



SUBLIME SYMMETRY

The Mathematics behind De Morgan's Ceramic Designs

TEACHERS' MATHS RESOURCE PACK



Lesson plans and workbook for using William De Morgan's ceramic designs to teach mathematics at KS2



SUBLIME SYMMETRY

INTRODUCTION

The visual arts are a great tool for teaching mathematical concepts, such as symmetry, pattern and shape. This area of education has been widely researched and there is much evidence to support the idea that using art to teach mathematics, particularly geometry, to pupils who are visual and kinaesthetic learners can be beneficial for their learning and comprehension of the subject.

The idea for the *Sublime Symmetry* exhibition stems from The De Morgan Foundation's own research into William De Morgan's use of mathematics to create his ceramic designs and discovery of the links between the devices he used and the geometry taught in mathematics at KS2 today.

VISIT SUBLIME SYMMETRY

Whilst this pack can be used as a stand-alone classroom resource, it has been designed to complement a school trip to *Sublime Symmetry*.

Please contact Guildhall Art Gallery directly to organise a school visit to see the exhibition, from 11 May 2018 to 28 October 2018.

Tanya Dean, Education and Information Assistant
Guildhall Art Gallery

Guildhall Yard, London EC2V 5AE

guildhall.artgallery@cityoflondon.gov.uk



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SUBLIME SYMMETRY

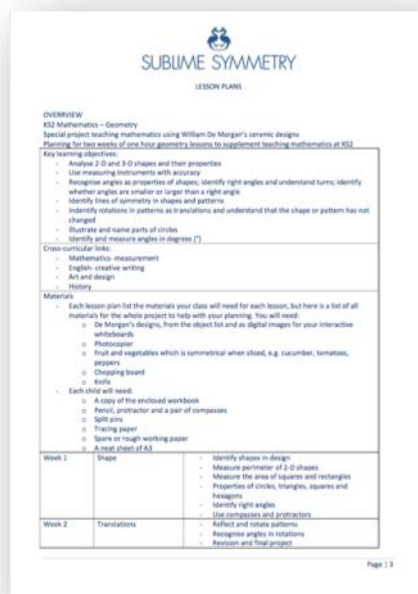
HOW TO USE THE TEACHERS' MATHS RESOURCE PACK

This Teachers' Maths Resource Pack provides everything you need to teach two weeks of core geometry at KS2 using William De Morgan's ceramic designs. Offering an innovative and exciting way to teach and learn, the pack contains lesson plans which can be added directly to your own termly planning, ideas for creative lessons and a workbook which can be printed out and given directly to pupils.

AT A GLANCE

The lesson plans in this pack are designed so that they can be added straight into your termly planning. They are also packed with ideas so that you can adapt them to suit your own needs too.

The first section gives you an overview of the lesson, lists the learning outcomes and lets you know which materials you will need to deliver the lesson.



The second section is a detailed lesson plan full of fun ideas to encourage pupils to engage with William De Morgan's work and understand how maths can be used in art.

The content may have to be adapted depending on the ability and level that you teach.



The pupils' workbook is made up of worksheets that will guide pupils through the entire KS2 curriculum for geometry.

Each worksheet is clearly labelled



Activities are explained in text boxes



Large colourful images are used on every page to make the worksheets engaging and appealing



The worksheets are designed so that all pupils can attempt to complete them.



However, they are colour coded to show the difficulty level:

- A **green** logo indicates lower level worksheets
- An **orange** logo indicates intermediate level worksheets
- A **purple** logo indicates higher level worksheets



SUBLIME SYMMETRY

SUBLIME SYMMETRY EXHIBITION FACTSHEET

WILLIAM DE MORGAN (1839 – 1917)

De Morgan was a pre-eminent ceramic designer of the late Victorian period.

His father, Augustus De Morgan, was the first Professor of Mathematics at University College London and he inherited his father's great mathematical skill.

In 1871 he blew up a fireplace which he had turned into a makeshift kiln!

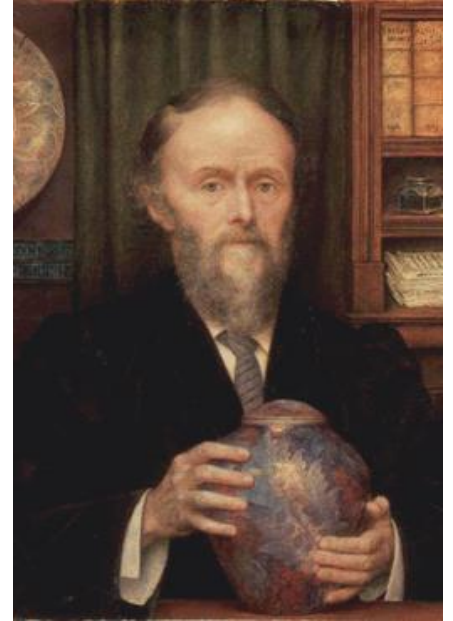
He met William Morris in 1863 and the two were great friends. De Morgan was influenced by Morris's Arts and Crafts aesthetic.

De Morgan had a great imagination and created his own animal and floral designs.

He was heavily influenced by Middle Eastern and Turkish ceramic designs.

His interest in geometry is evident in his ceramic designs which are based on rules of symmetry, pattern and manipulating the properties of shapes.

Aged 65 he became a very successful author.



SUBLIME SYMMETRY

A school visit to *Sublime Symmetry* will encourage pupils to engage directly with the ceramics on display and explore the mathematical devices William De Morgan has used to create the patterns and designs they can see.

You should ask pupils to identify different shapes they can see; square tiles, circular plates and triangular decoration. They should also be able to identify designs with lines of symmetry and rotational symmetry and explain these features of the designs.

The workbook contained in this Teachers' Resource Pack supports a school trip to *Sublime Symmetry*. Rather than use the images in the workbook, pupils can see the real object and complete their worksheets directly from the ceramics and drawings on display.





SUBLIME SYMMETRY

LESSON PLANS

OVERVIEW

KS2 Mathematics – Geometry

Special project teaching mathematics using William De Morgan's ceramic designs

Planning for two weeks of one hour geometry lessons to supplement teaching mathematics at KS2

Key learning objectives:

- Analyse 2D and 3D shapes and their properties
- Use measuring instruments with accuracy
- Recognise angles as properties of shapes; identify right angles and understand turns; identify whether angles are smaller or larger than a right angle
- Identify lines of symmetry in shapes and patterns and appreciate the beauty of symmetry in art
- Identify rotations in patterns as translations
- Illustrate and name parts of circles
- Identify and measure angles in degrees (°)

Cross-curricular links:

- Mathematics: measurement
- English: creative writing
- Art and design: pattern making, surface design, composition
- History: The Victorian period and the work of William De Morgan and the Arts and Crafts movement

Materials:

- Each lesson plan list the materials pupils will need for each lesson. Here is an overview of all materials for the whole project to help with your planning. You will need:
 - o De Morgan's designs, from the object list and as digital images for your interactive whiteboards
 - o Photocopier
 - o Fruit and vegetables which is symmetrical when sliced, e.g. cucumber, tomatoes, peppers
 - o Chopping board
 - o Knife
- Each child will need:
 - o A copy of the enclosed workbook
 - o Pencil, protractor and a pair of compasses
 - o Split pins
 - o Tracing paper
 - o Spare or rough working paper
 - o A neat sheet of A3

Week 1	Shape	<ul style="list-style-type: none">- Identify shapes in design- Measure perimeter of 2D shapes- Measure the area of squares and rectangles- Properties of circles, triangles, squares and hexagons- Identify right angles- Use compasses and protractors
Week 2	Translations	<ul style="list-style-type: none">- Reflect and rotate patterns- Recognise angles in rotations- Revision and final project



SUBLIME SYMMETRY

LESSON PLANS

LESSON 1 OF 10 – INTRODUCTION AND SHAPE – SQUARES

Background		
Objectives	<ul style="list-style-type: none">- Understand that William De Morgan was a Victorian ceramic designer who used mathematical devices to construct his designs- Accurately measure and recreate one of De Morgan’s square designs- Identify a right angle and understand that this measures 90°- Vocab: line, angle, polygon	
Success Criteria	The child can independently: <ul style="list-style-type: none">- Recognise squares and their properties	
Assessment	<ul style="list-style-type: none">- Question and answer session- Completion of worksheets to acceptable level	
Prerequisites	<ul style="list-style-type: none">- Previous work on geometry and properties of basic shape from KS1/KS2	
Materials	<ul style="list-style-type: none">- William De Morgan’s designs- Pencil- Shape worksheets 1 – 4 from the education pack- Plastic shapes as a learning aid	
Other resources	<ul style="list-style-type: none">- De Morgan Foundation website: www.demorgan.org.uk- Victorian web: http://www.victorianweb.org/art/design/demorgan/intro.html- Victorian Ceramics: http://www.victoriansceramics.com/william-de-morgan.html- Visit the Sublime Symmetry exhibition at a venue near you	
Lesson Plan		
Time	Activity	Key points/outcome
15 minutes	Introduction	<ul style="list-style-type: none">- Introduce or reintroduce William De Morgan and some of his designs to the class- Pick out De Morgan’s designs which feature basic shapes- Use interactive boards or image printouts to draw basic shapes over De Morgan’s elaborate designs
35 minutes	Worksheets	<ul style="list-style-type: none">- Complete introduction sheet and square worksheets 1 – 4 from education pack- Extension work: <i>Rose and Trellis Tile</i> is 15cm x 15cm. How many tiles would be required to tile walls that are a) 150 x 30cm, b) 300m² and c) 150cm x 300cm? How many smaller squares would be on each wall?
10 minutes	Tidy away and plenary	<ul style="list-style-type: none">- Pupils should work in pairs to explain to each other how William De Morgan used squares in his designs- Question and answer session



