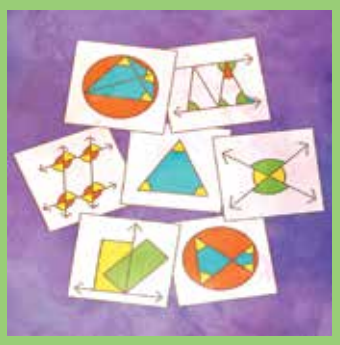
Mathematics

Geometric Reasoning

Student Handbook



CLI

CONNECTED LEARNING INITIATIVE

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TISS

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CLIx (2018)

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The **Connected Learning Initiative (CLIx)** is a technology enabled initiative at scale for high school students. The initiative was seeded by Tata Trusts, Mumbai and is led by Tata Institute of Social Sciences, Mumbai and Massachusetts Institute of Technology, Cambridge, MA USA. CLIx offers a scalable and sustainable model of open education, to meet the educational needs of students and teachers. The initiative has won UNESCO's prestigious 2017 King Hamad Bin Isa Al-Khalifa Prize, for the Use of Information and Communication Technology (ICT) in the field of Education.

CLIx incorporates thoughtful pedagogical design and leverages contemporary technology and online capabilities. Resources for students are in the areas of Mathematics, Sciences, Communicative English and Digital Literacy, designed to be interactive, foster collaboration and integrate values and 21st century skills. These are being offered to students of government secondary schools in Chhattisgarh, Mizoram, Rajasthan and Telangana in their regional languages and also released as Open Educational Resources (OERs).

Teacher Professional Development is available through professional communities of practice and the blended Post Graduate Certificate in Reflective Teaching with ICT. Through research and collaborations, CLIx seeks to nurture a vibrant ecosystem of partnerships and innovation to improve schooling for underserved communities.

Collaborators:
Centre for Education Research & Practice – Jaipur, Department of Education, Mizoram University – Aizawl, Eklavya – Bhopal, Homi Bhabha Centre for Science Education, TIFR – Mumbai, National Institute of Advanced Studies – Bengaluru, State Council of Educational Research and Training (SCERT) of Telangana – Hyderabad, Tata Class Edge – Mumbai, Inter-University Centre for Astronomy and Astrophysics – Pune, Govt. of Chhattisgarh, Govt. of Mizoram, Govt. of Rajasthan and Govt. of Telangana.

Any questions, suggestions or queries may be sent to us at:
contact@clix.tiss.edu

Mathematics

Geometric Reasoning

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This handbook belongs to:

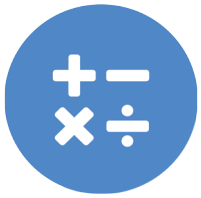
Name: .....

Class: .....

Section: .....

Table of Contents

Note: * Lessons without hands-on activities are not included in this workbook



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Special Thanks
To the students and teachers of all the schools where we piloted our modules.
To all the teachers, copyeditors and Rajasthan and Telangana team for their time and effort in the revalidation of content

Module Overview

About Geometric Reasoning Module

Geometric Reasoning Module (Parts I and II) has been designed to develop the reasoning abilities of 8^{th} and 9^{th} class students. There are a total of 5 units in the Geometric Reasoning module which will help students develop an understanding of (2D) shapes, and the ability to analyze, discuss and argue confidently about shapes in terms of their attributes and properties. The module will also help students develop definitions of various special quadrilaterals on the basis of their properties. Moving forward from Geometric Reasoning Part I, the Part II will help students develop a relational understanding of the different types of special quadrilaterals, and also to understand the need for proofs in Mathematics. A digital game named PoliceQuad is designed to help students think deeper about the properties of Geometric shapes while playing the game. LOGO Turtle and Geogebra are free and open source software which give students visual experiences of verifying many concepts, properties and theorems in Geometry.

The modules have digital as well as hands-on activities and formative assessments form an integral part of this course. There are Pre and Post assessments at the start and end of each module on the digital platform. The course is prepared by conforming with the current State and NCERT syllabi and the activities designed in this course focus on developing thinking and reasoning abilities of the students. The Mathematics modules will be installed in the school computer labs using a server based model.

How to use this book ?

This book contains some of the activities of the module that are hands-on (involving classroom discussions) which are to be used in conjunction with other materials that are present on the CLIx platform. These hands-on activities and worksheets help to elicit and consolidate learning of Geometrical shapes and should be done in a proper sequence along with the digital activities. Students may do the problems in the space provided in this workbook or in their notebooks and discuss with their teachers and peers.

The CLIx platform is a digital platform that makes use of both the digital content and the workbook content. The platform has features like Notebook, Discussion and Gallery where students can give their responses, comments and upload their work respectively.

Geometric Reasoning
Part I

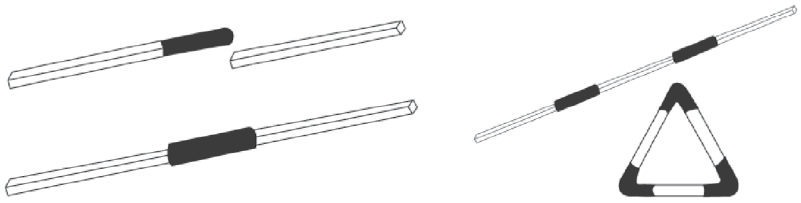
Unit 1: Concept of Shape

Lesson 1.1: What is shape?

Activity 1: Matchstick shapes

Work in your group. You will need a set if (used) matchsticks and cycle valve tubes.

Task 1: Make a triangle, a square and pentagon using the matchsticks and valve tubes.



Task 2: Perform these actions (mentioned in the table) on the square. Discuss in your group and note whether the shape changes or not.

	Action	Does the shape change?	Why do you think so ?
1	Sliding the shape on the floor/desk		
2	Rotating the shape on the floor/desk		
3	Flipping the shape on the floor/desk		
4	Pressing on the opposite vertices of the shape		

Task 3: Try pressing on the opposite vertices of the pentagon. Does it change shape ? Now try doing the same with the triangle. Does it change shape?

Extension Task 1: Try making as many different shapes as possible by deforming/twisting the pentagon (without breaking it or opening up the joints). In particular, try to make
a triangle that has exactly two sides equal

- a four sided polygon
- a star shape

Extension Task 2: Try making a triangle in which all three sides are of different length. What would be the minimum number of matchsticks needed for this?

Unit 2: Analysing and Describing Shapes

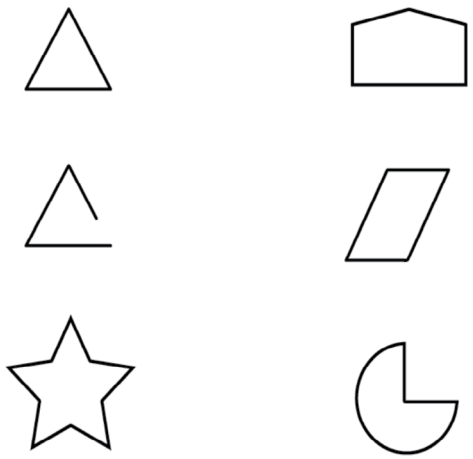
Lesson 2.1: Analysing shapes

In this lesson, students play the digital game **"Police Quad"** - Mission 1 on the platform. This Mission of the game helps students in developing understanding of shapes through property-based reasoning tasks.

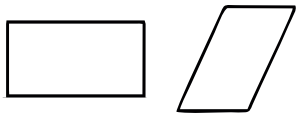
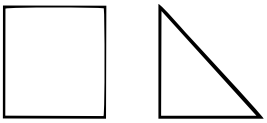
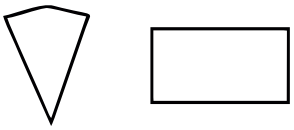
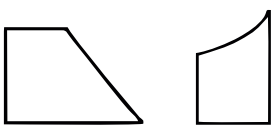
Activity 1: Sorting shapes

Work individually on the following tasks and then discuss with your group.

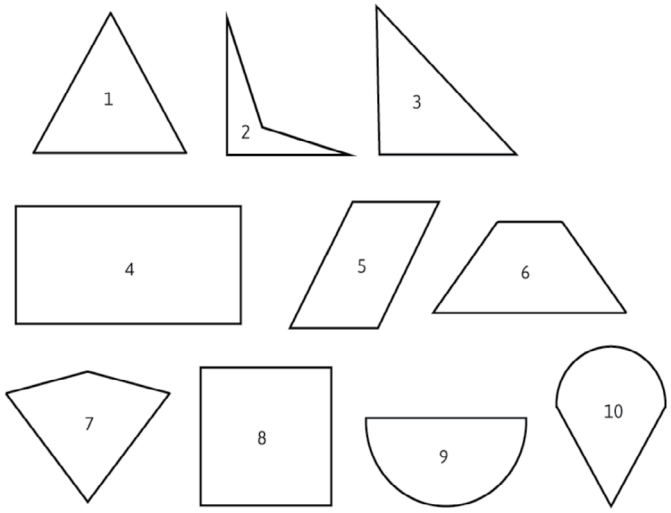
Task 1: Write 1-2 lines about (or properties of) each of the following shapes



Task 2: Observe the two shapes given in each of the following sets. List as many similarities and differences that you can between the two. One example is given for the first set.

