



CANDIDATE
NAME

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CENTRE
NUMBER

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CANDIDATE
NUMBER

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0607/61

May/June 2023

1 hour 40 minutes

No additional materials are needed.

- Answer both part **A** (Questions 1 to 4) and part **B** (Questions 5 to 7).
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You should use a graphic display calculator where appropriate.
- You may use tracing paper.
- You must show all necessary working clearly, including sketches, to gain full marks for correct methods.
- In this paper you will be awarded marks for providing full reasons, examples and steps in your working to communicate your mathematics clearly and precisely.

- The total mark for this paper is 60.
- The number of marks for each question or part question is shown in brackets [].

This document has **16** pages. Any blank pages are indicated.

Answer **both** parts **A** and **B**.

A INVESTIGATION (QUESTIONS 1 to 4)

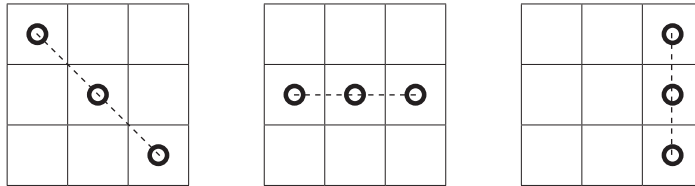
WINNING LINES (30 marks)

You are advised to spend no more than 50 minutes on this part.

This investigation looks at the number of winning lines on a grid.

- 1 In a game you win by making a straight line of three **O**s on a 3 by 3 grid.

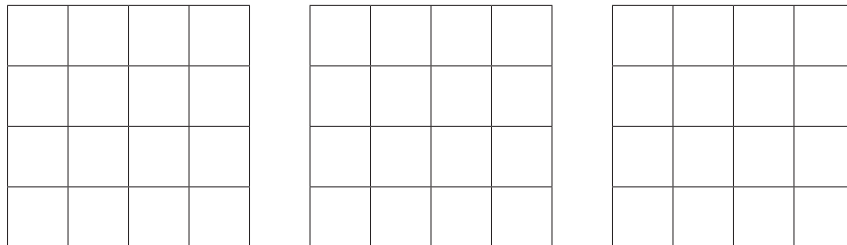
Examples of a winning line with three **O**s.



There are 8 different winning lines.

- (a) Another grid is 4 by 4.
You now need four **O**s in a line to win.

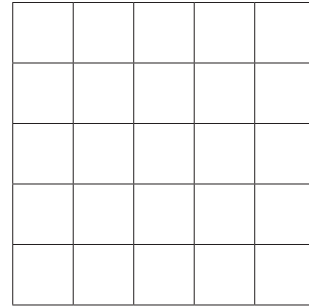
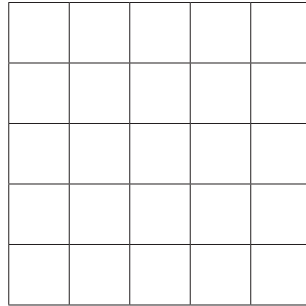
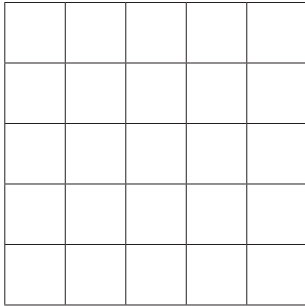
Find the number of winning lines on a 4 by 4 grid.
You may use the grids to help you.



..... [2]

- (b) Another grid is 5 by 5.
You now need five ●s in a line to win.

Find the number of winning lines on a 5 by 5 grid.
You may use the grids to help you.



..... [1]

- (c) A grid is n by n .
You need n ●s in a line to win.

Find an expression, in terms of n , for the number of winning lines.
Give your answer in its simplest form.

..... [2]

- 2 A grid is n by n .
In a different game a winning line is one **○** less than n .
To make a line, the **○**s must be in squares that are next to each other.

(a) In a 3 by 3 grid you need two **○**s in a line to win.

Complete the table to find the number of winning lines with two **○**s.
You may use the grids below the table to help you.

Size of grid	Number of winning lines			
	Horizontal	Vertical	Diagonal	Total
3 by 3			8	

[2]

(b) In a 4 by 4 grid you need three **○**s in a line to win.