SUBLIME SYMMETRY

LESSON PLANS

LESSON 2 OF 10 – CIRCLES

Background		
Objectives	<ul style="list-style-type: none">- Identify and label parts of a circle in William De Morgan’s designs- Use compasses to create own William De Morgan-inspired plate design- Vocab: arc, radius, diameter, circumference, sector, tangent, right angle, obtuse angle, acute angle	
Success Criteria	The child can independently: <ul style="list-style-type: none">- Recognise and draw properties of circles	
Assessment	<ul style="list-style-type: none">- Question and answer session- Completion of worksheets to acceptable level	
Prerequisites	<ul style="list-style-type: none">- Previous work on geometry and properties of basic shape from KS1/KS2, lesson 1	
Materials	<ul style="list-style-type: none">- William De Morgan’s designs- Pencil- Compasses- Shape worksheets 5 – 9 from the education pack	
Lesson Plan		
Time	Activity	Key points/outcome
10 minutes	Introduction	<ul style="list-style-type: none">- Introduce or reintroduce William De Morgan and some of his designs featuring circles to the class- William De Morgan’s <i>Five Drawings for Border Designs</i> is a key image (worksheet 8)
35 minutes	Worksheets	<ul style="list-style-type: none">- Complete worksheets 5 – 9 from education pack- Higher level/extension/homework: Look at <i>Dragon and Scroll Plate</i>. Draw a De Morgan inspired design for a dish which has four equal sectors. What should the angle of each sector be to ensure they are equal?
10 minutes	Tidy away and plenary	<ul style="list-style-type: none">- Pupils should be able to describe De Morgan’s use of circles in his designs and identify his use of different parts of circles to create his designs



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LESSON PLANS

LESSON 3 OF 10 – TRIANGLES

Background		
Objectives	<ul style="list-style-type: none">- Compare and classify different triangles- Identify and measure acute and obtuse angles- Vocab: isosceles, equilateral, scalene, right-angled triangle	
Success Criteria	The child can independently: <ul style="list-style-type: none">- Recognise triangles and measure angles using a protractor	
Assessment	<ul style="list-style-type: none">- Question and answer session- Completion of worksheets to acceptable level	
Prerequisites	<ul style="list-style-type: none">- Previous work on geometry and properties of basic shape from KS1/KS2, lesson 1 – 2	
Materials	<ul style="list-style-type: none">- William De Morgan’s designs- Pencil- Compasses- Protractor- Shape worksheets 10 – 12 from the education pack- Spare paper	
Lesson Plan		
Time	Activity	Key points/outcome
15 minutes	Introduction	<ul style="list-style-type: none">- Introduce or reintroduce William De Morgan and some of his designs and explain worksheets- Use images of different triangles on interactive board and ask pupils to identify and describe them.- Identify angles as right angles, obtuse angles and acute angles- William De Morgan’s <i>Bee Plate</i> is a key image (worksheet 12)
35 minutes	Worksheets	<ul style="list-style-type: none">- Complete worksheets 10 – 12 from education pack- Extension/homework: construct your own insect design for a plate based on an equilateral triangle
10 minutes	Tidy away and plenary	<ul style="list-style-type: none">- Pupils should be able to describe De Morgan’s use of triangles in his designs and identify his use of different parts of triangles to create his designs



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LESSON PLANS

LESSONS 4 AND 5 OF 10 – HEXAGONS

Background		
Objectives	<ul style="list-style-type: none">- Understand the mathematical construction of complex shapes and patterns	
Success Criteria	The child can independently: <ul style="list-style-type: none">- Use compasses to make patterns and shapes	
Assessment	<ul style="list-style-type: none">- Question and answer session- Completion of worksheets to acceptable level	
Prerequisites	<ul style="list-style-type: none">- Previous work on geometry and properties of basic shape from KS1/KS2, lessons 1 – 3	
Materials	<ul style="list-style-type: none">- William De Morgan’s designs- Pencil- Compasses- Protractor- Shape worksheets 13 – 15 from the education pack- Spare paper- Photocopier	
Lesson Plan		
Time	Activity	Key points/outcome
10 minutes	Introduction	<ul style="list-style-type: none">- Introduce or reintroduce William De Morgan and some of his designs to the class- Explain worksheets and constructions using compasses
Lessons 4 and 5	Hexagons	<ul style="list-style-type: none">- Complete worksheets 13 – 15 from education pack- Draw a William De Morgan-inspired design based on your hexagon drawing- You might find it easier to photocopy the pupils hexagon drawings, then they can design their own dish using the template they have drawn
10 minutes at the end of each lesson	Tidy away and plenary	<ul style="list-style-type: none">- Pupils should be able to identify various shapes, angles and constructions in William De Morgan’s designs from images of his ceramics



SUBLIME SYMMETRY

LESSON PLANS

LESSONS 6 AND 7 OF 10 – LINES OF SYMMETRY

Background		
Objectives	<ul style="list-style-type: none">- Understand symmetry and identify it in the work of William De Morgan	
Success Criteria	The child can independently: <ul style="list-style-type: none">- Draw lines of symmetry on De Morgan’s designs- Understand symmetry occurs in nature and in shapes and patterns- Describe confidently a line of symmetry	
Assessment	<ul style="list-style-type: none">- Question and answer session- Completion of worksheets to acceptable level	
Prerequisites	<ul style="list-style-type: none">- Previous work on geometry and properties of basic shape from KS1/KS2, lessons 1 – 5	
Materials	<ul style="list-style-type: none">- William De Morgan’s designs- Pencil- Tracing paper- A range of fruits with symmetry when sliced, e.g. tomatoes- Reflective symmetry worksheets 16 – 17 from the education pack	
Lesson Plan		
Time	Activity	Key Points/outcome
25 minutes	Introduction (and clean up)	<ul style="list-style-type: none">- Symmetry occurs naturally – slice kiwis, strawberries, oranges etc to show naturally occurring symmetry (and provide healthy snacks!)- Ask pupils to find the number of lines of symmetry in basic shapes and William De Morgan’s elaborate designs to understand the basic idea of lines of symmetry
Lessons 6 and 7	Worksheets	<ul style="list-style-type: none">- Complete worksheets 16 – 17 from education pack
10 minutes at end of each lesson	Tidy away and plenary	<ul style="list-style-type: none">- Pupils should be able to identify various shapes, angles and constructions in William De Morgan’s designs from images of his ceramics



SUBLIME SYMMETRY

LESSON PLANS

LESSON 8 OF 10 – ROTATIONS AND ANGLES

Background		
Objectives	<ul style="list-style-type: none">- Identify rotational symmetry in shape and patterns- Recognise angles as a property of shape or a description of a turn in a complex pattern- Identify right angles, recognise that two right angles make a half-turn, three make three quarters of a turn and four a complete turn	
Success Criteria	The child can independently: <ul style="list-style-type: none">- Identify and describe to another a rotation in the design- Count the number of rotations in a design- Measure the angle of a rotation in the design	
Assessment	<ul style="list-style-type: none">- Question and answer session- Completion of worksheets to acceptable level	
Prerequisites	<ul style="list-style-type: none">- Introduction to William De Morgan’s designs- Previous work on geometry and properties of basic shape from KS1/KS2 and lessons 1 – 7	
Materials	<ul style="list-style-type: none">- William De Morgan’s designs- Split pins- Pencil- Tracing paper- Rotation worksheets 18 – 21 from the education pack	
Lesson Plan		
Time	Activity	Key points/outcome
15 minutes	Introduction	<ul style="list-style-type: none">- Introduce or reintroduce William De Morgan and some of his designs to the class- Pick out De Morgan’s designs which feature rotational symmetry- Use interactive boards or image printouts to rotate an image of the design and count how many times it is repeated.- Explain that each quarter turn around the centre point of the design has an angle of 90°
30 minutes	Worksheets	<ul style="list-style-type: none">- Complete worksheets 18 – 21 from the education pack- Extension work: Pupils can draw their own basic De Morgan flower on separate paper and make a pattern by tracing and rotating it
10 minutes	Tidy away and plenary	<ul style="list-style-type: none">- Pupils should work in pairs to explain to each other how many quarter turns are in the designs and the angles these turns measure in degrees. They should understand that a quarter turn measures 90° and is one right angle- Question and answer session