Set	Similarities	Differences
	1) Both have exactly 4 sides 2) Both have 2 pairs of parallel sides	1) The first shape has right angles, the second does not
		
		
		

Task 3: Look at the collection of shapes below. Based on their properties, sort them into two groups in as many different ways as you can. An example is shown in the table.



Property	These shapes have it	These shapes don't have it
Has exactly 4 straight sides	2, 4, 5, 6, 7, 8	1, 3, 9, 10

Extension Task 1: Draw 3 different shapes that have the following property 'all sides equal'. 'All sides equal' is one way which the shapes that you got are similar. What is one difference between them?

Extension Task 2:
Draw a shape that has both these properties:
i. exactly 5 sides
ii. exactly 2 right angles

Extension Task 3:
Draw a shape that has all these properties:
i. exactly 4 sides
ii. exactly 2 right angles
iii. exactly 1 pair of sides parallel

Lesson 2.2: Describing shapes

*Please refer to this lesson on the **CLIx platform***

In this lesson, students play **"Police Quad"** - Mission 2, which helps students in strengthening property-based understanding of shapes through shape description tasks. The Mission also helps develop strategic thinking.

Unit 3: Classifying and Defining Shapes

Lesson 3.1: Classifying shapes

*Please refer to this lesson on the **CLIx platform***

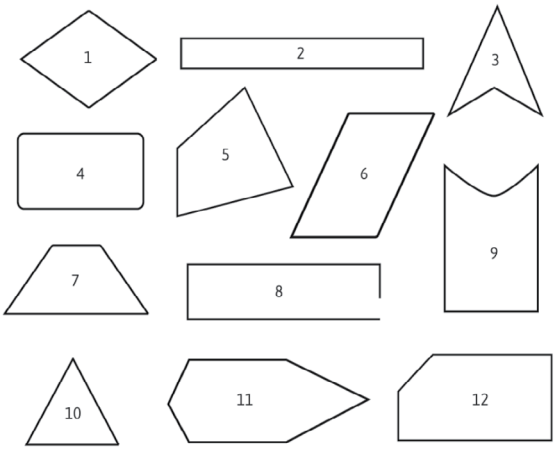
In this lesson, students play **"Police Quad"** - Mission 3. This Mission helps students engage in property-based classification, reasoning and informal deduction tasks.

Lesson 3.2: Defining shapes

Activity 1: What is a quadrilateral

Work individually on the following tasks and then discuss with your group.

Task 1: Look at the collection of shapes and sort them based on their properties into two groups- 'Quadrilaterals' and 'Not quadrilaterals'.



Now, fill in the table below.

These are qauadrilaterals	These are not quadrilaterals

For each shape, discuss why you think it is a quadrilateral, or not. Now complete the following: I think "a quadrilateral is

Lesson 3.3 : Defining special quadrilaterals

In this lesson, students use **"Turtle Logo"** to construct, identify and define special quadrilaterals.

Activity 1: Constructing rectangles

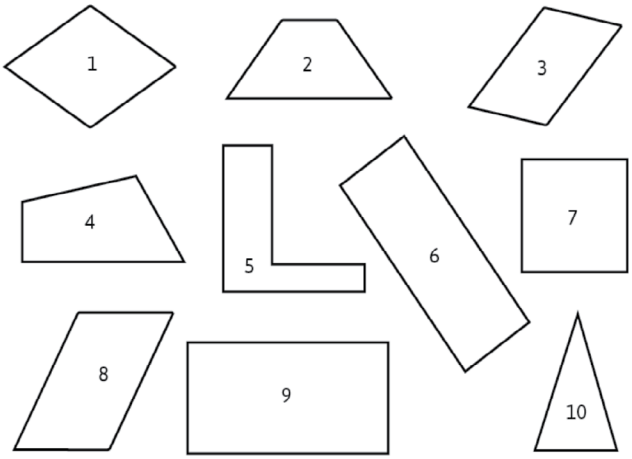
*Please refer to this activity on the **CLIx platform***

Activity 2: Exploring special quadrilaterals

Work individually on the following tasks and then discuss with your group.

Task 1: Look at the collection of shapes and sort them into those that are parallelograms and those that are not. Fill in the table.

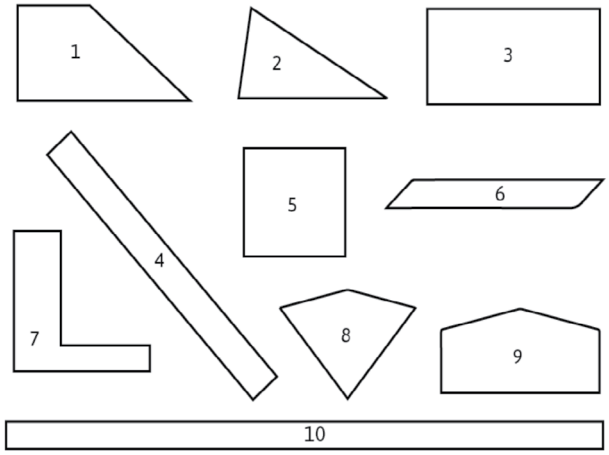
These are parallelograms	These are not parallelograms



For the shapes which are not parallelograms, explain why. Based on this, write your definition of a parallelogram. I think "a parallelogram is

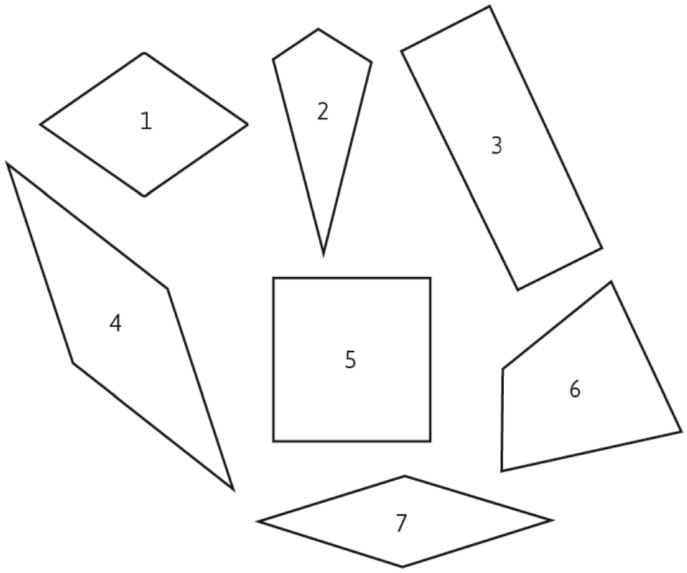
Task 2: Look at the collection of shapes and sort them into those that are rectangles and those that are not. Fill in the table

These are rectangles	These are not rectangles



Based on this, write your definition of a rectangle.
I think "a rectangle is

Task 3: Look at the collection of shapes and sort them into those that are rhombuses and those that are not.



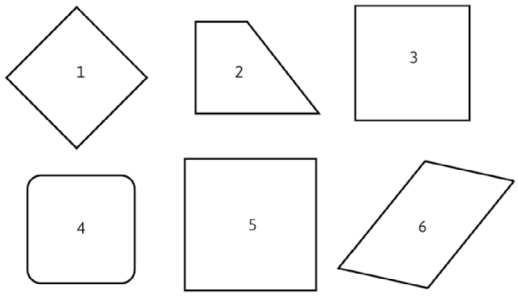
Now, fill in the table below.

These are rhombuses	These are not rhombuses

Based on this, write your definition of a rhombus
I think "a rhombus is

Task 4: Look at the collection of shapes and sort them into those that are squares and those that are not. Fill in the table

These are squares	These are not squares



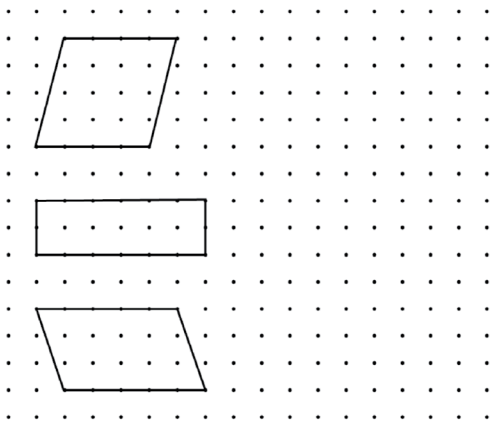
Based on this, write your definition of a square.