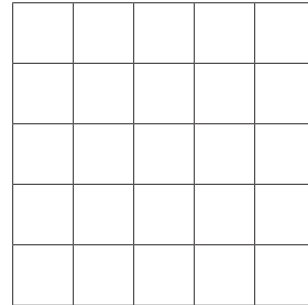
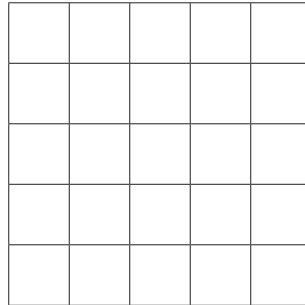
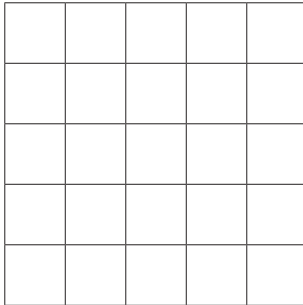
Complete the table to find the number of winning lines with three **○**s.
You may use the grids below the table to help you.

Size of grid	Number of winning lines			
	Horizontal	Vertical	Diagonal	Total
4 by 4				

[2]

- (c) Copy your results from **part (a)** and **part (b)** into this table.
Complete the table.
You may use the grids below the table to help you.

Size of grid	Number of winning lines			
	Horizontal	Vertical	Diagonal	Total
3 by 3			8	
4 by 4				
5 by 5			8	
n by n				



[2]

- (d) In an n by n grid you need $(n - 1)$ ●s in a line to win.
 n must be at least 3.

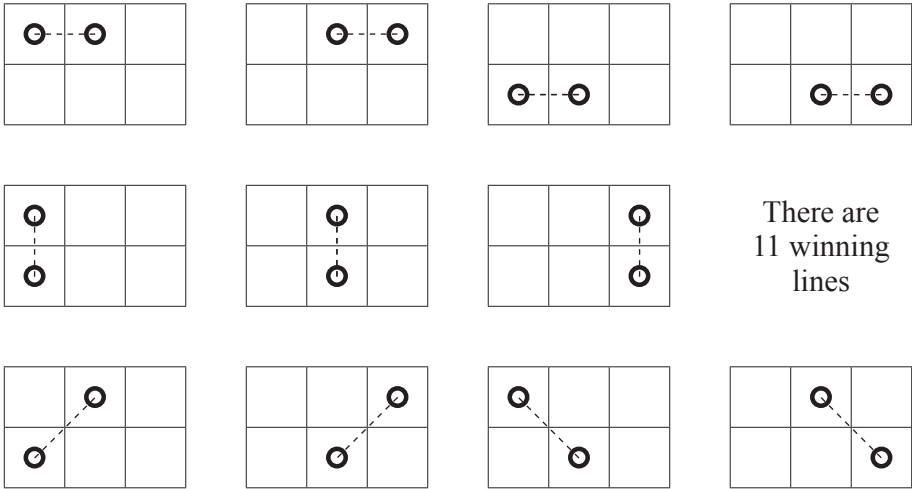
In one grid the total number of winning lines is a square number less than 50.

Find the grid size.

..... [3]

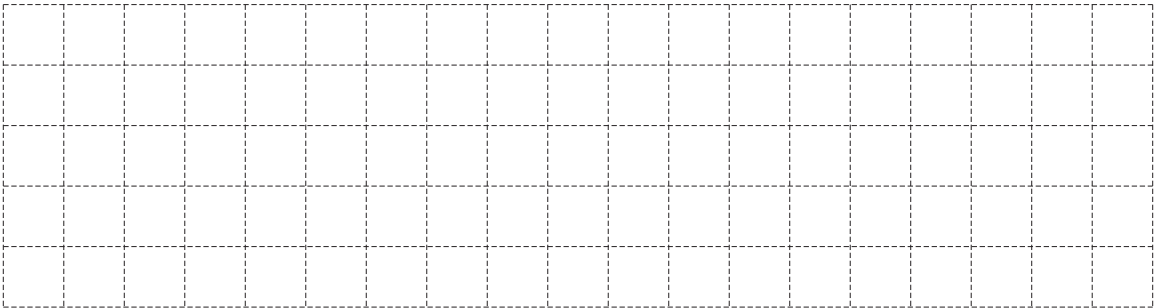
- 3 A rectangular grid has height 2 and width at least 2.
You need two **O**s in a line to win.