SUBLIME SYMMETRY

LESSON PLANS

LESSONS 9 AND 10 OF 10 – REVISION AND FINAL PROJECT

Background		
Objectives	<ul style="list-style-type: none">- Review work completed based on the mathematics in De Morgan’s designs- Appreciate De Morgan’s designs as being for the decoration of physical 3D ceramic objects- Successfully explain to others with appropriate language the mathematical constructs in De Morgan’s designs	
Success Criteria	<ul style="list-style-type: none">- Successful completion of the exhibition curator project	
Assessment	<ul style="list-style-type: none">- Final exhibition curator project work and any end-of-topic tests or assessments	
Prerequisites	<ul style="list-style-type: none">- Previous work on geometry and properties of basic shape from KS1/KS2, lessons 1 – 8	
Materials	<ul style="list-style-type: none">- A selection of William De Morgan’s designs printed in colour and cut out- Previous work completed- Large sheet of paper for neat work	
Lesson Plan – Class as Curator The Class as Curator project allows pupils to select objects designed by William De Morgan for their own exhibition. Pupils think of which theme they would like to focus on from the work done on De Morgan’s mathematical designs, for example the properties of circles, and select six objects which best fit this theme. They plan how these objects should be displayed, write an introduction to the mathematical theme they have selected and write an exhibition label for each object to explain how it has been designed mathematically. This project will encourage pupils to reflect on the work they have done so far and enable them to practically apply their mathematical knowledge to a real-life scenario.		
Time	Activity	Key points/outcome
15 minutes	Introduction	<ul style="list-style-type: none">- Explain the project and the work to be carried out over the next two lessons, this encourages the pupils to plan their time- Use interactive board to show images of De Morgan’s work and ask pupils to pick out a mathematical feature they can see in each image
20 minutes	Object selection	<ul style="list-style-type: none">- From the image printouts, pupils choose a theme and pick six objects to illustrate this theme. They then stick them down on a large sheet of paper, leaving space to write an introduction and information about each object
30 minutes	Writing the introduction	<ul style="list-style-type: none">- Write an introduction to the particular theme of their exhibition using research, in rough and then on their sheet
45 minutes	Write a description of each object	<ul style="list-style-type: none">- Use worksheets from previous lessons in series to research the mathematical devices used in the designs of the objects selected- Write a short description of each object in rough then on their sheet
10 minutes	Tidy and plenary	<ul style="list-style-type: none">- Pupils volunteer to describe their exhibition to the class



SUBLIME SYMMETRY

The Mathematics behind De Morgan's Ceramic Designs



Reflective symmetry



Rotations



Angles

This maths workbook belongs to:

Art Fund_



LONDON
MATHEMATICAL
SOCIETY
EST. 1865



THE
DE MORGAN FOUNDATION

WILLIAM DE MORGAN

What have you found out about William De Morgan?

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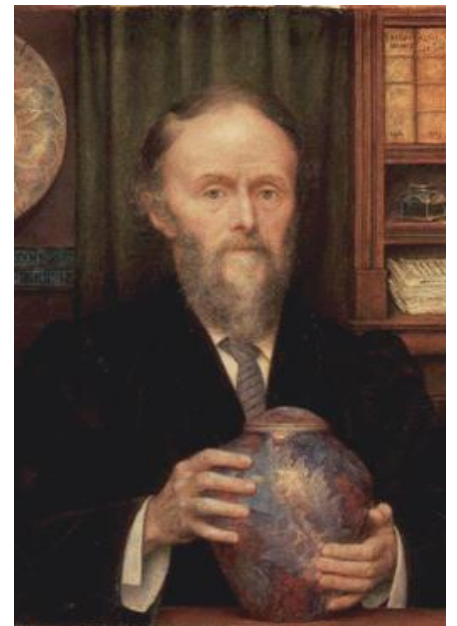
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WILLIAM DE MORGAN'S DESIGNS

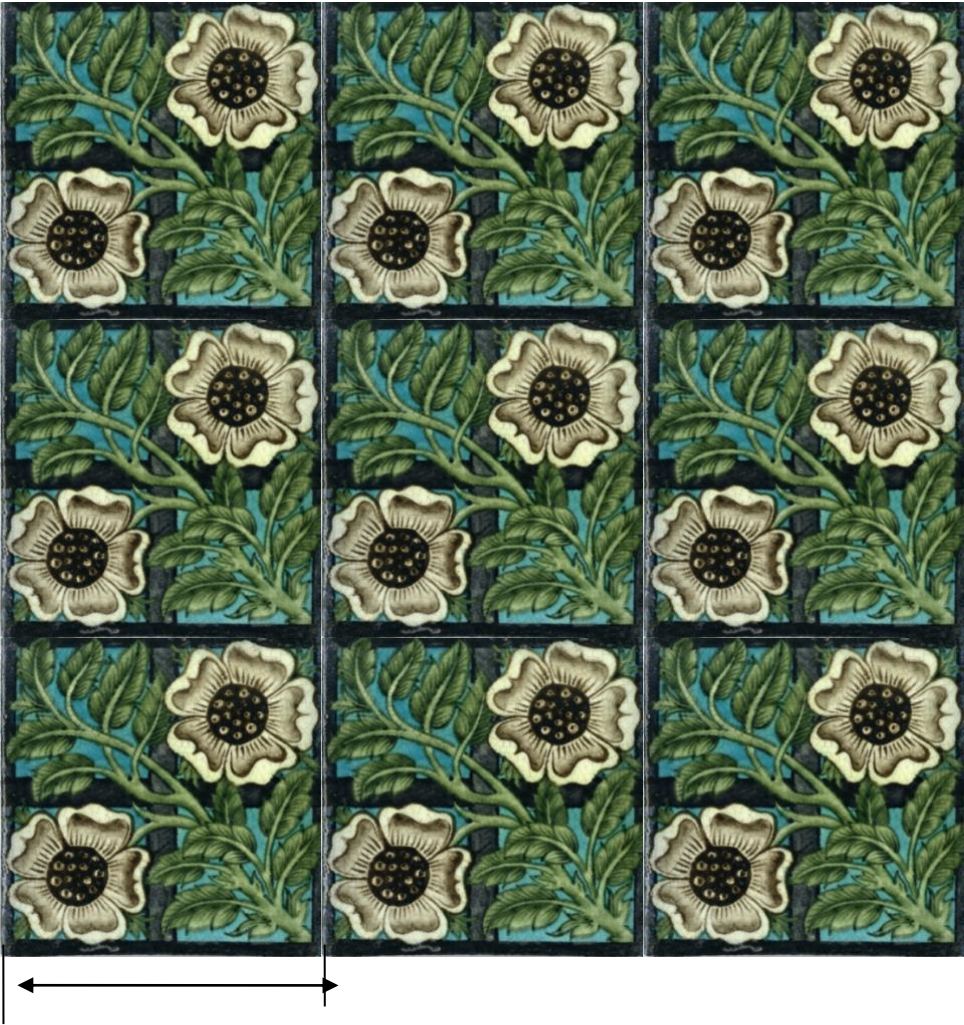
List all of the shapes you can see in each design.

SQUARES

This is William De Morgan's tile design *Rose and Trellis*. The design is made up of many squares.

A polygon is a shape made up of straight sides. Is a square a polygon?



..... cm

Use a ruler to measure the length of one tile of this design and fill in the blank space above.

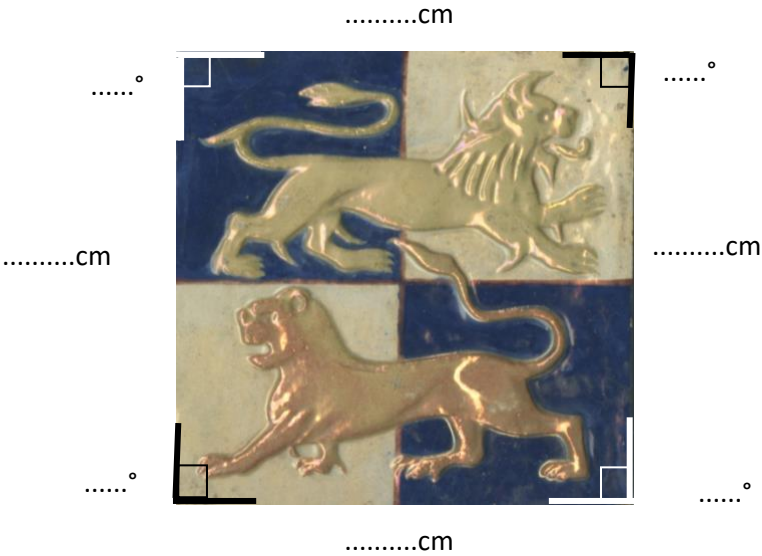
How many tiles have been used in the design above?