Lesson 3.4: Properties of special quadrilaterals

Activity 1: Making property lists

Work individually on the following tasks and then discuss with your group.

Task 1a: Shown here are some examples of parallelograms. Draw two more examples of parallelograms on the dot paper. (Make sure that your parallelograms are different from the ones already given)

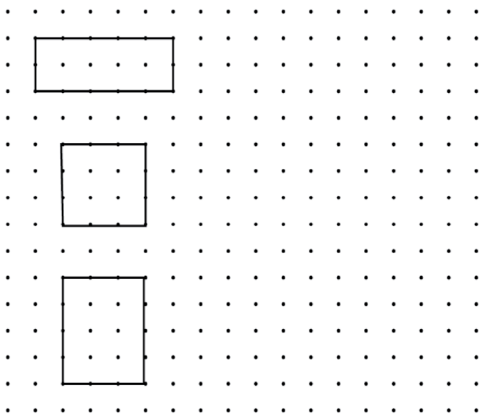


Task 1b: Write down the ways in which these parallelograms are different from each other.

Task 2: Observe the parallelograms in Task 1 and make a list of as many properties as you can. Remeber, the properties should be common to ALL the examples!

Properties of a Parallelogram		
Side Properties	**Angle Properties**	**Diagonal Properties**

Task 3a: Shown here are some examples of rectangles. Draw 2 more examples of rectangles on dot paper. (Make sure that your rectangles are different from the ones already given!)



Task 3b: Write down the ways in which these rectangles are different from each other.

_____

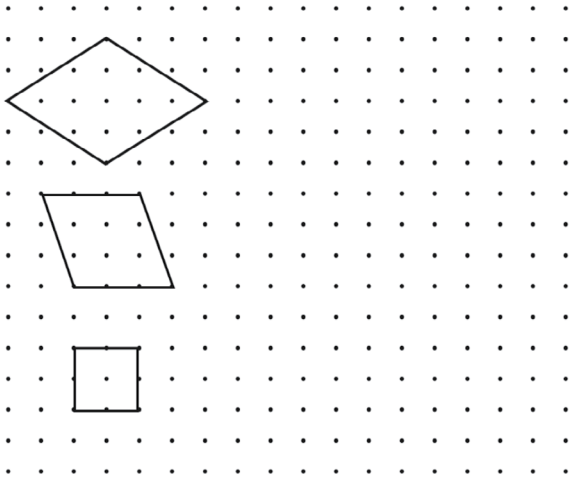
_____

_____

Task 4: Observe the rectangles in Task 3 and make a list of as many properties as you can. Remember, the properties should be common to ALL the examples.

Properties of a Rectangle		
Side Properties	**Angle Properties**	**Diagonal Properties**

Task 5a: Shown here are some examples of rhombuses. Draw 2 more examples of rhombuses on dot paper. (Make sure that your rhombuses are different from the ones already given!)



Task 5b: Write down the ways in which these rhombuses are different from each other.

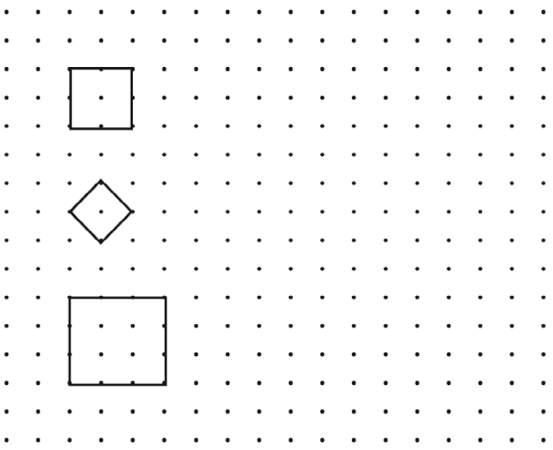
_____

_____

Task 6: Observe the rhombuses in Task 5 and make a list of as many properties as you can. Remember, the properties should be common to ALL the examples!

Properties of a Rhombus		
Side Properties	**Angle Properties**	**Diagonal Properties**

Task 7a: Shown here are some examples of squares. Draw 2 more examples of squares on dot paper. (Make sure that your squares are different from the ones already given!)



Task 7b: Write down the ways in which these squares are different from each other.

_____

_____

Task 8: Observe the squares in Task 7 and make a list of as many properties as you can. Remember, the properties should be common to ALL the examples!

Properties of a Square		
Side Properties	**Angle Properties**	**Diagonal Properties**

Geometric Reasoning
Part II

Unit 1: Property-Based Reasoning

Lesson 1.1: Relationships among special quadrilaterals

Activity 1: Representing relationships 1

*Please refer to this activity on the **CLIx platform***

In this activity, students play **"Police Quad"** - Mission 4. This Mission of the game is meant to initiate discussion on hierarchical class-relationships among parallelograms, rhombuses, rectangles and squares.

Activity 2: Creating property stacks

Work individually on the following tasks and then discuss with your group.

Task 1: Study the table of properties below. Put a tick (√) mark in a cell if the corresponding shape has the given property. Leave the cell blank if it doesn't.

The first row is done for you.

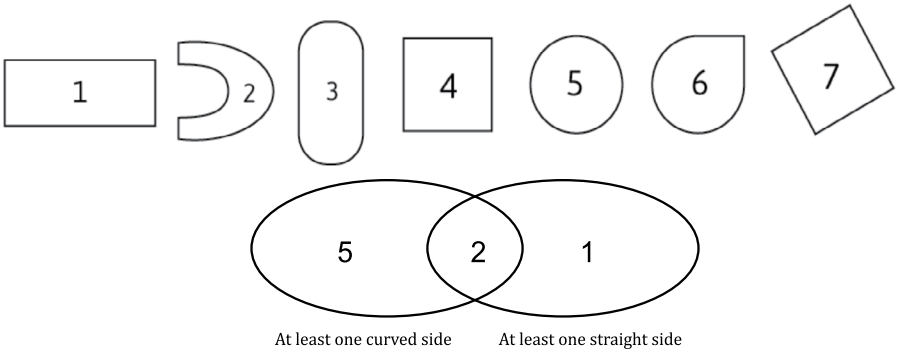
	Properties	Square	Rectangle	Parallelogram	Rhombus
1	Closed figure made of 4 line segments only	✓	✓	✓	✓
2	Pairs of opposite sides equal in length				
3	Pairs of opposite sides are parallel				
4	Opposite angles are congruent				
5	Diagonals bisect each other				
6	All angles are right angles / are equal				
7	Adjacent angles are equal				
8	Diagonals are equal in length				
9	Adjacent sides are equal in length				
10	All 4 sides are equal in length				
11	Diagonals are perpendicular to each other				

Lesson 1.2: Representing relationships

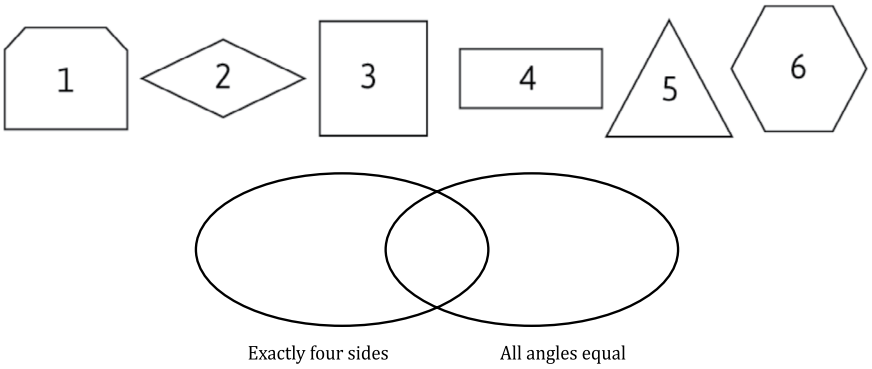
Activity 1: Representing relationships 1

Work individually on the following tasks and then discuss with your group.

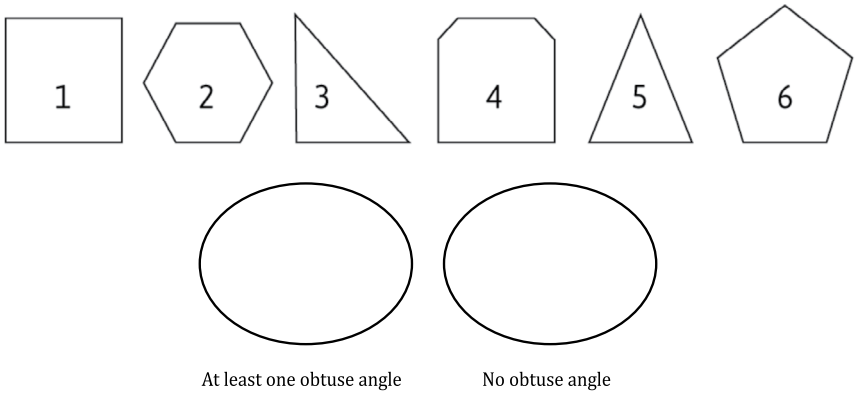
Task 1: Write the numbers corresponding to each of the shapes below in the appropriate place in the given Venn diagram. Some are done for you.