These diagrams show all the winning lines with two **O**s on a 2 by 3 grid.



- (a) Complete the table for the number of winning lines with two **O**s.
You may use the grid below the table to help you.

Size of grid	Number of winning lines			
	Horizontal	Vertical	Diagonal	Total
2 by 2	2	2	2	6
2 by 3	4	3	4	11
2 by 4	6	4		
2 by 5		5	8	
2 by w		w		



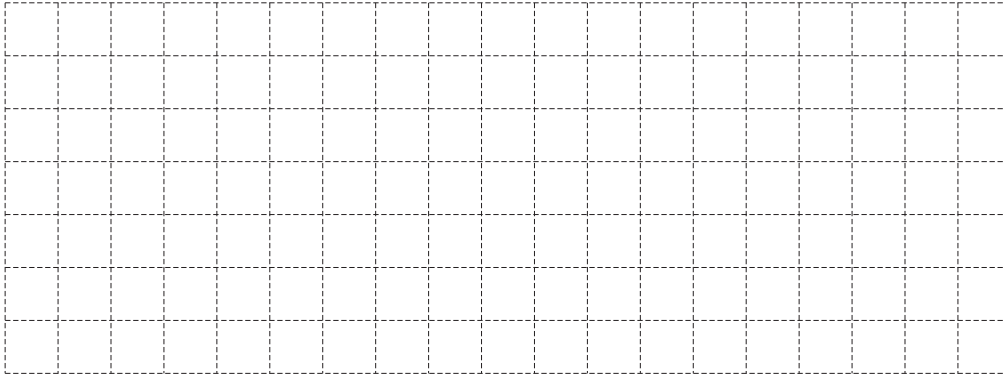
- (b) A rectangular grid has height n and width w where $n \geq 2$ and $w \geq n$.
Any winning line of $\bigcirc$ s has n $\bigcirc$ s.

- (i) Give a reason why there are always w vertical winning lines.

.....

..... [1]

- (ii) Find an expression, in terms of n and w , for the **total** number of horizontal winning lines.
You may use the grid to help you.



..... [2]

- (iii) Use **part (i)** and **part (ii)** and the geometry of the grid to find an expression for the total number of winning lines.
Do not simplify your expression.

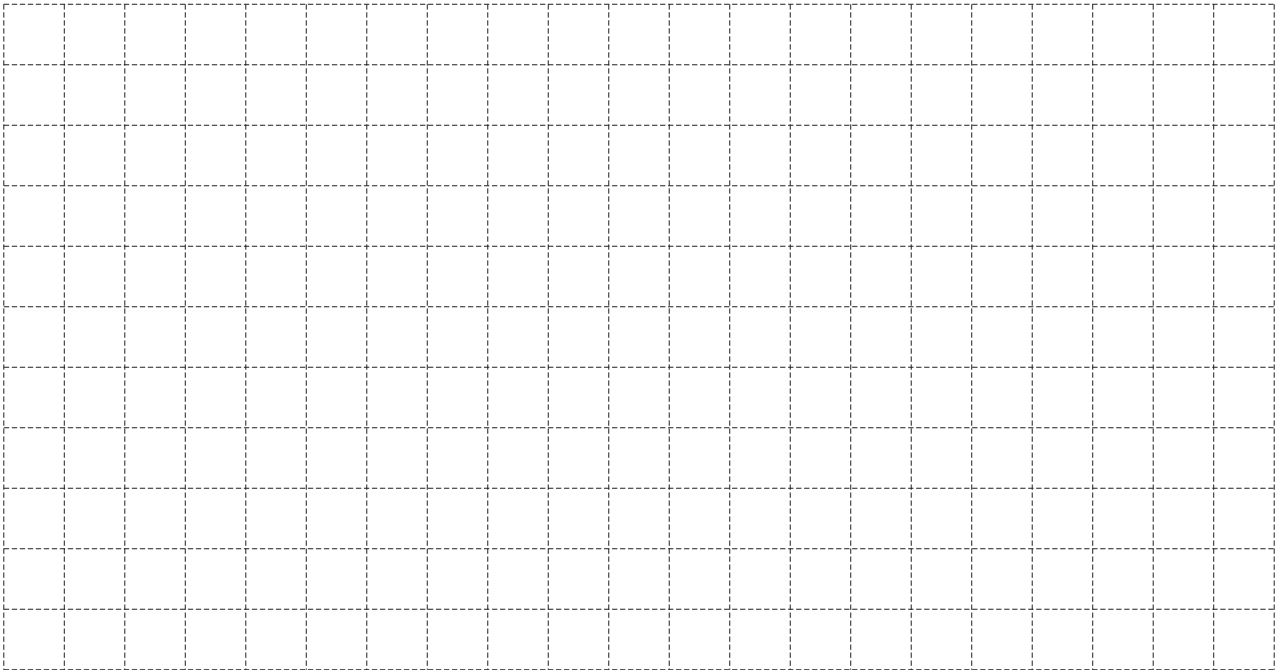
..... [1]