Use this measurement to work out the

heightcm and the area cm² of the design

SQUARES

- A QUADRILATERAL is a polygon with four sides.
- REGULAR POLYGONS have equal sides and equal angles.



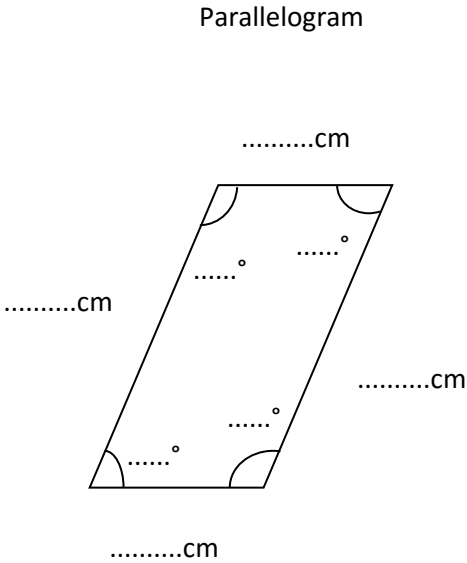
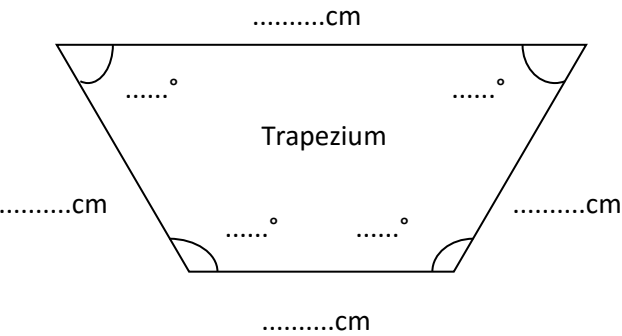
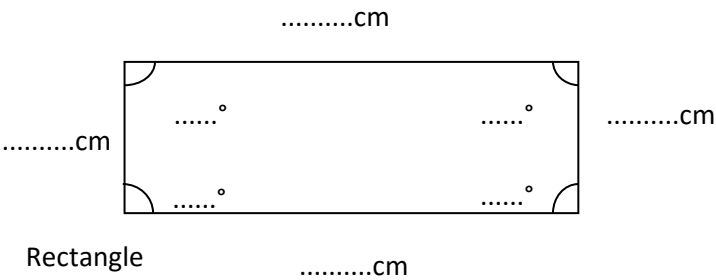
Measure the sides and angles of William De Morgan’s *Heraldic Lion Tile* using a ruler and a protractor.

Is a square a quadrilateral? Is a square a regular polygon?

The angles you have measured in the square tile above are called right angles. A right angle measures°

Shapes that have four sides, which are not all equal, and angles that are not all right angles, are called IRREGULAR QUADRILATERALS.

Measure the sides and angles of these quadrilaterals to check whether they are irregular?



SQUARES

William De Morgan once went on a boat trip down the River Thames. He wrote a story about it and joked about the hotel he stayed in, because it is called the Complete Angler. He said ‘it is called so after an Angle of 360° in the immediate neighbourhood. We saw the Obtuse Angler standing there.’

An angler is another word for a fisherman, but De Morgan jokes that it sounds like an angle.


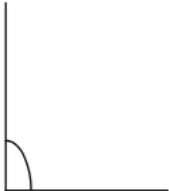



Measure the angles used to make up De Morgan’s *Rose and Trellis* design.



What do the angles inside the square add up to?

Why did William De Morgan joke that a ‘complete angler’ might measure 360°?

De Morgan says he saw an Obtuse Angler. An OBTUSE ANGLE is an angle bigger than a right angle of 90°. An angle smaller than a right angle is called an ACUTE ANGLE. Measure these angles and label them as acute angle, right angle or obtuse angle.

- a)

- b)

- c)

- d)

- e).....




SQUARES

Use a ruler and a protractor to draw the outline of another four square tiles that will complete the tile pattern below.

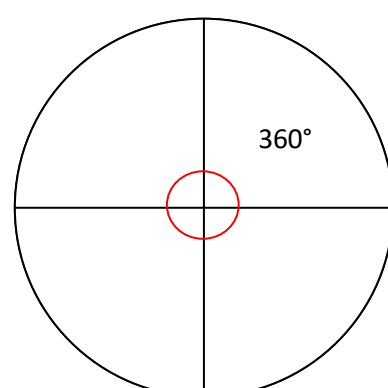
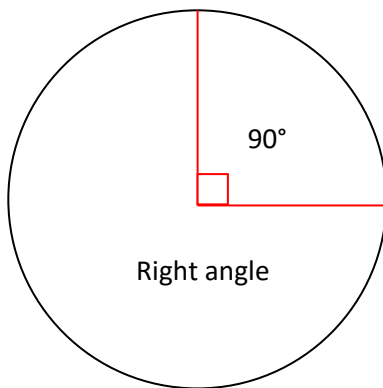
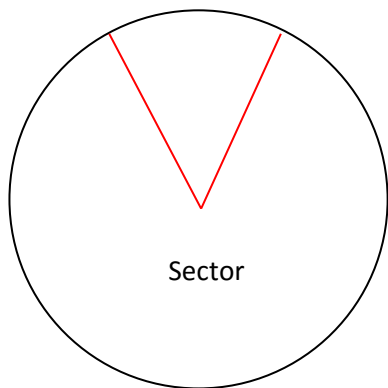
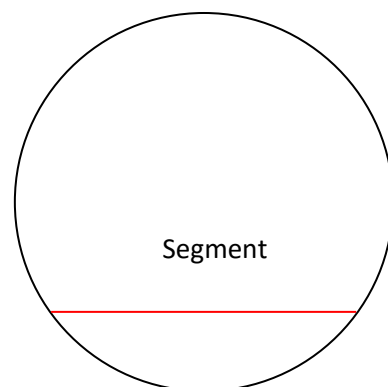
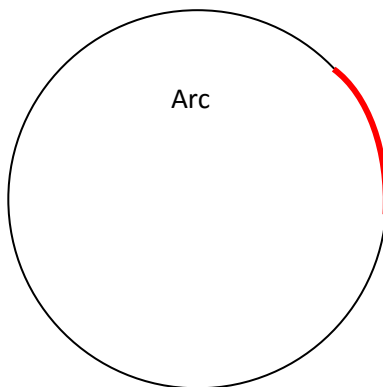
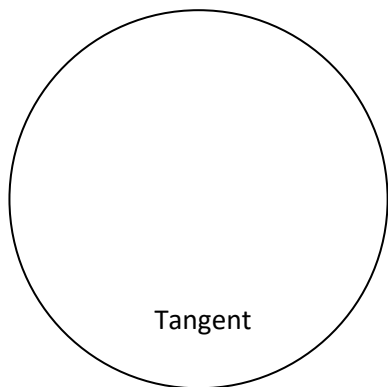
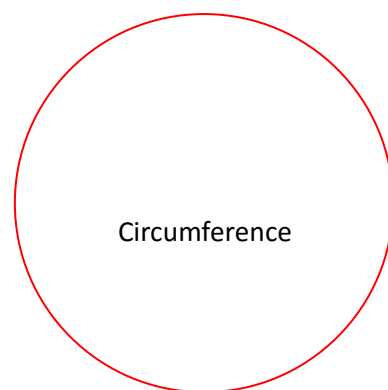
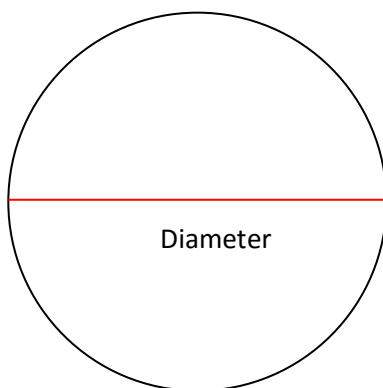
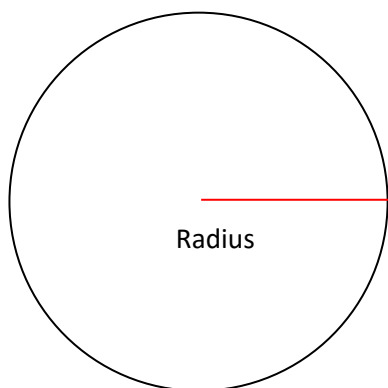
Each tile is a square, so make sure that all of the sides of your squares have equal lengths and right angles in the corners, that measure 90° .

