

**Question 3**

Start of Question

Use your answers to the previous question to find the area of turf needed for the proposed lawn shown below, which has a circular flowerbed in the middle. Round your answer to the nearest square metre.

Start of Figure



End of Figure

End of Question

[View answer - Question 3](" \l "Session3_Answer12)

End of Activity

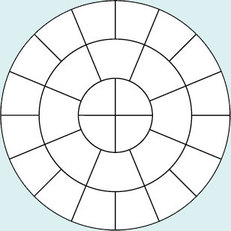
Start of Activity

**Question 4**

Start of Question

A manufacturer produces a patio kit consisting of 28 paving slabs which are shaped so that they fit together to form rings, as shown. The outside edge of each ring is a circle, and all three circles have the same centre. Circles with the same centre are called **concentric circles**. The slabs are of three sizes, one for each ring of the patio. All of the slabs in a particular ring are identical.

Start of Figure



End of Figure

The radii of the three circles are 0.4 m, 0.8 m and 1.2 m.

Making appropriate assumptions, calculate which of the three types of slab is the heaviest and which the lightest.

End of Question

[View answer - Question 4](" \l "Session3_Answer13)

End of Activity

Start of Box

**Hint**

Try breaking the problem in question 4 down into steps and considering what you know about what you want to find out. You know the radii of the circles, so can find the area of each circle. That should help you to find the area of each ‘ring’ of slabs. Then count how may slabs are in each ring and use that to work out the area of each slab.

End of Box

## 3.3 Volumes

What is a volume? The word usually refers to the amount of three-dimensional space that an object occupies. It is commonly measured in cubic centimetres (cm3) or cubic metres (m3).

A closely related idea is capacity; this is used to specify the volume of liquid or gas that a container can actually hold. You might refer to the volume of a brick and the capacity of a jug – but not vice versa. Note that a container with a particular volume will not necessarily have the same amount of capacity. For example, a toilet cistern will have a smaller capacity than its total volume because the overflow pipe makes the volume above the pipe outlet unusable. Some units are used only for capacity – examples are litre, gallon and pint; cubic centimetres and cubic metres can be used for either capacity or volume.

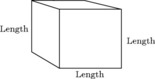
One of the simplest solid shapes is a **cube**; it has six identical square faces.

Start of Box

Volume of a cube = length × length × length = (length) 3

End of Box

Start of Figure



End of Figure

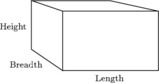
A cuboid (or rectangular box) has 6 rectangular faces as shown below.

Start of Box

Volume of a rectangular box = length × breadth × height

End of Box

Start of Figure



End of Figure

The length × breadth is the area of the bottom (or top) of the box, so an alternative formula is

volume of box = area of base × height.

The volume formula can also be written as

volume  = area of end face × length

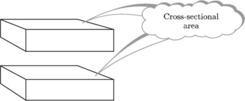
or

volume = area of front face × breadth

## 3.4 Cylinders and shapes with a uniform cross-section

An important idea when calculating volumes of simple shapes is that of a **cross-section**. In the case of the rectangular box considered above, it is possible to slice through the box horizontally so that the sliced area is exactly the same as the area of the base or top; in other words, the areas of the horizontal cross-sections are equal.

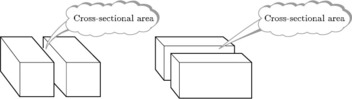
Start of Figure



End of Figure

Likewise, you could slice through the box vertically in either of two different directions, producing cross-sections that are the same as either the end faces or the front and back faces.

Start of Figure



End of Figure

For objects that have a constant cross-sectional area, there is a very useful formula for the volume.

Start of Box

Volume = cross-sectional area × length

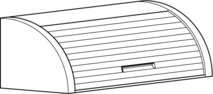
(length is measured at right angles to the cross section)

End of Box

Notice that this fits with the formula for the volume of a rectangular box.

Bear in mind that many objects can only be sliced in one direction to produce a constant cross-sectional area. This bread bin is one example.

Start of Figure



End of Figure

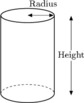
Another example is a cylinder. The formula at the top of the page can be used to find the volume of a cylinder because a cylinder has a constant cross-sectional area if it is sliced parallel to the circular face – the cross-sectional area is the area of the circle that forms the base of the cylinder, that is D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_e4b5a438fc7dfc49ade4787a0c6fc5b58644abd7_pi.png × (radius)2. The following formula can then be deduced.

Start of Box

Volume of cylinder = D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_e4b5a438fc7dfc49ade4787a0c6fc5b58644abd7_pi.png × (radius)2 × height

End of Box

Start of Figure



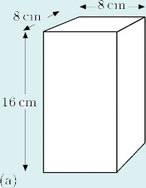
End of Figure

Start of Example

**Example 15**

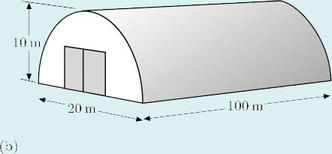
Find the volumes of these objects.

Start of Figure



End of Figure

Start of Figure



End of Figure

[View answer - Example 15](" \l "Session3_Answer14)

End of Example

### Try some yourself

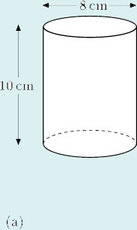
Start of Activity

**Question 1**

Start of Question

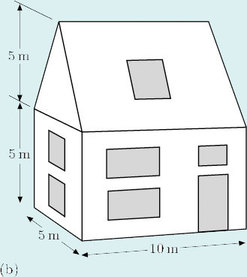
Find the volumes of these objects.

Start of Figure



End of Figure

Start of Figure



End of Figure

End of Question

[View answer - Question 1](" \l "Session3_Answer15)

End of Activity

Start of Activity

**Question 2**

Start of Question

Two car manufacturers both claim that their models have an engine capacity of 2 litres. The two models have four-cylinder, four-stroke engines.

The table below shows the details of the four cylinders.

Start of Table

|  |  |  |  |
| --- | --- | --- | --- |
| **Car model** | **Cylinder diameter (bore)/mm** | **Cylinder height (stroke)/mm** | **Number of cylinders** |
| A | 86 | 86 | 4 |
| B | 92 | 75 | 4 |

End of Table

By working out the total volume of the four cylinders for each model in cm3, find out if the manufacturers’ claims are true.

(Hint: 1 litre = 1000 cm3.)

End of Question

[View answer - Question 2](" \l "Session3_Answer16)

End of Activity

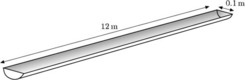
Start of Activity

**Question 3**

Start of Question

The guttering pictured here has a semicircular cross-section. Find the volume of water that the guttering will hold when full.

Start of Figure



End of Figure

End of Question

[View answer - Question 3](" \l "Session3_Answer17)

End of Activity

## 3.5 Scaling areas and volumes

In OpenLearn course [Diagrams, graphs and charts](http://www.open.edu/openlearn/science-maths-technology/mathematics-and-statistics/mathematics-education/diagrams-charts-and-graphs/content-section-0?utm_source=openlearn&utm_campaign=ol&utm_medium=ebook) you saw how a scale is used on plans of houses and other structures. The scale makes it possible to take a length on the plan and calculate the corresponding length in reality. The scale can also be used to convert between areas on the plan and real areas. Moreover, if a three-dimensional scale model is made, it is possible to use the scale to convert between volumes in the model and the real volumes.