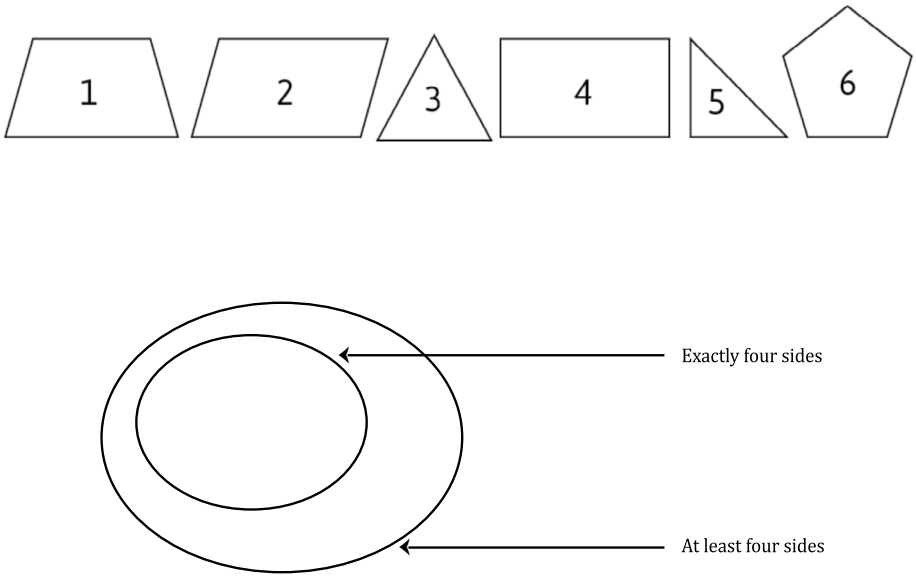
Task 2: Write the numbers corresponding to each of the shapes below in the appropriate place in the given Venn diagram.



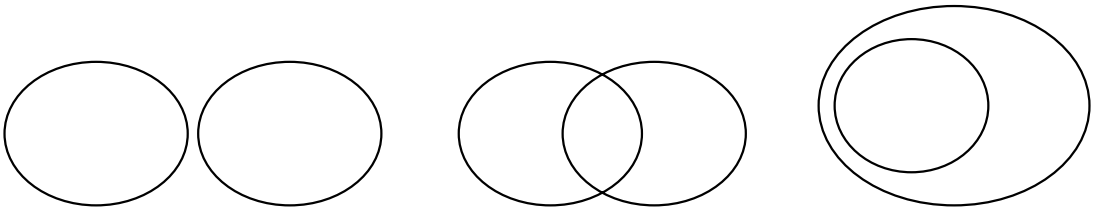
Task 3: Write the numbers corresponding to each of the shapes below in the appropriate place in the given Venn diagram.



Task 4: Write the numbers corresponding to each of the shapes below in the appropriate place in the given Venn diagram.



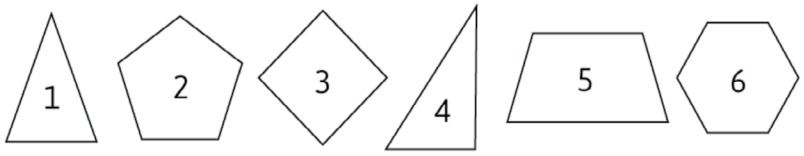
For Tasks 5 to 8, consider the three types of Venn diagrams Type 1, Type 2 or Type 3 shown below.



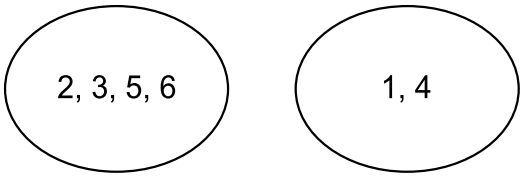
Type 1 Type 2 Type 3

Task 5: Consider two groups of shapes:
- Group 1: has at least 4 straight sides
- Group 2: has less than 4 straight sides

a. Which type of Venn (Type 1, 2 or 3) would be the most appropriate to classify a group of shapes by these two properties? Justify your choice. Draw it in the space provided below.
b. Now classify these shapes into the Venn diagram you selected. (Write the numbers in the appropriate place. Some are done for you)



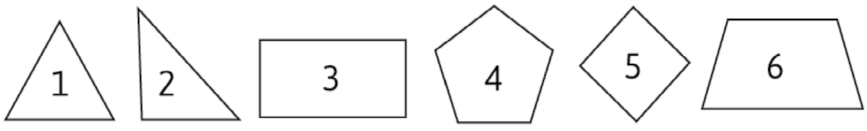
(This task is done as an example for you.)

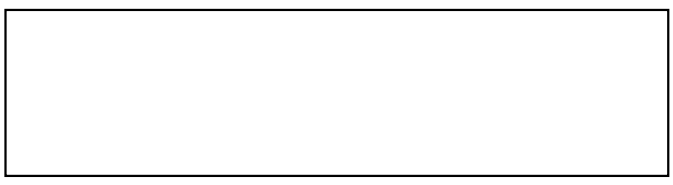


Atleast four straight sides Less than four straight sides

Task 6: Consider two groups of shapes:
- Group 1: has all sides equal
- Group 2: has at least 1 right angle

a. Which type of Venn (Type 1, 2 or 3) would be the most appropriate to classify a group of shapes by these two properties? Justify your choice. Draw it in the space provided below.
b. Now classify these shapes into the Venn diagram you selected. (Write the numbers in the appropriate place.)

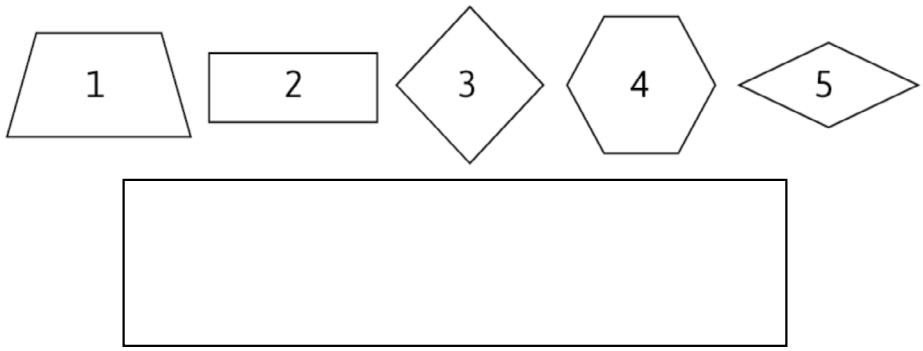




Task 7: Consider two groups of shapes:

- Group 1: has at least one pair of opposite sides parallel
- Group 2: has no sides parallel

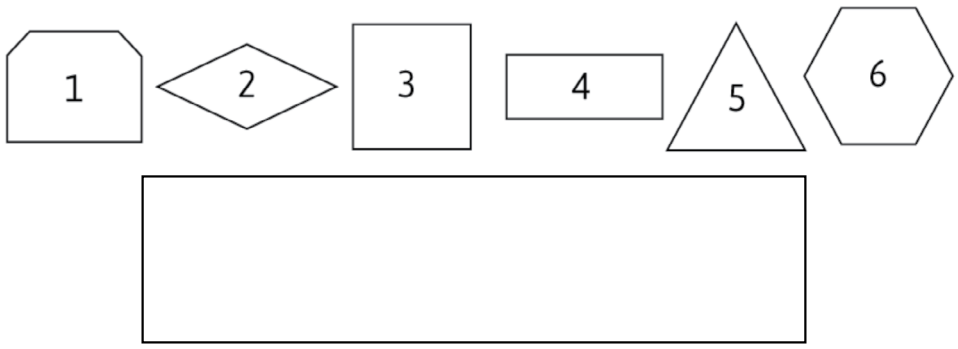
a. Which type of Venn (Type 1, 2 or 3) would be the most appropriate to classify a group of shapes by these two properties? Justify your choice. Draw it in the space provided below.
b. Now classify these shapes into the Venn diagram you selected. (Write the numbers in the appropriate place.)