Try and draw in the flowers and the black swan design.



CIRCLES

There are many important features of circles which have been labelled below. Use this key to draw these features on William De Morgan's plate designs on the next page.



WORKSHEET 6

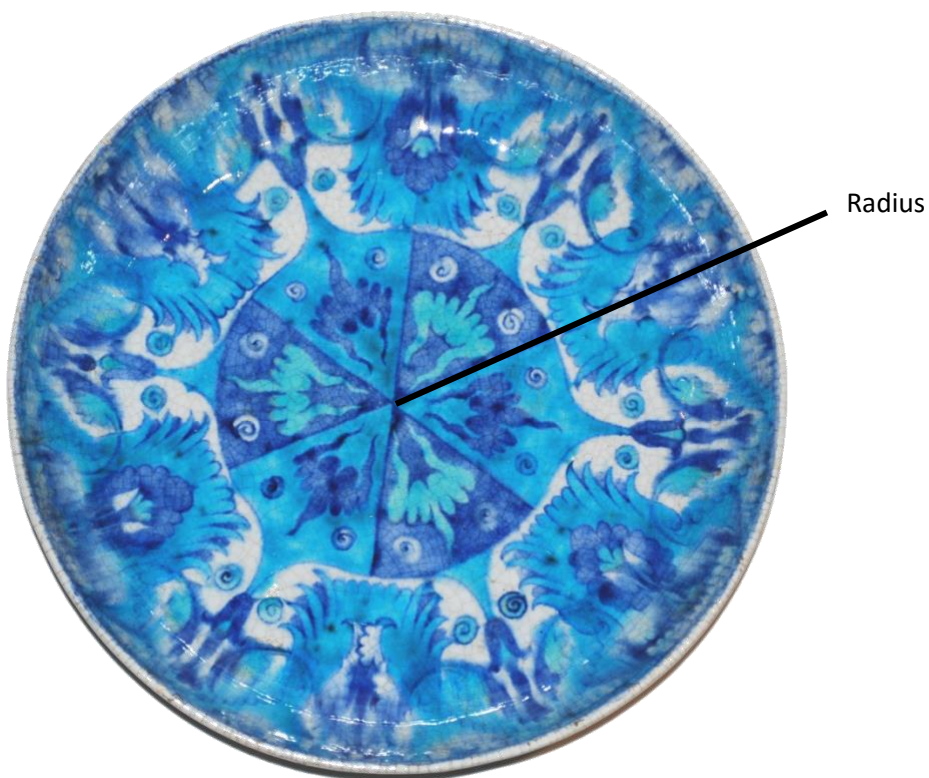


SUBLIME SYMMETRY

CIRCLES

Use the key to draw and label all of the properties of circles that William De Morgan has used in these designs.

Two have been done for you.



CIRCLES

Many of William De Morgan's designs for plates are designed around different sized circles.

How many circles are there in this design?

Measure the radius of the plate?

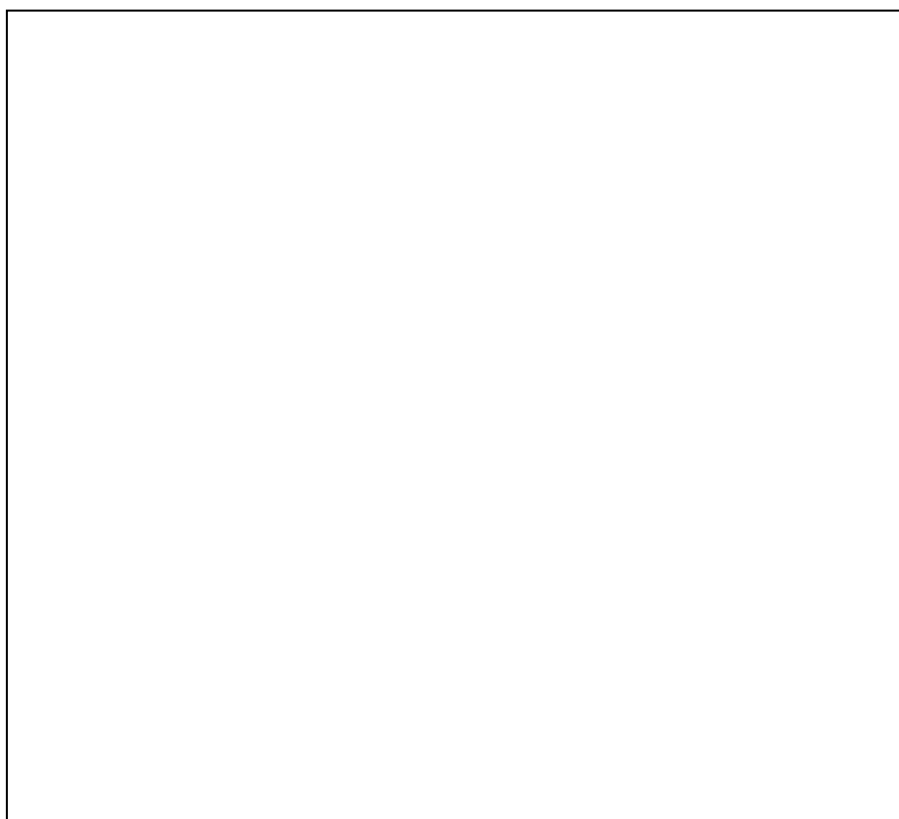
..... cm

Measure the diameter of this plate?

..... cm



William De Morgan would always decorate the backs of his plates with circle patterns. Can you use compasses to design a reverse pattern for this plate?

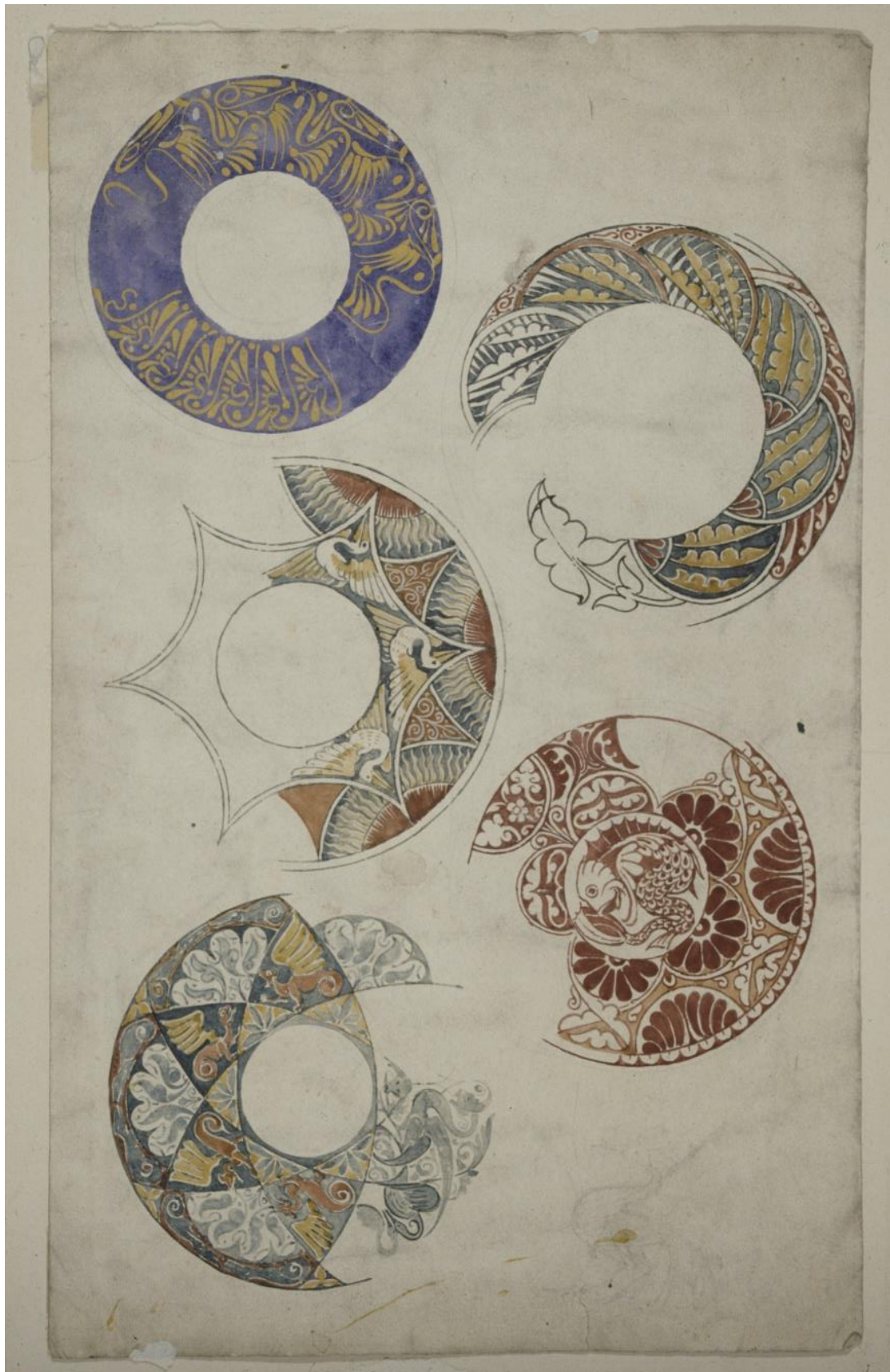




CIRCLES

Circles are shapes with only one side that goes on forever.