Start of Example

**Example 16**

Dudley's and June's hobby is constructing dolls' houses. They decide to make a model of their own house, using a scale in which 1 cm on the model represents 20 cm on their real house.

They are making the curtains for the model. The window in the real dining room measures 240 cm by 120 cm. What is the area of the real window and the area of the window in the model? How many times greater is the real area?

[View answer - Example 16](" \l "Session3_Answer18)

End of Example

This example has demonstrated a general result:

Start of Box

To scale areas, multiply or divide by the scale squared.

End of Box

Start of Example

**Example 17**

Dudley and June have a cold-water tank in their loft, which has a capacity of 250 litres. If they make a scale model of the tank, what will its capacity be?

[View answer - Example 17](" \l "Session3_Answer19)

End of Example

This example illustrates a general result:

Start of Box

To scale volumes, multiply or divide by the scale cubed.

End of Box

### Try some yourself

Start of Activity

**Question 1**

Start of Question

Calculate the area of a carpet in a model house if the real carpet has an area of 22 m2. On the scale used, 1 cm represents 0.25 m.

End of Question

[View answer - Question 1](" \l "Session3_Answer20)

End of Activity

Start of Activity

**Question 2**

Start of Question

A model steam engine that runs in a park is built to a scale such that 1 cm represents 0.2 m. On the model there is space in the tender for D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_f5cc5625e2db3269dd2e928a80b7fcb4cf0ee4f3_mu120_b_i073e.gif m3 of coal. What volume of coal could be carried in the real engine's tender?

End of Question

[View answer - Question 2](" \l "Session3_Answer21)

End of Activity

## 4 OpenMark quiz

Now try the [quiz](https://students.open.ac.uk/openmark/mu120-08.module7/) and see if there are any areas you need to work on.

## Conclusion

This free course provided an introduction to studying Mathematics. It took you through a series of exercises designed to develop your approach to study and learning at a distance and helped to improve your confidence as an independent learner.

## Keep on learning

Start of Figure

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End of Figure

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Start of Box

For reference, full URLs to pages listed above:

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End of Box

## Acknowledgements

Adapted from the works of [Steve Jurvetson](http://www.flickr.com/photos/44124348109@N01/175152824): [Details correct as of 8th July 2008]

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## Solutions

## Question 1

#### Answer

Every hour the minute hand turns through 360°. It will have made five such revolutions in five hours. This amounts to 1800°.

The hour hand turns through 30° every hour (D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_0134a3c4a567f3135a05a176137e75c9e8254f68_mu120_b_si010e.gif of 360°). In five hours it will turn through 5 × 30° = 150°.

[Back to - Question 1](" \l "Session1_Activity1)

## Question 2

#### Answer

* (a) D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_c2783d5a2ede9a11c50ef2daa232edac08138728_mu120_b_i029e.gif or D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_fd5feead7472346759ae81357f8a42ff12c0a9f5_angle.gifCAB.
* (b) D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_5813e4274ab19e6d6927e28ff1f65e6a33bbedaa_mu120_b_si012e.gif or D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_fd5feead7472346759ae81357f8a42ff12c0a9f5_angle.gifBCA.
* (c) γ or D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_fd5feead7472346759ae81357f8a42ff12c0a9f5_angle.gifDAC.
* (d) δ or D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_3421d2391e86182f0d57c52cd7665507522f9261_mu120_b_si013e.gif.

[Back to - Question 2](" \l "Session1_Activity2)

## Question 1

#### Answer

* (a) Any of the following could be used: D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_580e07963ffaee5d82b01bcd3780ff3d4e391cf1_mu120_b_i041e.gif, D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_68f927d9276e3d60d005a8ef68dc0d4dbd2010d8_mu120_b_i028e.gif, D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_fd5feead7472346759ae81357f8a42ff12c0a9f5_angle.gifBAC, D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_c2783d5a2ede9a11c50ef2daa232edac08138728_mu120_b_i029e.gif, D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_fd5feead7472346759ae81357f8a42ff12c0a9f5_angle.gifCAB.
* (b) α = 80°.
* (c) Because α is less than 90°, it is an acute angle.
* (d) As the three angles of a triangle always add up to 180°,

Start of $1

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End of $1

* Therefore

Start of $1

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End of $1

[Back to - Question 1](" \l "Session1_Activity3)

## Question 2

#### Answer

* (a) Red party: 120°.

Blue party: 95°.

Yellow party: 95°.

Green party: 50°.

* (b) 120° + 95° + 95° + 50° = 360°.
* (c) Since 360° represents 100%, 1° will represent D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_35b46d1b17b2335b5a31050fdbd410c2c3d7b4a6_mu120_b_si014e.gif or D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_febab11c487da65784344eb06b2dd589e63a63a9_mu120_b_si015e.gif.
* So the Red party polled

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_04f34f503399b1bfe782e5cb95e3ac8e142f9658_mu120_b_su028e.gif

End of $1

The Blue party and the Yellow party polled

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_fcbf8b0fdc9708871a87e5193620be36ad116d4d_mu120_b_su029e.gif

End of $1

The Green party polled

Start of $1

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End of $1

[Back to - Question 2](" \l "Session1_Activity4)

## Example 1

#### Answer

The eight spokes divide the circle up into eight equal parts. Therefore the angle required is found by dividing 360° by 8 to give 45°.

[Back to - Example 1](" \l "Session1_Example1)

## Question 1

#### Answer

* (a) Each of the four angles is 360° ÷ 4 = 90°.
* (b) The two upper angles are both 180° ÷ 2 = 90°, and the lower angle is 180°.
* (c) Each of the six angles is 360° ÷ 6 = 60°.
* (d) Each of the twenty angles is 360° ÷ 20 = 18°.
* (e) The acute angle between the hands is 360° ÷ 12 = 30°; the reflex angle is 360° − 30° = 330°.
* (f) Each of the three angles is 360° ÷ 3 = 120°.

[Back to - Question 1](" \l "Session1_Activity5)

## Example 2

#### Answer

* (a) As the angles are on a line,

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_15d87b3ebc6091489cfa7047ed67fa5978b0238b_mu120_b_u045e.gif

End of $1

* (b) As the angles are at a point,

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_944172cfcfd60367ed4216fc36c4ba2c953814a3_mu120_b_u046e.gif

End of $1

[Back to - Example 2](" \l "Session1_Example2)

## Example 3

#### Answer

* (a) The angle turned through at A is 180° − 125° = 55°.
* (b) The angle turned through at B is 180° − 101° = 79°, and the angle turned through at C is 180° − 123° = 57°.

So the total angle that the students have turned through when they arrive at D is 55° + 79° + 57° = 191°.

* (c) The angle that the students need to turn through at S is 180° - 118° = 62°.
* (d) Suppose the students complete the whole course and, at the finish, face in the same direction as at the start, they will overall have made one complete turn, that is, 360°.