Task 8: Consider the property set:

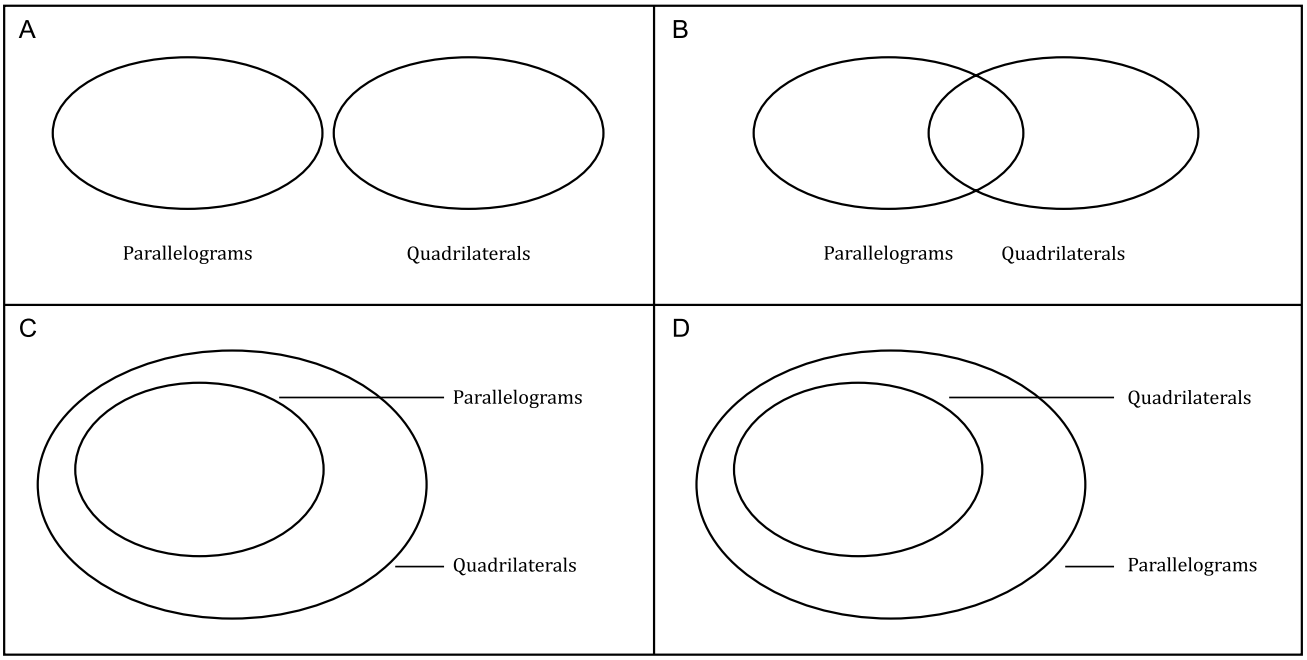
- at least 3 straight sides
- exactly 4 straight sides

a. Which type of Venn (Type 1, 2 or 3) would be the most appropriate to classify a group of shapes by these two properties? Justify your choice. Draw it in the space provided below.
b. Now classify these shapes into the Venn diagram you selected, by the given properties.

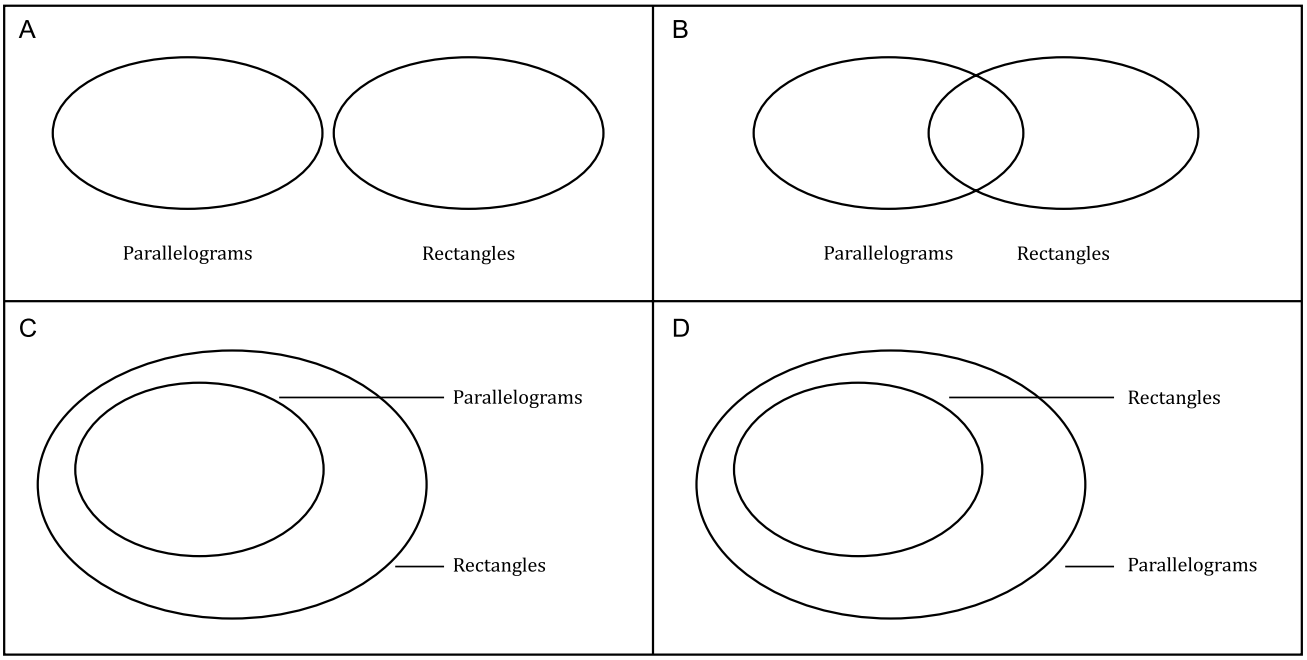


Activity 2: Representing relationships 2

Task 1: Which of these is the correct representation of the set of parallelograms and quadrilaterals, and why? (You may want to use the definition of quadrilaterals and parallelograms and their properties to see how they are related.)



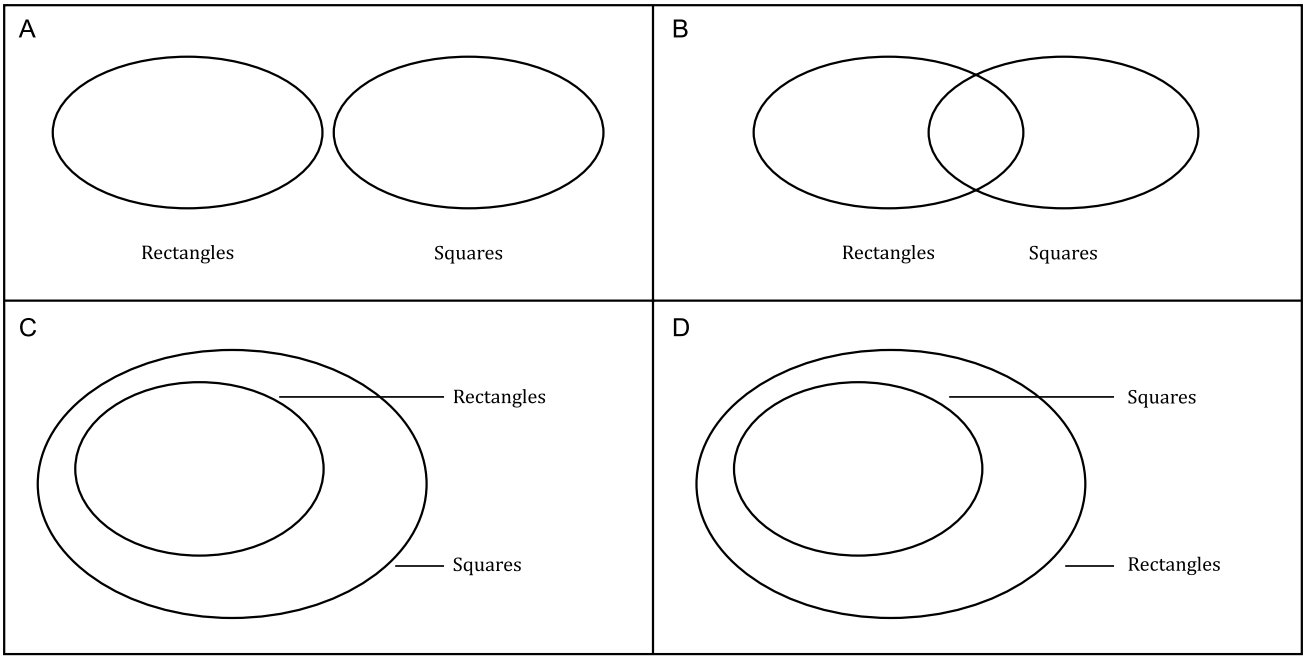
Task 2: Which of these is the correct representation of the set of parallelograms and rectangles, and why? (You may want to use the definition of parallelograms and rectangles and their properties to see how they are related.)