Look at these William De Morgan designs. Can you see how he has used arcs to create circular patterns?

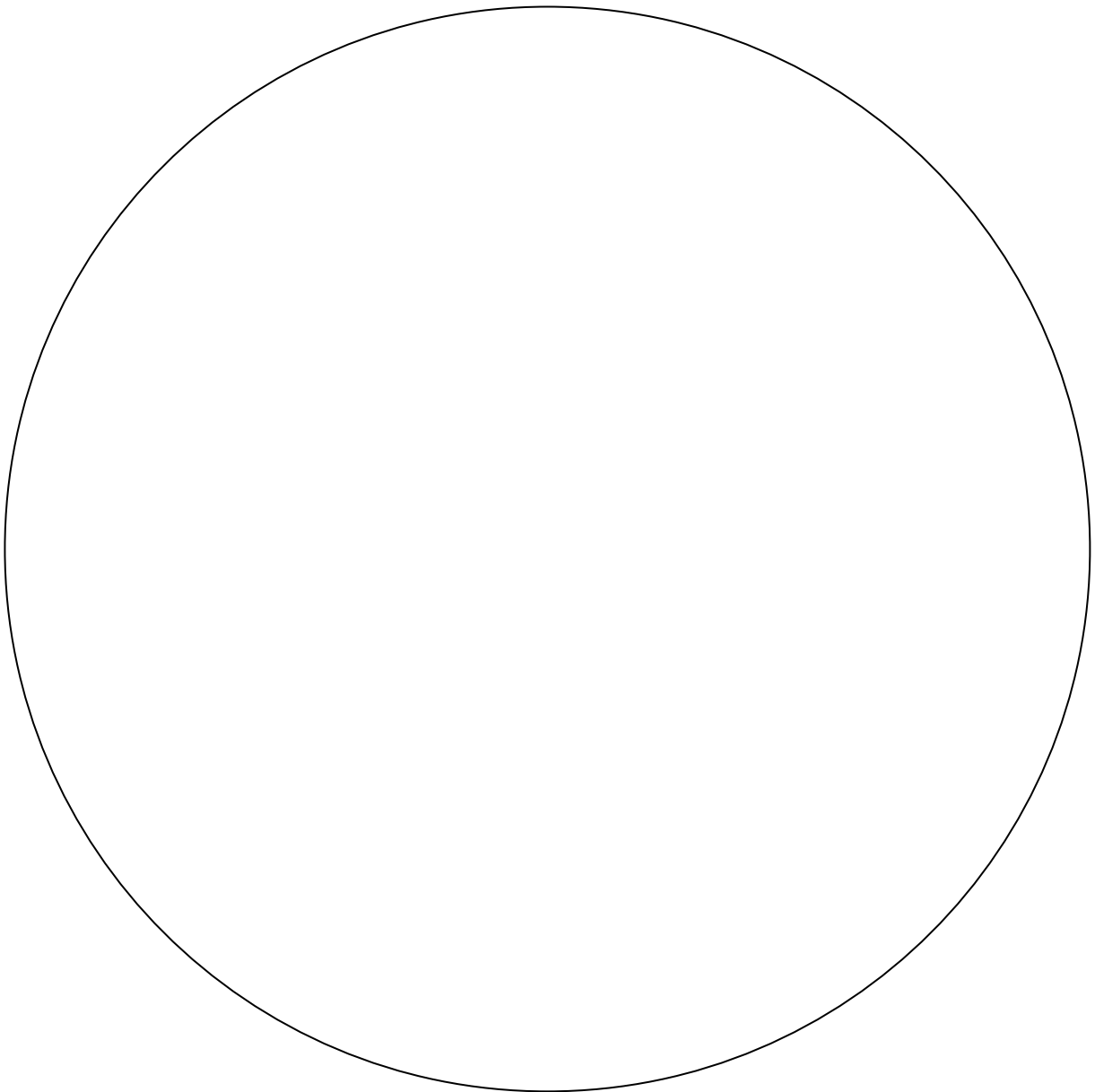


CIRCLES

Using compasses, try making your own plate design that is made up of arcs like William De Morgan's designs.

When you have finished, label any of the parts of a circle you can see in your design from the list below.

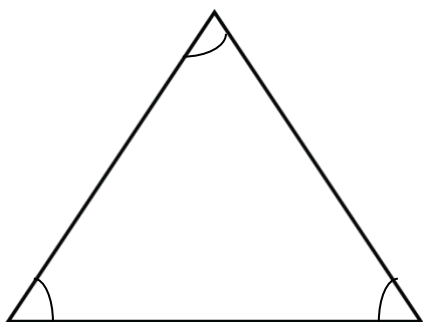
- Circumference
- Radius
- Diameter
- Tangent
- Arc
- Segment



TRIANGLES

Triangles are polygons with three sides.
There are many different types of triangle.

1. Equilateral triangle

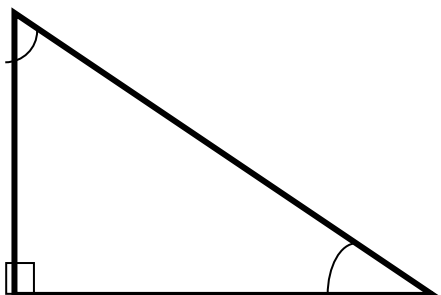


An equilateral triangle has three equal sides.

Three equal angles which measure°

The total of the three angles is°

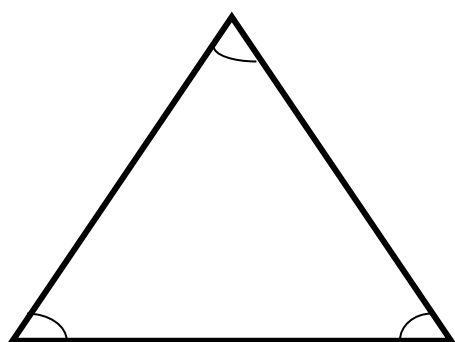
2. Right-angle triangle



One angle is a right angle. A right angle measures°

The three angles add up to°

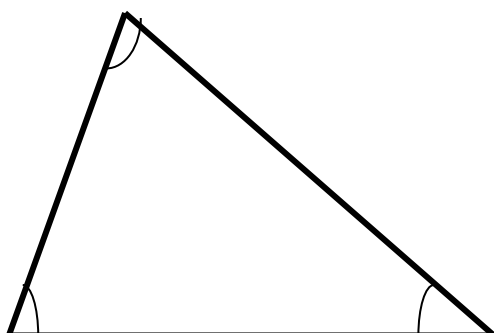
3. Isosceles triangle



An isosceles triangle has equal sides and
..... equal angles.

The three angles add up to°

4. Scalene triangle



A scalene triangle has no equal sides or angles.

The three angles add up to°

The three angles in a triangle always add up to°



TRIANGLES

3



Find the triangles in this tile design. Measure the angles and sides of each and explain what type of triangle each is.

1.°°°cmcmcm

Triangle 1 is a triangle

2.°°°cmcmcm

Triangle 2 is a triangle

3.°°°cmcmcm

Triangle 3 is a triangle

4.°°°cmcmcm

Triangle 4 is a triangle

5.°°°cmcmcm

Triangle 5 is a triangle



TRIANGLES



In this plate, William De Morgan has designed three beetles in triangles.

Join the yellow dots and the blue dots to reveal these triangles.

Measure the sides and angles of the triangles. What sort of triangle have you drawn?



HEXAGONS

If you look carefully, you will see that William De Morgan has used a hexagon to organise this design. Join the yellow dots to help you.