So

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_cb2aa73b3da3e8facd2a865fb7fae4545a3a9f17_mu120_b_u047e.gif

End of $1

hence

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_429830704eb5a3356698a13598dad467b9d870e6_mu120_b_u048e.gif

End of $1

[Back to - Example 3](" \l "Session1_Example3)

## Question 1

#### Answer

* (a) γ = 180° − 90° − 60° = 30°.
* (b) δ = 360° − 130° − 60° − 60° = 110°.

[Back to - Question 1](" \l "Session1_Activity6)

## Example 4

#### Answer

First, calculate how many students there were altogether:

16 + 32 + 12 = 60 students.

The whole pie chart (360°) must, therefore, represent 60 students. This means that each student is represented by 360° ÷ 60 = 6°. So the angles for the three slices are

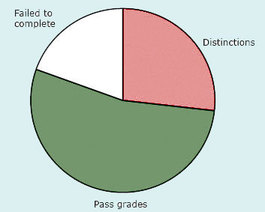
Start of Table

|  |  |
| --- | --- |
| distinctions | 16 × 6 = 96° |
| pass grades | 32 × 6 = 192° |
| failed to complete | 12 × 6 = 72° |

End of Table

The pie chart can be constructed by carefully measuring these angles at the centre of a circle. The slices should be labelled, and an appropriate title given to the chart. The source of the data should also be stated.

Start of Figure



Pie chart showing results of 60 mathematics students over a five-year period (Source: Tutor's own records)

[View description - Pie chart showing results of 60 mathematics students over a five-year period (Source: ...](" \l "Session1_Alternative8)

End of Figure

[Back to - Example 4](" \l "Session1_Example4)

## Question 1

#### Answer

Since one hour will be represented by 360° on the pie chart, 1 minute will be represented by 360° ÷ 60 = 6°.

So the required angles on the chart are:

Start of Table

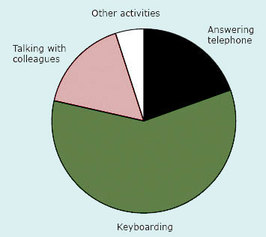
How office staff spend their time (Source: Company survey)

|  |  |
| --- | --- |
| Keyboarding | 35 × 6° = 210° |
| Answering telephone | 12 × 6° = 72° |
| Talking with colleagues | 10 × 6° = 60° |
| Other activities | 3 × 6° = 18° |

End of Table

Check: 210° + 72° + 60° + 18° = 360°.

Start of Figure



End of Figure

[Back to - Question 1](" \l "Session1_Activity7)

## Question 1

#### Answer

* (a) 130°, 50°, 130°.
* (b) 120°, 60°, 120°.
* (c) 90°, 90°, 90°.

[Back to - Question 1](" \l "Session1_Activity8)

## Example 5

#### Answer

Line l is parallel to line m, therefore α and the angle 60° are corresponding angles. So α = 60°.

The angles 60° and θ are vertically opposite angles. So θ = 60°.

Line r is parallel to line s, therefore θ and β are corresponding angles. So β = 60°.

[Back to - Example 5](" \l "Session1_Example5)

## Example 6

#### Answer

Line l is parallel to line m, therefore D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_b349c2389949c761a048aa73d7eca8f57e07ad45_mu120_b_i045e.gif and D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_25b2620a4683f803c3659cbf2c735957510ebd24_mu120_b_i046e.gif are alternate angles. So

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_717eb61404060dcbf2ac043be80e63d3394d8948_mu120_b_u050e.gif

End of $1

Similarly, D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_bf0bab55fdd422390537258d4c6aa1bd79459a95_mu120_b_i047e.gif and D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_53a09139d0d432cd24d28503d25efe1bfe6e20d0_mu120_b_i048e.gif are alternate angles. But

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_0c3829cac15411dc371394ba336346de75d87118_mu120_b_u051e.gif

End of $1

and hence

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_4bd300ccdbd280ba7211f32ababd25e8ec28ab4d_mu120_b_u052e.gif

End of $1

[Back to - Example 6](" \l "Session1_Example6)

## Question 1

#### Answer

(a) Now D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_f337b21b6ea8d8d29f680d4dc3d75371ef82f0da_mu120_b_su031e.gif so D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_670f2ab7b9f56f86702e8187d97e8a9323e26ca0_mu120_b_su032e.gif

But D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_c9775229e7306ff3a343233b73abe8af3ad47c05_mu120_b_su033e.gif so D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_c89fe2d03e929728d8678da18164eb9c5c5bef3a_mu120_b_su034e.gif

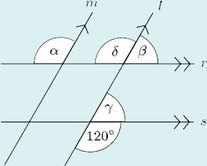
[Back to - Question 1](" \l "Session1_Activity9)

## Question 2

#### Answer

(b)

Start of Figure



End of Figure

There are many ways of finding the sizes of these angles. This is only one of them:

As D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_ab9f1a04b065710f4c05144a905107c7b672022c_mu120_b_su035e.gif it follows that D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_da8ede542ccac86cb8540fa2b3865e9dd863f76d_mu120_b_su036e.gif

But D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_02a6b2f8b30d76f228fbee10a9c13bc3fe48ead3_mu120_b_su037e.gif so D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_f859445d6aefcb9c6dd8ad6043f677eb2f662108_mu120_b_su038e.gif

Similarly, D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_75960e781c527096f4254431cad52c570661c5e5_mu120_b_su039e.gif so D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_1517491838a50b30b973cbbc89f6c84d21e7fa92_mu120_b_su040e.gif

But D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_4dea88d8a1ae054a152604ca9000b386487be197_mu120_b_su041e.gif so D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_c89fe2d03e929728d8678da18164eb9c5c5bef3a_mu120_b_su042e.gif

[Back to - Question 2](" \l "Session1_Activity10)

## Question 3

#### Answer

(c) α = 45° (alternate angles).

β = 55° (alternate angles).

[Back to - Question 3](" \l "Session1_Activity11)

## Question 4

#### Answer

(d) α = D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_68f927d9276e3d60d005a8ef68dc0d4dbd2010d8_mu120_b_i028e.gif = 30° (alternate angles).

β = D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_d2832d46873f5b1764a5c9166b47cbf37dce7456_mu120_b_si017e.gif = 70° (corresponding angles).

[Back to - Question 4](" \l "Session1_Activity12)

## Question 5

#### Answer

(e) As D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_5f398c1ffbbdccba4d29ca4c64febee61ab2af13_mu120_b_su043e.gif it follows that D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_33b14dbfe838a8f4a74d23292d8246d39943a49f_mu120_b_su044e.gif

But β and D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_40270ca9d492c9ebc33c377947381aa537c88cd9_mu120_b_si018e.gif are corresponding angles, so D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_f859445d6aefcb9c6dd8ad6043f677eb2f662108_mu120_b_su038e.gif

Whereas α and D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_40270ca9d492c9ebc33c377947381aa537c88cd9_mu120_b_si018e.gif are alternate angles, so D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_fa037b301dd79d9ad0242bf7cd4d017bf5bf2c36_mu120_b_su046e.gif

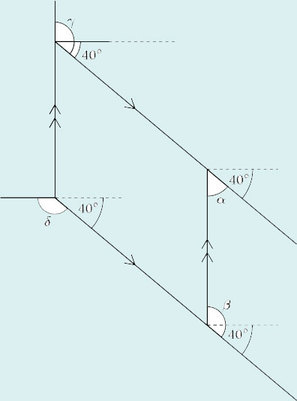
[Back to - Question 5](" \l "Session1_Activity13)

## Question 6

#### Answer

It is a good idea to sketch a diagram, adding some horizontal lines where necessary.