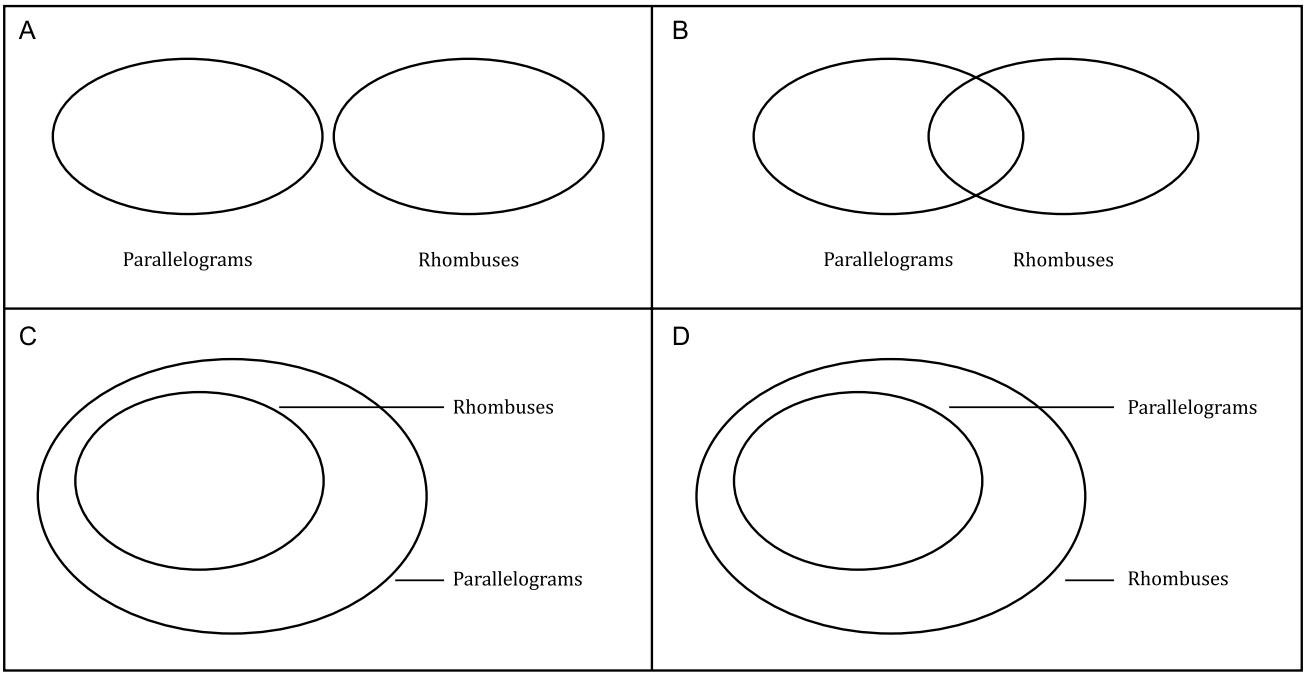
Task 3: Based on task 2, which of the following statements is correct? And why?

a. All parallelograms are rectangles
b. All rectangles are parallelograms
c. Some rectangles are parallelograms (and some are not)
d. No parallelogram is a rectangle

Task 4: Which of these is the correct representation of the set of rectangles and squares, and why? (You may want to use the definition of quadrilaterals and parallelograms and their properties to see how they are related)



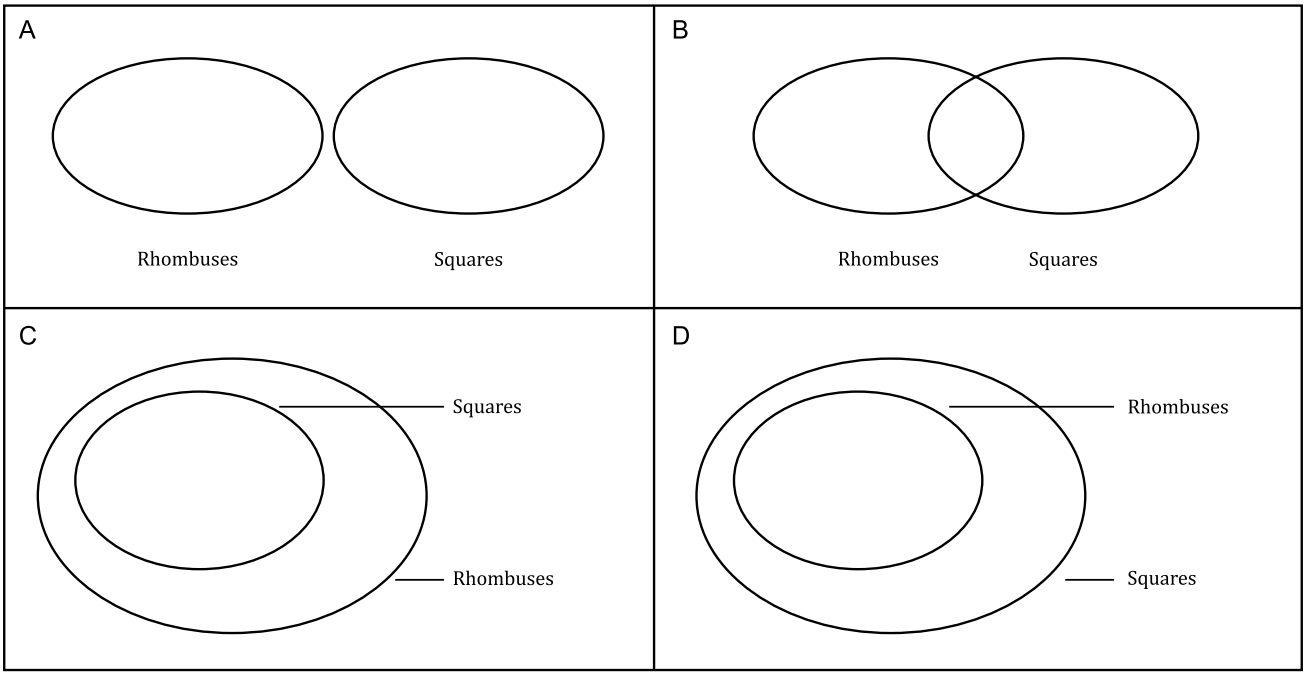
Task 5: Which of these is the correct representation of the set of parallelograms and rhombuses, and why? (You may want to use the definition of parallelograms and rhombuses and their properties to see how they are related.)



Task 6: Based on task 4, which of the following statements is correct? And why?

a. All parallelograms are rhombuses
b. All rhombuses are parallelograms
c. Some rhombuses are parallelograms (and some are not)
d. No parallelogram is a rhombus

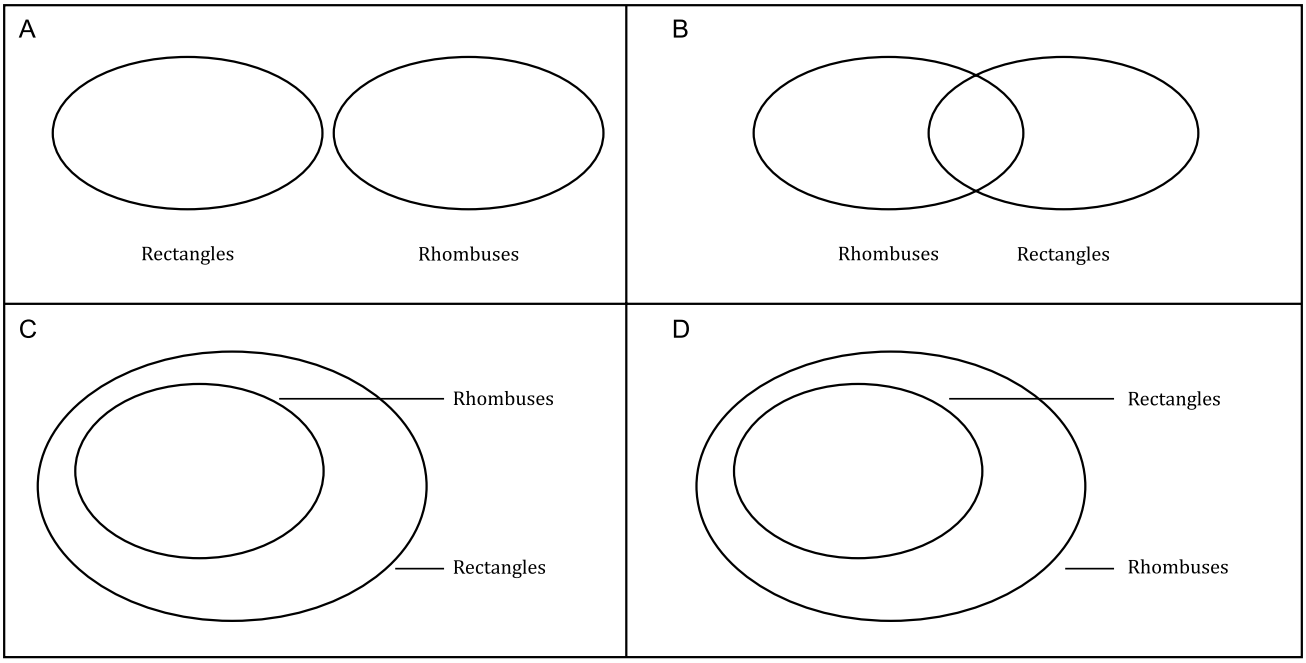
Task 7: Which of these is the correct representation of the set of rhombuses and squares, and why? (You may want to use the definition of rhombuses and squares and their properties to see how they are related.)