- (iv) Using your answer to **part (iii)** show that, when $w = 2n$, the expression for the total number of winning lines is $n^2 + 5n + 2$.

- 4 A rectangular grid has height n and width w , where n must be at least 3 and $w \geq n$. Any winning line of $\bigcirc$ s has $(n - 1)$ $\bigcirc$ s.

- (a) Complete the table with an expression for the number of diagonal winning lines in terms of n and w . You do not need to simplify your expression. You may use the grid below the table to help you.

Grid with width w	
Number of horizontal winning lines	$n(w - n + 2)$
Number of vertical winning lines	$2w$
Number of diagonal winning lines	



- (b) A grid of height 4 contains 54 winning lines with three **O**s.

Find the width of the grid.

..... [3]

B MODELLING (QUESTIONS 5 to 7)**THE SPEED OF SOUND (30 marks)**

You are advised to spend no more than 50 minutes on this part.

This task is about the speed of sound travelling through the air.

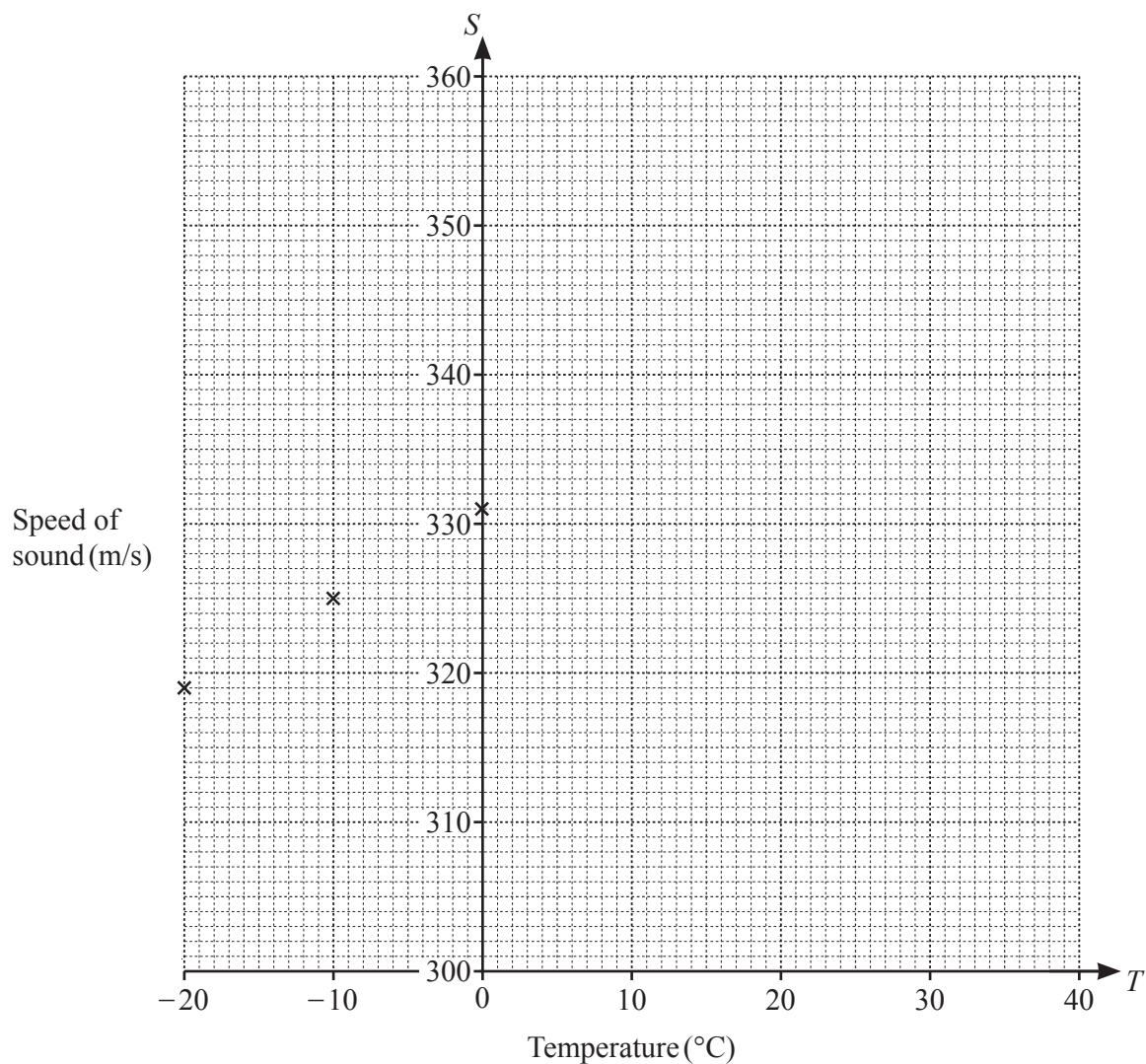
The speed of sound, S m/s, is often given as 343 m/s.