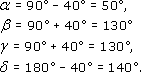
Start of Figure



End of Figure

Assume the lines marked are pairs of parallel lines. Then, since the handrail makes an angle of 40° with the horizontal,

Start of $1



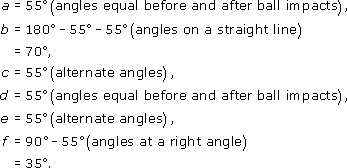
End of $1

[Back to - Question 6](" \l "Session1_Activity14)

## Question 7

#### Answer

Start of $1



End of $1

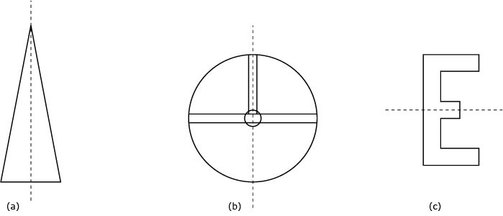
[Back to - Question 7](" \l "Session1_Activity15)

## Question 1

#### Answer

Each of the shapes has only one line of symmetry, so these are the only possible answers.

Start of Figure



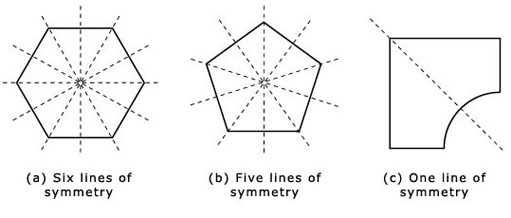
End of Figure

[Back to - Question 1](" \l "Session2_Activity1)

## Question 2

#### Answer

Start of Figure



End of Figure

[Back to - Question 2](" \l "Session2_Activity2)

## Question 3

#### Answer

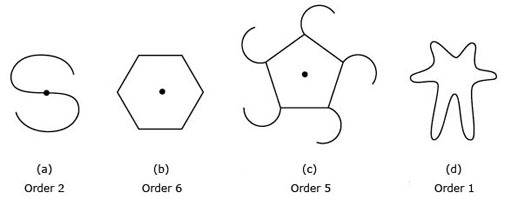
* (a) The dartboard has rotational symmetry.
* (b) The letter Z has rotational symmetry.
* (c) The letter K does not have rotational symmetry.

[Back to - Question 3](" \l "Session2_Activity3)

## Question 4

#### Answer

Start of Figure



End of Figure

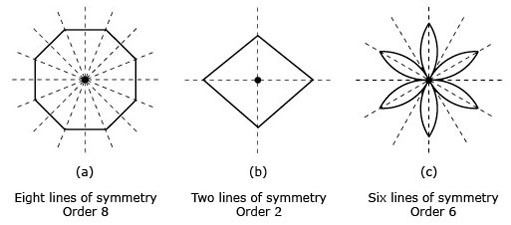
Notice that (d) has no rotational symmetry and no centre of rotation.

[Back to - Question 4](" \l "Session2_Activity4)

## Question 5

#### Answer

Start of Figure



End of Figure

[Back to - Question 5](" \l "Session2_Activity5)

## Example 7

#### Answer

First, look at the angles of ΔABD: D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_f2e4f8c9008c2e6a571fbab35430d2b1a410980a_mu120_b_i051e.gif and D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_563f0779b4e47f73719d26476b85ea9fe14ba12d_mu120_b_i052e.gif

Then, by the angle sum property of triangles,

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_df1553a63ed29b262ae86cf1e88ab416610cfa12_mu120_b_u053e.gif

End of $1

So

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_59912e50cc5fee6447ba4a8fd85f38378b1ecb66_mu120_b_u054e.gif

End of $1

and

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_4c03ae871cc59cebf7d883d4c867df7ce1a4d25b_mu120_b_u055e.gif

End of $1

As CDB is a straight line and α = 60°, it follows that

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_dc19ea1f93f7846affb1fc23964b8d907eeb645c_mu120_b_u056e.gif

End of $1

Now consider the angles of ΔADC: D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_75bc5d3550a48107f1a1ba67aeae5a768fa1493d_mu120_b_i053e.gif and D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_8a12f2d2181dedf174f74219ae3779952bab1f90_mu120_b_i054e.gif

Therefore

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_68ec5f8de5f39ce050da990b0a4a1a062f582a47_mu120_b_u057e.gif

End of $1

So

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_a39fed9921f76f0523059c453be9800696f00393_mu120_b_u058e.gif

End of $1

(Check for yourself that the angles of ΔABC also add up to 180°.)

[Back to - Example 7](" \l "Session2_Example1)

## Example 8

#### Answer

* (a) As α and 50° are the base angles, α = 50°. By the angle sum property of triangles,

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_2aa271af6f9076cb736f90d825e20614685d627d_mu120_b_u059e.gif

End of $1

therefore

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_5926f9aed6ec8da5f9beeae00077dd3302dc942c_mu120_b_u060e.gif

End of $1

* (b) As γ and δ are the base angles, γ = δ. In this triangle,

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_e5c4d63fb559d58c289c7a20432325be64d95bca_mu120_b_u061e.gif

End of $1

therefore

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_35a0e3564c6ae218035258fe5a8bd6563f2991bc_mu120_b_u062e.gif

End of $1

[Back to - Example 8](" \l "Session2_Example2)

## Example 9

#### Answer

From ΔABC,

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_7f5860a163e2fbbb454d109d8ede0a3506f8b9d5_mu120_b_u063e.gif

End of $1

From ΔACD,

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_3f02302715fde17cade9fa29b9307ad7eeeb3a2f_mu120_b_u064e.gif

End of $1

Then the sum of all the angles of the quadrilateral is

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_84b15225fcb53d5441b930ba5932bcbab4f1a863_mu120_b_u065e.gif

End of $1

[Back to - Example 9](" \l "Session2_Example3)

## Question 1

#### Answer

* (a) In ΔABC,

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_24e9d4c984774558c570386fb5e8acdef4c529c2_mu120_b_su049e.gif

End of $1

therefore

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_48a8bc191f3a11c54a5609d8c5caab621bc59a66_mu120_b_su050e.gif

End of $1

* (b) In ΔFGH,

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_1bec7dac3f11b6c861c4b1fbb472dbcece2da3c4_mu120_b_su051e.gif

End of $1

therefore

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_1ede16e34b7c26bbf0ece64fd5fefd5cd8fb2e5f_mu120_b_su052e.gif

End of $1

As EFG is a straight line,

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_7a8814333ab388ff6a88d967fd8a46e6125c367c_mu120_b_su053e.gif

End of $1

So

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_bf856de34cefe8aa891d26bc7ad0aac996cb9134_mu120_b_su054e.gif

End of $1

In ΔEFH,

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_7854f5f93aafba32798a8c00187603530a6b98b1_mu120_b_su055e.gif

End of $1

[Back to - Question 1](" \l "Session2_Activity6)

## Question 2

#### Answer

Lines XY and XZ are of equal length. This means that the triangle is isosceles, so the base angles D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_0e5b21c2679a8d5a5d5e874ef49b109ca567de08_mu120_b_i030e.gif and D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_cfe6ecf0d5c9e0e7e0aa4e9b21301f213db424b0_mu120_b_i031e.gif are equal. Then D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_fc537209f7ea6affa83b7486b552d528b139bd0d_mu120_b_i032e.gif

The third angle in the triangle is a right angle: D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_f27117d86959c264cf636729d82558f879749d35_mu120_b_i033e.gif.