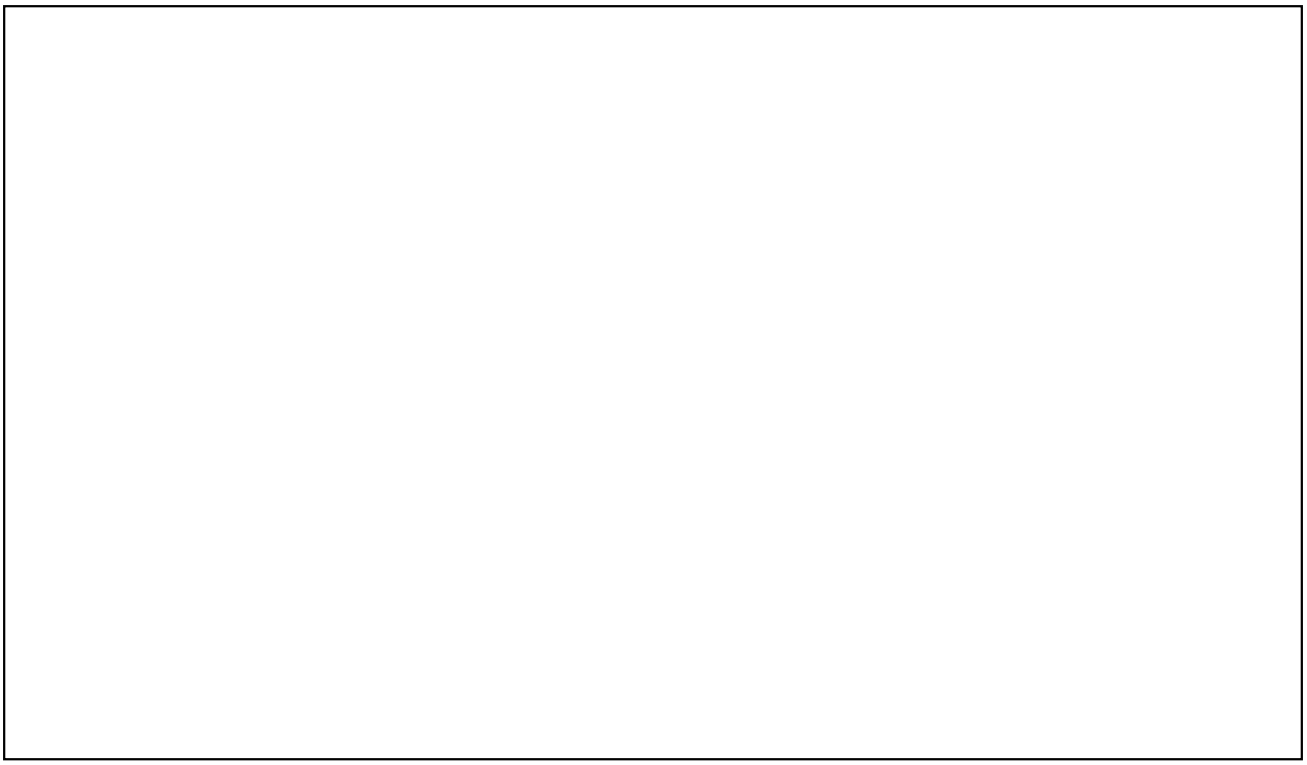
Based on this choose the correct word that completes the sentence.

i. _____ rhombuses are squares. (All/Some/No)
ii. _____ squares are rhombuses. (All/Some/No)

Task 8: Which of these is the correct representation of the set of parallelograms and rhombuses, and why? (You may want to use the definition of parallelograms and rhombuses and their properties to see how they are related.)



Task 9: Using the representation chosen in the above tasks, represent quadrilaterals, parallelograms, rhombuses , rectangles and squares in one diagram. Represent quadrilaterals using a rectangle and use appropriate circles to represent the remaining quadrilaterals.



Lesson 1.3: Discussing definitions

*Please refer to this lesson on the **CLIx platform***

In this lesson, students will be discussing definitions of different quadrilaterals and will represent the relationship between quadrilaterals using Venn diagrams.

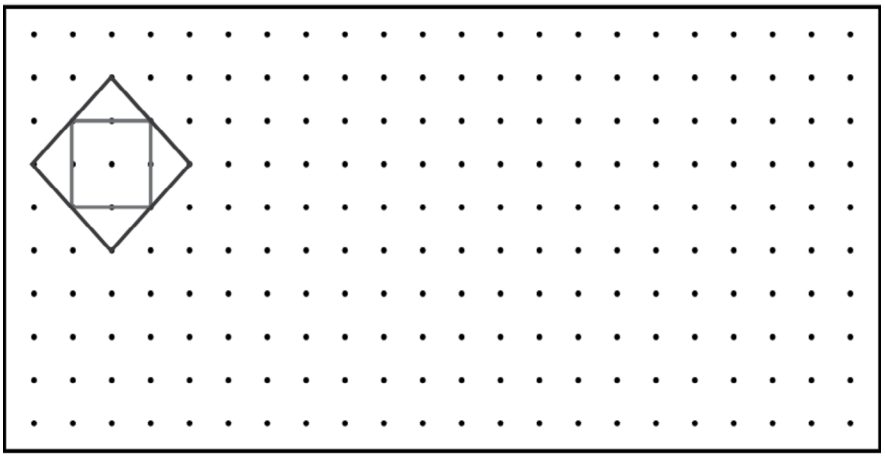
Unit 2: Understanding the Need for Proof

Lesson 2.1: Midpoint explorations

Activity 1: Midpoint explorations

Work individually on the following tasks and then discuss with your group.

Task 1: On the dot paper below, draw different squares. Join the midpoints of the sides of each of these squares (in order) to create a new quadrilateral. The first one is shown as an example.

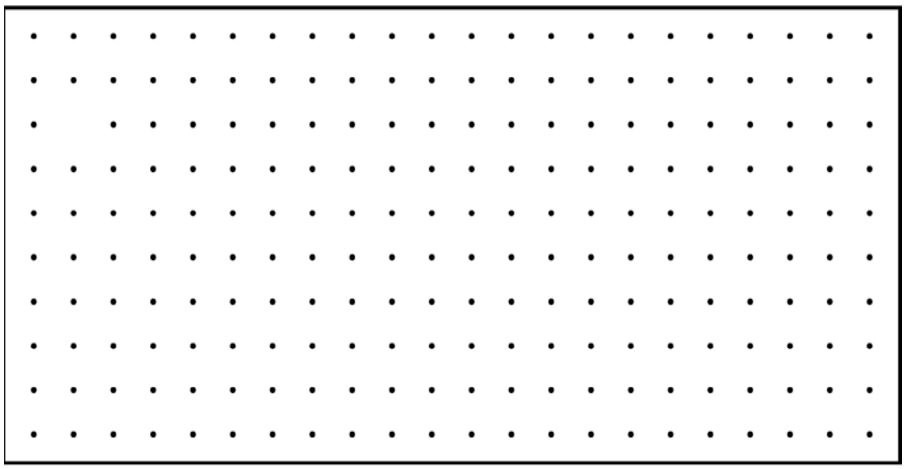


Observe each of the new quadrilaterals formed, and complete the following: The quadrilateral formed by joining the midpoints of sides of a square is a _____

Task 2: Suppose you were to join the midpoints of sides of a rectangle in a similar fashion. What shape do you think you might get? Think about it, and write your conjecture here:

The quadrilateral formed by joining the midpoints of sides of a _____is a_____

Task 3: Now verify your conjecture by drawing different rectangles on the dot paper below and joining the midpoints of the sides.