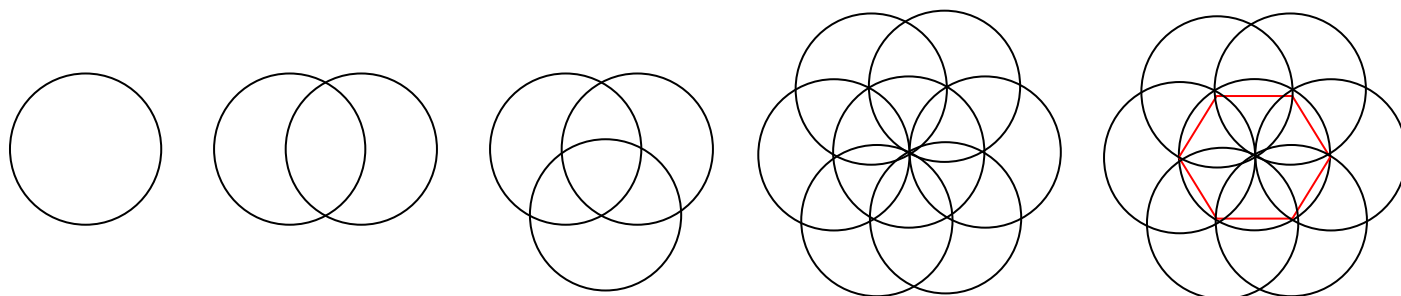


A regular polygon has sides of equal lengths and angles of equal sizes. Measure the sides and angles of the hexagon you have just drawn.

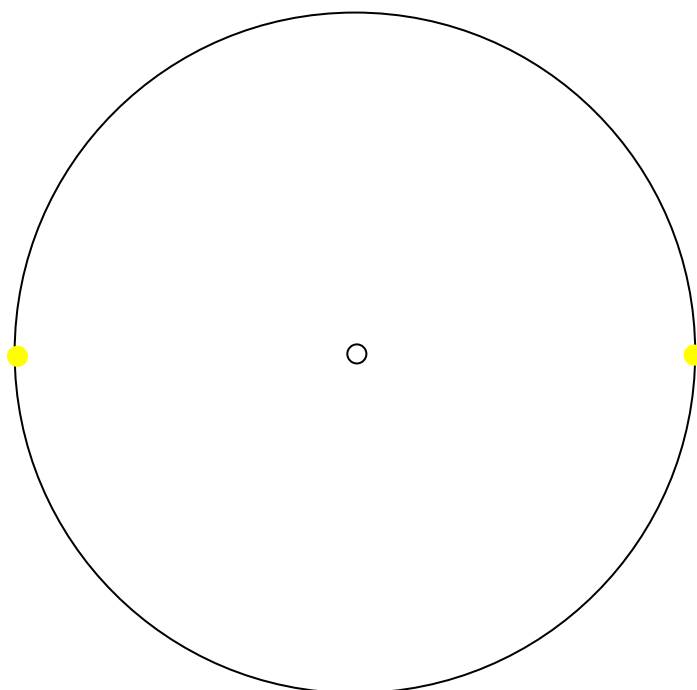
Is this a regular hexagon?



HEXAGONS



You can use circles to draw a regular hexagon. Keeping your compasses at 4.5cm, put your compass point on each yellow dot and draw two circles.



Then draw four more circles with a 4.5cm radius by placing the point of your compasses where the lines of the circles cross. Join the points of the flower shape to draw a hexagon.



HEXAGONS

Use your compasses to draw a hexagon in the space provided.

1. Set the length of your open compasses to 3cm.
2. Place the point on the X and draw a circle.
3. Place the point anywhere on the circle's circumference, and draw another circle. Keep your length at 3cm.
4. Draw a circle on all of the points where the circumferences of circles cross over, until you can see a flower shape with six petals.
5. Join the petal tips using a ruler.
6. Do you have a hexagon? Go over the outline of the hexagon in pen and then rub out your pencil markings.
7. Measure and label all of the sides and angles of your hexagon. Is it a regular polygon?

X



REFLECTIVE SYMMETRY

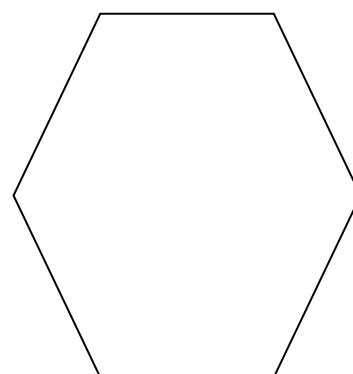
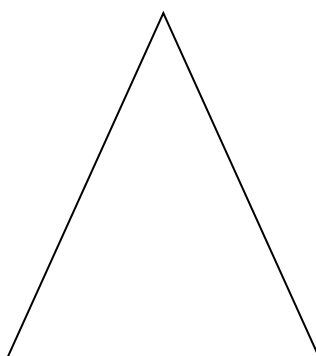
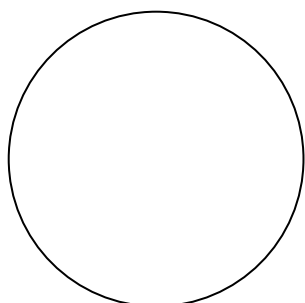
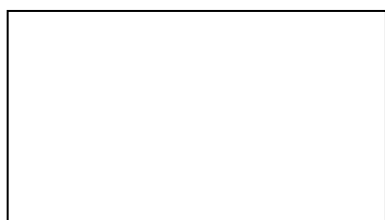
A shape or pattern has a line of symmetry if both halves are mirror images of each other. William De Morgan made lots of his designs with a line of symmetry.



Place a mirror on the line of symmetry to reflect the image.

Can you make each half look exactly like the whole design?

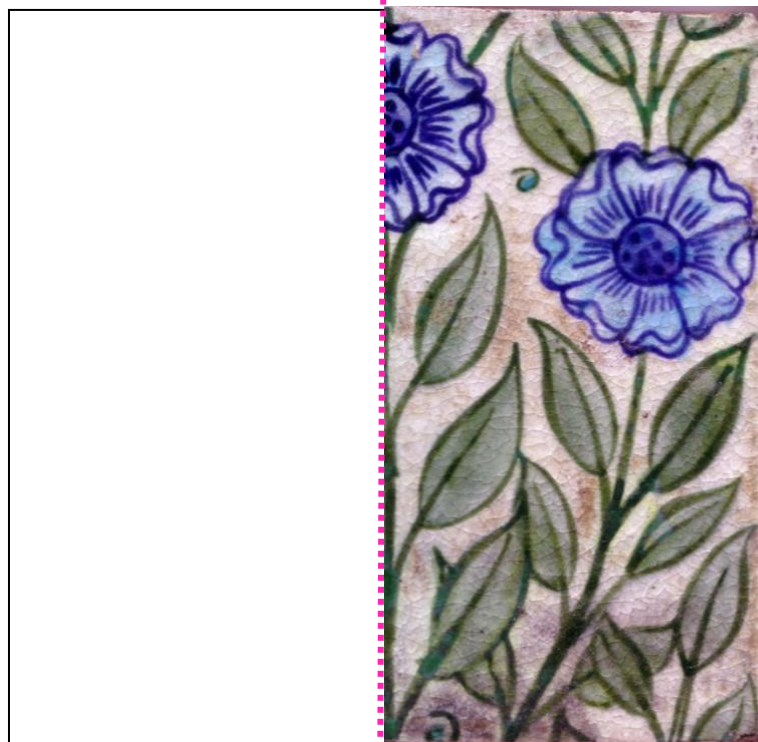
This tile panel by William De Morgan has a line of symmetry which has been drawn on it for you. Can you draw all of the lines of symmetry in the shapes below?





REFLECTIVE SYMMETRY

Trace over the outline of these William De Morgan tiles on tracing paper. Flip the paper over and stick it down to finish off the symmetrical design.





ROTATIONS

When a shape or pattern is repeated around a point, it has rotational symmetry.

How many times has the winged creature been rotated in this dish design?

1. Fix a sheet of tracing paper over William De Morgan's *Winged Feline Dish* by pushing a split pin through both sheets where X marks the spot.
2. Trace the top creature.
3. Rotate the tracing paper.