Because the three angles in a triangle must add up to 180°,

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_4f7545686b6a88336c02412dd228b60d2d733da0_mu120_b_u043e.gif

End of $1

Hence

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_b4a51099f59361dab4eff4fa2687309722af7b7e_mu120_b_u044e.gif

End of $1

[Back to - Question 2](" \l "Session2_Activity7)

## Question 3

#### Answer

* (a) As this is an isosceles triangle, α = β.

So

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_9f1a7d92d38e2483553597a35b6fc0ea0b3b2a92_mu120_b_su056e.gif

End of $1

Therefore

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_883f1e37ea2cb2816a18ec2c2d74347e6ce5a482_mu120_b_su057e.gif

End of $1

* (b) As this is an isosceles triangle, γ = δ.

So

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_cd9c38bc93e61740ee32e08a3863db032698f53a_mu120_b_su058e.gif

End of $1

Therefore

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_69bab255c35248bae1c97b5dd52e6df46afeed39_mu120_b_su059e.gif

End of $1

[Back to - Question 3](" \l "Session2_Activity8)

## Example 10

#### Answer

Assume that the wall is vertical, and that the ground and BE are both horizontal. Also assume that BF and CE are at right angles to AD.

Consider the angles of ΔACD: D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_adde458fa4e94e4c443138906cd2536dae75180e_mu120_b_i056e.gif and D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_cabd7eb1fd07c1db751769bab087b9f1a40ad23e_mu120_b_i057e.gif

Then

Start of $1

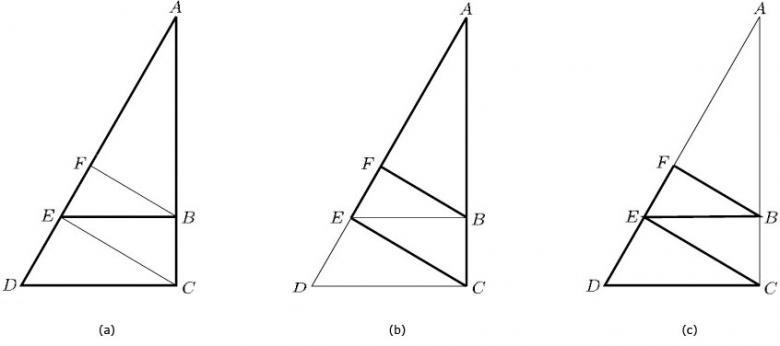
D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_a7bd438276ab49df1536e6fac8fa70c7f09bf4bb_mu120_b_u066e.gif

End of $1

It is easiest to see which triangles are similar if you look at them in pairs.

In each diagram, the two triangles under consideration are emphasised by heavy lines.

Start of Figure



End of Figure

In (a), both the triangles that are outlined by heavy lines have the same angle at A, 25°, and both also have a right angle (at C and B, respectively). Therefore the third angle in the two triangles (at D and E) must also be the same. (You can confirm this by noticing that these are corresponding angles.) The size of these angles must be 180° − 25° − 90° = 65°.

In (b), both triangles have the same angle at A, 25°, and they both have a right angle (at E and F, respectively). Then the third angle in each will be the same size, 65°.

In (c), each triangle has a right angle (at E and F, respectively), and D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_7e7e99008e6fb326581e3cf98ad4a670d255dc22_mu120_b_i058e.gif in the larger triangle is the same size as D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_877a3d15a63fe20b18f692d1d30cf43ceb87d2a6_mu120_b_i059e.gif in the smaller triangle (they are corresponding angles). These corresponding angles are each 65°; hence the third angle must again be 25°.

This gives six triangles, each with angles of 25°, 90° and 65°, and so all are similar.

There is a seventh triangle that is also similar to the others, ΔBEC. This has a right angle, and its angle D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_850c8d41603172e29d847344a7ed2422451bd152_mu120_b_i060e.gif in ΔECD (they are alternate angles), and so is 25°. Its third angle must therefore be 65°.

[Back to - Example 10](" \l "Session2_Example4)

## Question 1

#### Answer

Triangles a, c and g are similar since they have angles of 90°, 45° (and hence another angle of 45°).

Triangles b and f are similar since they have angles of 90°, 60° (and hence another angle of 30°).

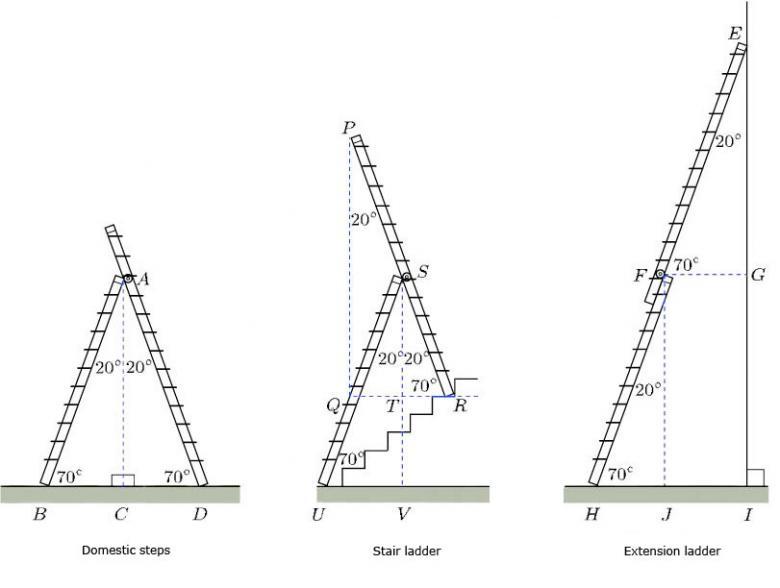
Triangles d, e and h are similar since they have angles of 45° and 60° (and hence another angle of 75°).

[Back to - Question 1](" \l "Session2_Activity9)

## Question 2

#### Answer

Start of Figure



End of Figure

There are many alternative solutions.

Here are some similar triangles which are identified by using the labels given in the diagram above:

Start of Table

|  |  |
| --- | --- |
| domestic steps | ΔACD and ΔACB, |
| stair ladder | ΔSTR, ΔSTQ, ΔPQR, ΔSVU, |
| extension ladder | ΔFJH, ΔEIH, ΔEGF. |

End of Table

Some congruent triangles are

Start of Table

|  |  |
| --- | --- |
| domestic steps | ΔACD and ΔACB, |
| stair ladder | ΔQST and ΔSTR. |

End of Table

[Back to - Question 2](" \l "Session2_Activity10)

## Question 3

#### Answer

**3**

* (a) All four of the given angles are right angles.
* (b) D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_33722cd32d76e057dd576abfb44946f63b6dfe67_mu120_b_i034e.gif (which is the same as D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_20f53b18fe67b0cb1b12a796526bacb685b751a6_mu120_b_i035e.gif) is equal to D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_60b7ec1a33ca590ea61a6a8565c8ed2d42bf9d87_mu120_b_i026e.gif. They are alternate angles.