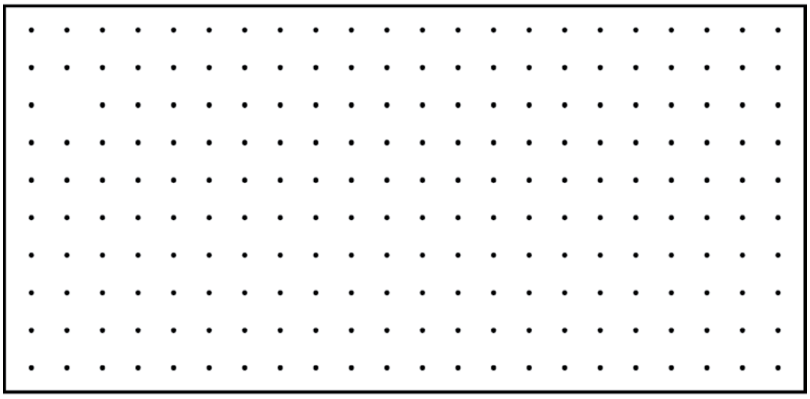


Task 4: Based on Task 3 does your conjecture hold? If not, how would you modify it?

Task 5: Now make similar conjectures about other special quadrilaterals, rhombus and parallelogram and verify them. Write your conjectures in the space provided, and use the dot grid for verifying.

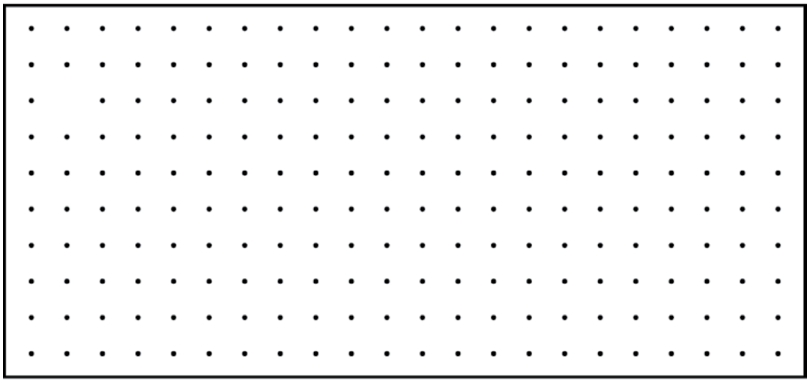
Conjecture 1

Conjecture 2



Task 6: Drawing on your observations in the 5 previous tasks, make a conjecture about the shape formed by joining the midpoints of sides of any quadrilateral.

Points to think about:
Would this be true for ALL quadrilaterals? How do you know? Explain your reasoning here. Use the dot grid below if necessary.



Extension Task 1: if possible, draw a quadrilateral, joining whose midpoints of sides in order gives a figure that is NOT a parallelogram. If not possible, explain why?

Lesson 2.2: Angle sum property

In this lesson, the **"Geogebra"** application is used to help students explore and verify angle sum property of quadrilaterals and also of other polygons.

Activity 1: Angle sum property of quadrilaterals

Work individually on the following tasks and then discuss with your group.

Task 1: Draw a quadrilateral ABCD and measure its (interior) angles. Record in the table below.

∠**A**	∠**B**	∠**C**	∠**D**	**Sum of all (interior) angles**

Task 2: Compare your quadrilateral with those of others in your class.

a. Do they appear the same?
b. Do you observe a pattern/regularity across all quadrilaterals? Write observation in the form of a conjecture:

Task 3**:** Refer to the pattern observed in Task 2.

a. Do you think this pattern will hold true for ALL quadrilaterals ?
b. Why or why not?

Task 4: Draw a quadrilateral and join any one of its diagonals. Without measuring, can you say what the sum of the interior angles of this quadrilateral will be? Write your reasons.

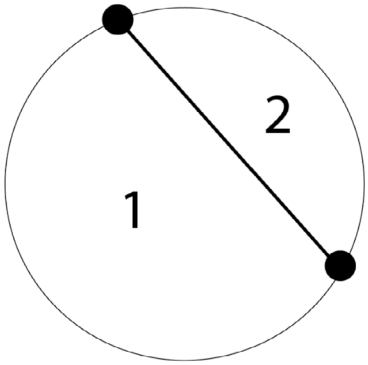
Extension Task 1: Do you think this property (sum of interior angles) will hold true for all parallelograms? Why or why not?

Lesson 2.3: Need for proof

Activity 1: Need for proof

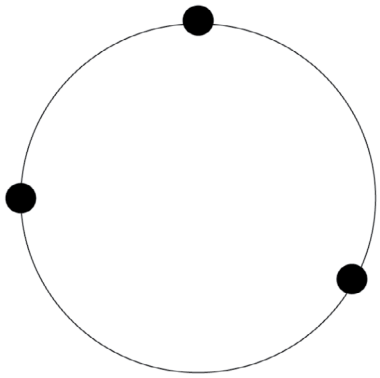
Work individually on the following tasks and then discuss with your group.

Task 1: Mark 2 distinct points on a circle and join them. Note how many separate regions the circle is divided into.



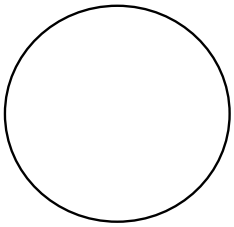
- Number of points on circle : _____
- Number of separate regions : _____

Task 2: Now draw another circle. Mark 3 distinct points on it. Join all possible pairs of points. How many separate regions is the circle divided into?



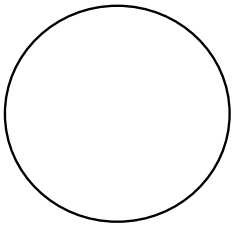
- Number of points on circle : _____
- Number of separate regions : _____

Task 3: Mark 4 distinct points on one circle, join all possible pairs of points. Note the number of (separate) regions the circle is divided into. In the other circle, do the same with 5 distinct points.



For four points on the circle

- Number of points on circle : _____
- Number of separate regions : _____



For five points on the circle

- Number of points on circle : _____
- Number of separate regions : _____

Task 4: Now record your observations from Task 3 in the table below.

Number of points on circle:	**2**	**3**	**4**	**5**
Number of separate regions:				

Task 5: What is the pattern you observe? Write it down. (You could write it as a 'rule' about the relationship between the number of points taken on the circle, and the number of separate regions the circle is divided into.)

_____

_____

Task 6: Do you think your 'rule' will hold true for ANY number of points taken on the circle ? Why or why not?

_____

_____

Task 7: Verify your 'rule' by taking:

i. 1 point on circle
   Number of separate regions: _____
ii. 6 points on circle
   Number of separate regions: _____

Task 8: Does your rule hold true? Based on this, would you like to change your response to Task 7? If yes, put the new response here.

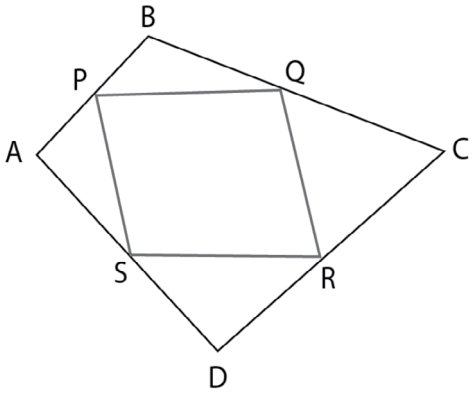
Points to think about:
How many examples do you think are 'enough' to prove a conjecture ?

How many examples do you think are 'enough' to disprove a conjecture ?

Lesson 2.4: Writing a proof

Activity 1: Proving midpoint result for quadrilaterals

Task 1: In the figure, PQRS is formed by joining the midpoints of a quadrilateral ABCD. Prove that PQRS is a parallelogram.



(Hint: **Use the result of the Midpoint Theorem The line joining the midpoints of two sides of a triangle is parallel to the third side and half of it.*)***

Lesson 2.5 : Proving and disproving

Activity 1: True and false statements

Work these out in your group, and then present your solution to the class. Use the space provided for working out your solution.

1. If you double a whole number, you get an even number.

☐ True ☐ False

2. If you add two odd numbers you will get an even number.

☐ True ☐ False

3. If you multiply two odd numbers you get an even number.

☐ True ☐ False

4. If you add 1 to a whole number you get a number less than 1,000,000,000,000,000,000,000.

☐ True ☐ False

5. If a parallelogram has one pair of adjacent sides equal, it is a rectangle.

☐ True ☐ False

6. If a parallelogram has at least one right angle, it is a rectangle.

☐ True ☐ False

7. If a quadrilateral has one pair of opposite sides equal, and the other pair parallel, then it is a parallelogram.

☐ True ☐ False

8. If a quadrilateral has one pair of opposite sides equal, and parallel, then it is a parallelogram.

☐ True ☐ False

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