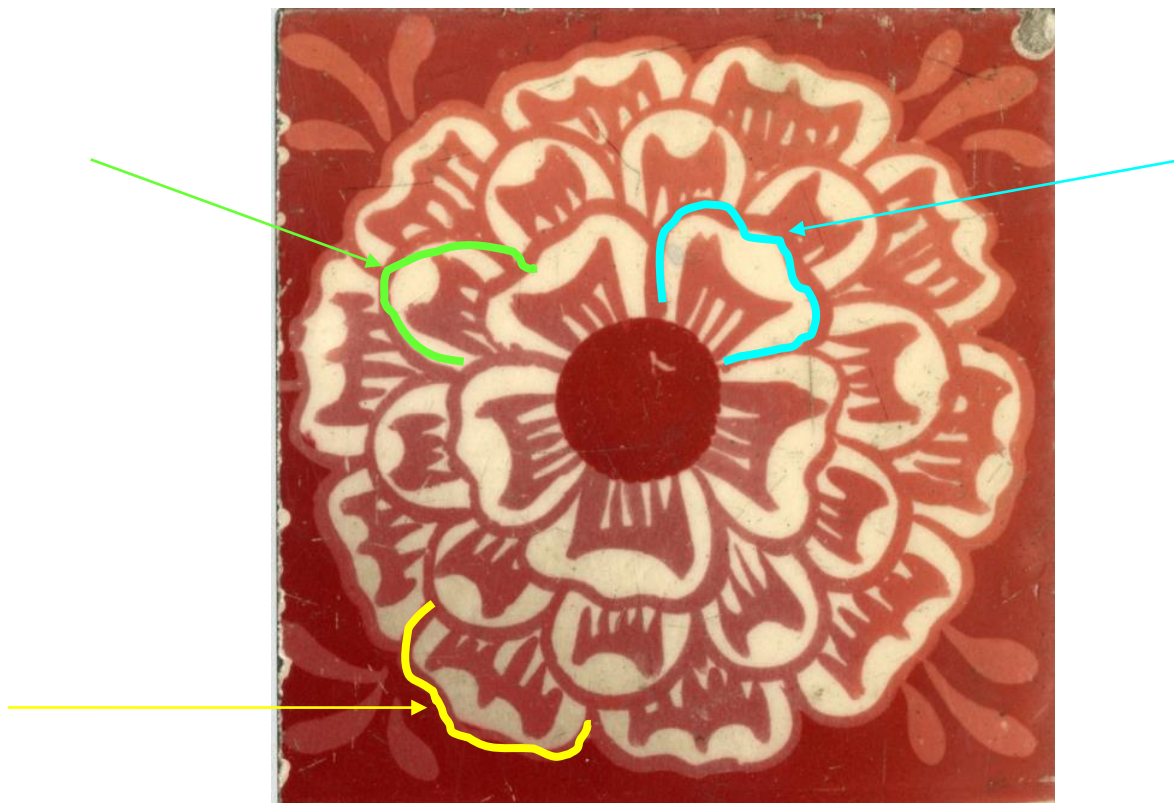
How many times has De Morgan rotated the creature in this design?





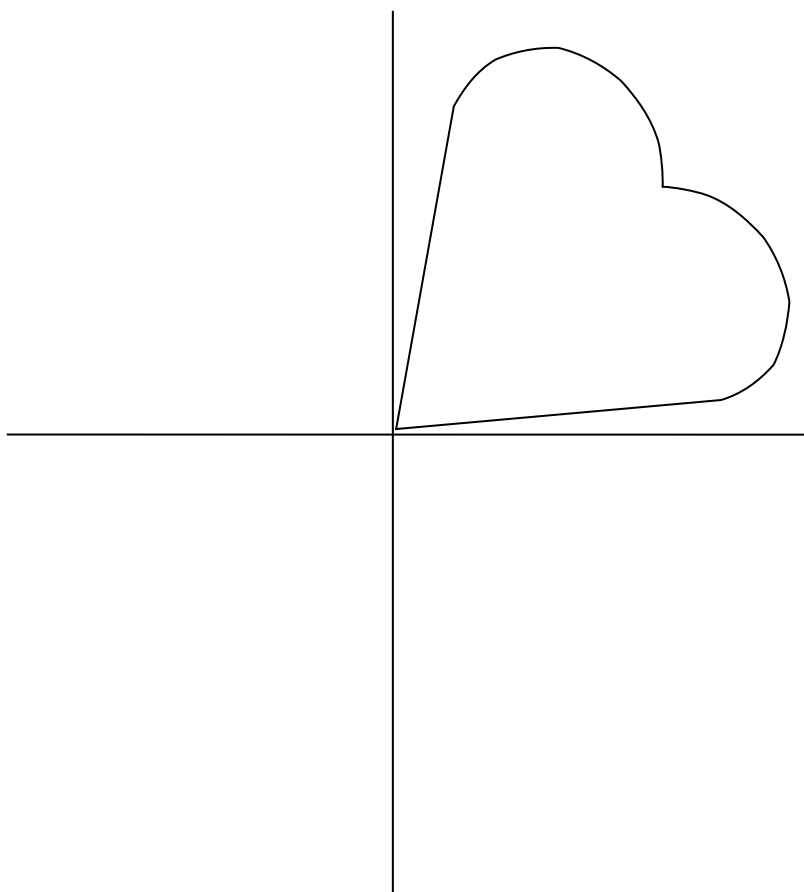
ROTATIONS

How many times has each petal shape been rotated in this tile design?



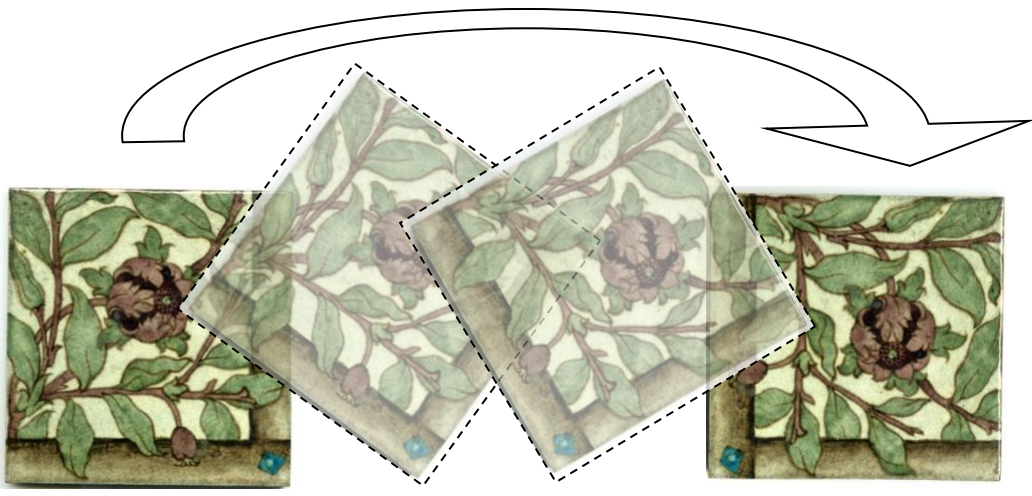
Draw a flower with rotational symmetry by rotating this petal and drawing it again in the spaces.

How many rotations of the same shape are there?



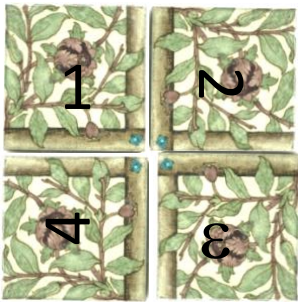
ROTATIONS

William De Morgan's *Rose and Trellis* tile design can be rotated to create a tile pattern.

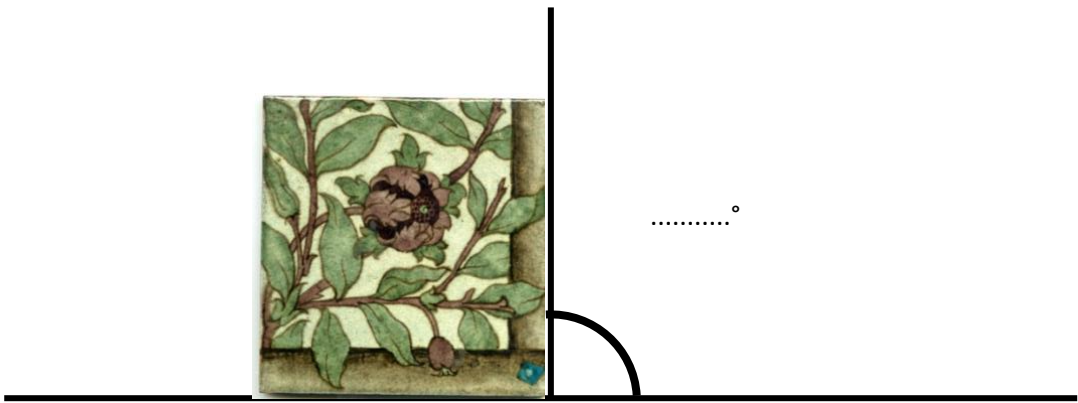


The tile has been rotated one quarter turn.

There are four quarter turns in one full turn.



You can measure the angle of a quarter turn. Measure the angle below.



As the tile rotates, it travels *through* the angle you have measured. We say that the shape has been rotated one turn through°

Cut out the tiles below.





ROTATIONS

Make your own rotating *Rose and Trellis* design.

1. Stick your first tile in position 1.
2. Place your second tile on top of tile 1 and then rotate it one quarter turn through 90° into space 2 and stick it down.
3. Place your third tile on top of tile 2 and rotate it one quarter turn through 90° into space 3 and stick it down.
4. Place your fourth tile on top of tile 3 and rotate it one quarter turn through 90° into space 2 and stick it down.