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_f1b3fb5754aa7b7682ea05040c303020fed87308_mu120_b_i037e.gif(which is the same as D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_a6c3e5e14a7a8015d1a672fed7d71337deb84d1a_mu120_b_i038e.gif) is equal to D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_60b7ec1a33ca590ea61a6a8565c8ed2d42bf9d87_mu120_b_i026e.gif. This is because ΔBCD and ΔOAF are similar: each has a right angle, and D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_143bd487d0e02c99cca644f061c43540d7bedecd_mu120_b_i039e.gif and D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_1a82698eed3bffe0e94fbcbf88a8120add9d0271_mu120_b_i040e.gif are corresponding angles.

* (c) There are four triangles that are similar to ΔOAF: they are ΔOBD, ΔDEF, ΔOCD and ΔBCD.

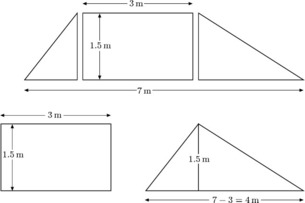
[Back to - Question 3](" \l "Session2_Activity11)

## Example 11

#### Answer

Divide the lawn into three parts – a rectangle and two triangles. Then combine the two triangles into one.

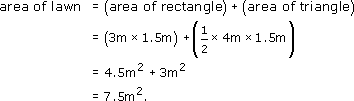
Start of Figure



End of Figure

So

Start of $1



End of $1

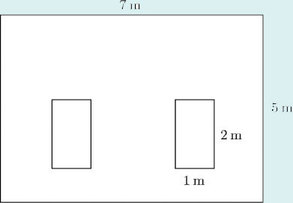
[Back to - Example 11](" \l "Session3_Example1)

## Example 12

#### Answer

The first thing to do when tackling a problem like this is to draw a diagram, and to include on it all the information that has been given.

Start of Figure



End of Figure

Note that, as the positions of the flowerbeds have not been specified, it does not matter where they are placed.

From the diagram,

area of garden = 7 m × 5 m = 35 m2,

area of one flowerbed = 2 m × 1 m = 2 m2.

Therefore,

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_77e5c12a4b9362936530d6b97fe258bf99e55c85_mu120_b_u072e.gif

End of $1

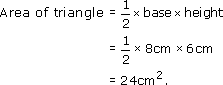
[Back to - Example 12](" \l "Session3_Example2)

## Question 1

#### Answer

(a)

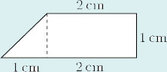
Start of $1



End of $1

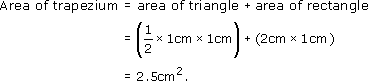
(b) The trapezium can be split into a triangle and a rectangle:

Start of Figure



End of Figure

Start of $1



End of $1

[Back to - Question 1](" \l "Session3_Activity1)

## Question 2

#### Answer

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_3c6b7bdc4c9ede36804ddb264d94b0c7ec995af2_mu120_b_su062e.gif

End of $1

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_f8bac4ec7317fbcc158c3ff995955ff863e6bd98_mu120_b_su063e.gif

End of $1

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_f69f1ad096d9d02cf045f3740978c274b98b09fc_mu120_b_su064e.gif

End of $1

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_0c4ee63b4011d6cb8094862730b5daae59262e05_mu120_b_su065e.gif

End of $1

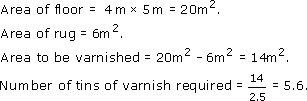
Therefore, the amount of material needed is 5250 cm2.

[Back to - Question 2](" \l "Session3_Activity2)

## Question 3

#### Answer

Start of $1



End of $1

So six tins will have to be purchased.

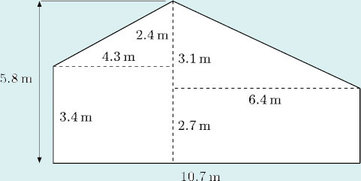
[Back to - Question 3](" \l "Session3_Activity3)

## Question 4

#### Answer

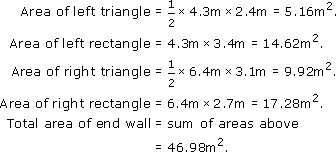
The end wall of the bungalow, minus the windows, can be divided into simple shapes as shown.

Start of Figure



End of Figure

Start of $1



End of $1

The dimensions of the windows, in metres, are 2.2 m by 1.45 m and 1.25 m by 0.88 m, respectively.

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_a937b2bf56d0a32c887c5c5dd489d0ec62514f24_mu120_b_su068e.gif

End of $1

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_72a5c6f64907fc5e55ab88405481d0226370709c_mu120_b_su069e.gif

End of $1

[Back to - Question 4](" \l "Session3_Activity4)

## Question 5

#### Answer

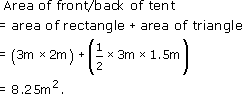
Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_c2af813767bfe20b7011cd897105e84a892535f3_mu120_b_su070e.gif

End of $1

Area of one side of tent = 2 m × 5 m = 10 m2.

Start of $1



End of $1

Area of door = 0.8 m × 1.75 m = 1.4 m2.

Total area of canvas

* = ( 2 × area of one side of sloping roof )
  + + ( 2 × area of side of tent )
  + + ( 2 × area of front/back of tent )
  + − ( area of door )
* = ( 2 × 10.6 m2 ) + ( 2 × 10 m2 )
  + + ( 2 × 8.25 m2 ) − 1.4 m2
* = 56.3 m2.

So 56.3 m2 of canvas are needed.

(In practice, the amount needed will depend upon the width of the canvas and on how many joins there are. It is likely that at least 60 m2 will be needed.)

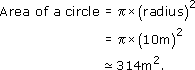
[Back to - Question 5](" \l "Session3_Activity5)

## Example 13

#### Answer

Circumference = 2D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_e4b5a438fc7dfc49ade4787a0c6fc5b58644abd7_pi.png × radius = 2D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_e4b5a438fc7dfc49ade4787a0c6fc5b58644abd7_pi.png × 10 m = 20D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_e4b5a438fc7dfc49ade4787a0c6fc5b58644abd7_pi.png m ≈ 62.8 m

Start of $1



End of $1

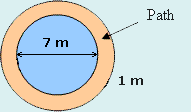
[Back to - Example 13](" \l "Session3_Example3)

## Example 14

#### Answer

The diagram shows the area of the path.

Start of Figure



End of Figure

This area can be found by calculating the area of the path and pond together, and then subtracting the area of the pond.

So, Area of path = Area of path and pond – Area of pond.

The pond and the path form a circle of diameter 1m + 1m + 7m = 9m. A circle of diameter 9m has a radius of 4.5 m.

So, the area of the path and pond = D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_e4b5a438fc7dfc49ade4787a0c6fc5b58644abd7_pi.png × 4.52 m2.

The pond has diameter 7 m, so its radius is 7 m ÷ 2 = 3.5 m.

Hence, the area of the pond = D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_e4b5a438fc7dfc49ade4787a0c6fc5b58644abd7_pi.png × 3.52 m2.

So, the area of the path = D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_e4b5a438fc7dfc49ade4787a0c6fc5b58644abd7_pi.png × 4.52 m2 − D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_e4b5a438fc7dfc49ade4787a0c6fc5b58644abd7_pi.png × 3.52 m2

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_6a38e619aded7f2b5b77706aedf16402e158a918_approxequal.gif25 m2.

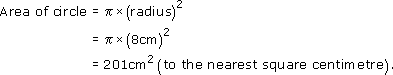
[Back to - Example 14](" \l "Session3_Example4)

## Question 1

#### Answer

* (a)

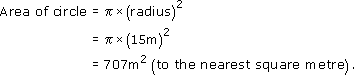
Start of $1



End of $1

* (b)

Start of $1



End of $1

[Back to - Question 1](" \l "Session3_Activity6)

## Question 2

#### Answer

* (a) Area = 10 m × 6 m = 60 m2.
* (b) Area = D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_e4b5a438fc7dfc49ade4787a0c6fc5b58644abd7_pi.png(1.1 m)2 ≈ 3.80 m2.
* (c) Area = D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_afe6e1259a3c2a64c85b2c64b179b01ec7edee57_mu120_b_i061e.gif × 10m × 5m = 25m2.

[Back to - Question 2](" \l "Session3_Activity7)

## Question 3

#### Answer

Add together the areas of the rectangle and the triangle from Question 2, and subtract the area of the circle to find

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_82cfa8809079dcd7e8bbc9a39dee63b02f384436_mu120_b_u067e.gif

End of $1

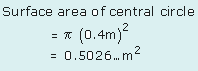
[Back to - Question 3](" \l "Session3_Activity8)

## Question 4

#### Answer

In the following calculation, full calculator accuracy numbers are indicated by three dots. For example the full calculator accuracy value for D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_e4b5a438fc7dfc49ade4787a0c6fc5b58644abd7_pi.png is written as 3.141 ... .

Start of $1



End of $1

There are four slabs in this circle, so each slab will have a

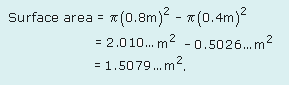
Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_e29c51b4e047bf6b965c993fb199691644f775bb_mu120_b_su076enew.gif

End of $1

The surface area of the eight slabs in the inner ring is calculated by subtracting the central circle from the circle with radius 0.8 m:

Start of $1



End of $1

There are eight slabs in the inner ring, so each slab will have a

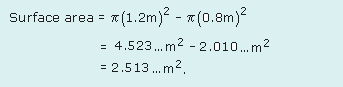
Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_d1310c8360928e59ffd3f3200704c321e70732ca_mu120_b_su078enew.gif

End of $1

Use a similar method to find the surface area of the outer ring of slabs:

Start of $1



End of $1

There are sixteen slabs in the inner ring, so each slab will have a

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_0722007738e8c0d32feb78aaf2bdcd7fa54ba016_mu120_b_su080enew.gif

End of $1

Start of Table

|  |  |  |
| --- | --- | --- |
| **Type of slab** | **Surface area/m2** |  |
| Central slab | 0.1257 | Lightest |
| Inner ring slab | 0.1885 | Heaviest |
| Outer ring slab | 0.1571 |  |

End of Table

Assuming that the slabs are of equal thickness, and are made of the same material, the weights of the slabs will be proportional to the surface areas. So the results show that the lightest slabs are in the central circle and the heaviest in the inner ring.

[Back to - Question 4](" \l "Session3_Activity9)

## Example 15

#### Answer

* (a) For this object,

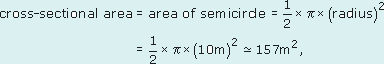
cross-sectional area = 8 cm × 8 cm = 64 cm2,

* therefore

volume = 16 cm × 64 cm2 = 1024 cm3.

* (b) For this object,

Start of $1



End of $1

therefore

volume ≅ 157 m2 × 100 m = 15 700 m3.

[Back to - Example 15](" \l "Session3_Example5)

## Question 1

#### Answer

(a)

Start of $1



End of $1

So

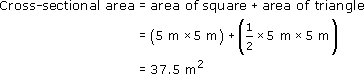
volume = 50.265 cm2 × 10 cm = 502.65 cm3.

Thus the volume is 503 cm3 (to the nearest cubic centimetre).

(If you used the approximate value of 3.14 for D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_0d5242de2ae2c50858ce6e1c3f81444657f68295_pi.gif, you will have got a cross-sectional area of 50.24 cm2 and a volume of 502.4 cm3.)

* (b)

Start of $1



End of $1

So

volume = 37.5 m2 × 10 m = 375 m3.

[Back to - Question 1](" \l "Session3_Activity10)

## Question 2

#### Answer

Car A has four cylinders, each with a radius of 4.3 cm and a height of 8.6 cm. The volume of one cylinder is calculated by using the formula

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_46f30272fdf9089fe52eb5386bc1467cde3d7cc2_mu120_b_su085e.gif

End of $1

So, the four cylinders will have

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_03779b5dbf9198d8df1c449750e5e69e3f44275e_mu120_b_su086e.gif

End of $1

Car B has four cylinders, each with a radius of 4.6 cm and a height of 7.5 cm. From the same formula, the four cylinders will have

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_82df7cf3df67d03a131a34815fb82a1735a38632_mu120_b_su087e.gif

End of $1

Therefore, both engines have a cubic capacity very close to 2000 cm3. They are both said to have two-litre engines. Hence the claims of both manufacturers are true.

[Back to - Question 2](" \l "Session3_Activity11)

## Question 3

#### Answer

The cross-section of the guttering is a semicircle of radius 0.05 m. So

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_6a476106c83cfebaf98100ab3fad6d2b5159af07_mu120_4m7_new1.gif

End of $1

Then, since the length of the guttering is 12m,

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_e57bac5083abfabf7abc47f342ae280a7c5f9a01_mu120_4m7_new.gif

End of $1

Therefore the guttering will hold about 0.047 m3 of water.

[Back to - Question 3](" \l "Session3_Activity12)

## Example 16

#### Answer

The real window has an area of 240 cm × 120 cm = 28 800 cm2. It might be easier to think of this in square metres, that is

Start of $1

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End of $1

To find the dimensions of the window in the model, divide the real lengths by 20 as the scale is 1 cm to 20 cm:

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_392f5104d54d893a8139d94e65503a0ca605138b_mu120_b_u087e.gif

End of $1

or in square metres,

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_d662b3b83009b7526b0707bb769875a932290dc9_mu120_b_u088e.gif

End of $1

Now find the number of times that the area of the real window exceeds the area of the window in the model:

working in square centimetres 28 800 ÷ 72 = 400,

or

working in square metres 2.88 ÷ 0.0072 = 400.

As the real lengths are 20 times greater than those on the model, the areas are 202 (= 400) times greater.

[Back to - Example 16](" \l "Session3_Example6)

## Example 17

#### Answer

Just as areas must be multiplied or divided by the scale squared, so volumes (and capacities) must be multiplied or divided by the cube of the scale. Here the capacity of the real tank must be divided by 203 (= 8000). Therefore

capacity of model tank = 250 litres ÷ 8000 = 0.03125 litres.

As there are 1000 cm3 in one litre,

capacity = 0.03125 × 1000 cm3 = 31.25 cm3.

A check on this value can be made by considering the volume of the real water tank. If it is assumed that the full tank holds exactly 250 litres, the volume of the tank would be at least 250 × 1000 cm3 = 250 000 cm3.

The question does not give the dimensions of the real tank, but to produce this volume, the dimensions might perhaps be 50 cm by 50 cm by 100 cm. (Note that 50 × 50 × 100 = 250 000.) The dimensions of the model of such a tank would be

Start of $1

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End of $1

So

volume of model tank = 31.25 cm3.

[Back to - Example 17](" \l "Session3_Example7)

## Question 1

#### Answer

(a) Since 1 cm in the model represents 25 cm in real life, areas must be scaled by 25 × 25 (the area scale is 252 because the length scale is 25). So

Start of $1

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End of $1

This can be converted to square centimetres by multiplying by 100 × 100:

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_66ca6a1796cc2eb021dcb69f8fb9aeab69951d76_mu120_b_su089e.gif

End of $1

Alternatively, you could convert to cm2 first:

Start of $1

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End of $1

So

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_ad8825d7a5be579212e91ba9b9710b77878ebab4_mu120_b_su088enew.gif

End of $1

[Back to - Question 1](" \l "Session3_Activity13)

## Question 2

#### Answer

Since 1 cm in the model represents 20 cm in real life, volumes must be scaled by 20 × 20 × 20.

So the volume of the tender in real life must be

Start of $1

D:\AaaF\OUT\httpswwwopeneduopenlearnocw_cmid4246_2021-12-10_11-38-06_nsfr2\word\assets\_0230f9300821c17ef9e73baebe4fe0666b377403_mu120_b_su092e.gif

End of $1

Thus the volume of coal that could be carried in the real engine's tender is 40 m3.

[Back to - Question 2](" \l "Session3_Activity14)

# Figure ang1

## Description

Figure ang1

[Back to - Figure ang1](" \l "Session1_Figure2)

# Figure ang2

## Description

Figure ang2

[Back to - Figure ang2](" \l "Session1_Figure3)

# Figure ang3

## Description

Figure ang3

[Back to - Figure ang3](" \l "Session1_Figure4)

# Uncaptioned Figure

## Description

Figure ang4

[Back to - Uncaptioned Figure](" \l "Session1_Figure5)

# Figure ang5

## Description

Figure ang5

[Back to - Figure ang5](" \l "Session1_Figure6)

# Figure ang6

## Description

Figure ang6

[Back to - Figure ang6](" \l "Session1_Figure7)

# Figure ang1

## Description

Acute angle

[Back to - Figure ang1](#Session1_Figure2)

# Figure ang2

## Description

Right angle

[Back to - Figure ang2](#Session1_Figure3)

# Figure ang3

## Description

Obtuse angle

[Back to - Figure ang3](#Session1_Figure4)

# Uncaptioned Figure

## Description

Half turn (Straight angle)

[Back to - Uncaptioned Figure](#Session1_Figure5)

# Figure ang5

## Description

Reflex angle

[Back to - Figure ang5](#Session1_Figure6)

# Figure ang6

## Description

Complete turn

[Back to - Figure ang6](#Session1_Figure7)

# Uncaptioned Figure

## Description

Figure 100

[Back to - Uncaptioned Figure](" \l "Session1_Figure8)

# Pie chart showing results of 60 mathematics students over a five-year period (Source: Tutor's own records)

## Description

Pie chart showing results of 60 mathematics students over a five-year period

[Back to - Pie chart showing results of 60 mathematics students over a five-year period (Source: Tutor's own records)](" \l "Session1_Figure24)

# Uncaptioned Figure

## Description

Vertically opposite angles

[Back to - Uncaptioned Figure](" \l "Session1_Figure26)

# Uncaptioned Figure

## Description

Parallel lines

[Back to - Uncaptioned Figure](" \l "Session1_Figure30)

# Uncaptioned Figure

## Description

Corresponding angles

[Back to - Uncaptioned Figure](" \l "Session1_Figure31)

# Uncaptioned Figure

## Description

Alternate angles

[Back to - Uncaptioned Figure](" \l "Session1_Figure35)

# A quadrilateral is a shape with four straight sides.

## Description

Quadrilateral

[Back to - A quadrilateral is a shape with four straight sides.](" \l "Session2_Figure2)

# A square has four equal sides and four right angles. Opposite sides are parallel.

## Description

Square

[Back to - A square has four equal sides and four right angles. Opposite sides are parallel.](" \l "Session2_Figure3)

# A rectangle has four right angles and opposite sides are equal and parallel.

## Description

Rectangle

[Back to - A rectangle has four right angles and opposite sides are equal and parallel.](" \l "Session2_Figure4)

# A parallelogram has opposite sides equal and parallel. Opposite angles are equal.

## Description

Parallelogram

[Back to - A parallelogram has opposite sides equal and parallel. Opposite angles are equal.](" \l "Session2_Figure5)

# A rhombus has four equal sides. Opposite sides are parallel and opposite angles are equal.

## Description

Rhombus

[Back to - A rhombus has four equal sides. Opposite sides are parallel and opposite angles are equal.](" \l "Session2_Figure6)

# Uncaptioned Figure

## Description

A circle with the centre is often labelled with the letter O.

[Back to - Uncaptioned Figure](" \l "Session2_Figure7)

# Uncaptioned Figure

## Description

Semicircle

[Back to - Uncaptioned Figure](" \l "Session2_Figure8)

# Uncaptioned Figure

## Description

Line symmetry

[Back to - Uncaptioned Figure](" \l "Session2_Figure12)

# Uncaptioned Figure

## Description

Scalene triangle

[Back to - Uncaptioned Figure](" \l "Session2_Figure17)

# Uncaptioned Figure

## Description

Car wheel trim

[Back to - Uncaptioned Figure](" \l "Session2_Figure18)

# Uncaptioned Figure

## Description

Rotational symmetry of order 1

[Back to - Uncaptioned Figure](" \l "Session2_Figure21)

# Uncaptioned Figure

## Description

Base angles

[Back to - Uncaptioned Figure](" \l "Session2_Figure35)

# Uncaptioned Figure

## Description

Diagram of a wooden buttress supporting the wall of a medieval church.

[Back to - Uncaptioned Figure](" \l "Session2_Figure50)

# Uncaptioned Figure

## Description

Diagram of the arrangement of the struts in a wall of a shed.

[Back to - Uncaptioned Figure](" \l "Session2_Figure55)

# Uncaptioned Figure

## Description

Trapezium-shaped lawn

[Back to - Uncaptioned Figure](" \l "Session3_Figure8)

# Uncaptioned Figure

## Description

The dimensions of a frame tent

[Back to - Uncaptioned Figure](" \l "Session3_Figure16)