This means that a sound will travel 343 metres in 1 second through dry air when the temperature is 20°C .

- 5 The table shows the speed of sound, correct to the nearest m/s, in dry air at different temperatures.

Temperature ($T^{\circ}\text{C}$)	-20	-10	0	10	20	30	40
Speed of sound (S m/s)	319	325	331	337	343	349	355

- (a) Plot these points on the axes below and draw a line of best fit.
The first three points have been plotted for you.



[3]

- (b) Find a model for S in terms of T .

..... [2]

- (c) (i) Find the speed of sound when the air temperature is 27°C .

..... [2]

- (ii) Ellie watches a storm approaching.

The air temperature is 27°C .

She sees a flash of lightning as it happens and hears the sound of its thunder 5 seconds later.

Use your answer to **part (i)** to find how far the flash is from Ellie in kilometres.

..... [2]

- 6 Humid air contains water vapour.
Sound travels at a different speed in humid air compared to its speed in dry air.

Air with 0% humidity is dry air.

Air with 100% humidity holds all the water vapour that it can.

The table shows the speed of sound, correct to 2 decimal places, for different values of humidity, when the temperature is 20 °C.

Humidity ($H\%$)	0	20	40	60	80	100
Speed of sound ($S\text{m/s}$)	343.37	343.62	343.87	344.12	344.37	344.62

- (a) Show that a linear relationship connects H and S .

[2]

- (b) (i) I is the increase in the speed of sound with humidity when the temperature is 20 °C.

Show that $I = 0.0125H$.

[1]

- (ii) Assume that the increase in **part (i)** is the same for all temperatures.
When $T = 0$ and $H = 0$, the speed of sound, correct to 2 decimal places, is 331.37 m/s.

Use this information and **part (i)** to change your model for S in **Question 5(b)**.
Give your answer in the form $S = x + yT + zH$, where x , y and z are constants.

..... [1]

- (c) A firework makes a loud bang.
The sound travels 1 km.
The temperature is 20°C .

Find the difference between the time for the sound to travel 1 km in dry air and the time to travel 1 km when the humidity is 63%.

Give your answer in seconds, correct to 5 decimal places.

..... [4]

- 7 In **Question 6(b)(ii)** you wrote a new model for the speed of sound using $I = 0.0125H$ that assumed I was the same at all temperatures.

In fact the increase in speed, I , does change as temperature changes.

- (a) This table shows values of I for some temperatures.

Temperature ($T^{\circ}\text{C}$)	-20	0	10	40
Increase (I)	$0.0006H$	$0.0031H$	$0.0056H$	$0.0412H$

This is a new model for I .

$$I = \frac{k^T}{350}H$$

When $T = 40$, find the value of k .

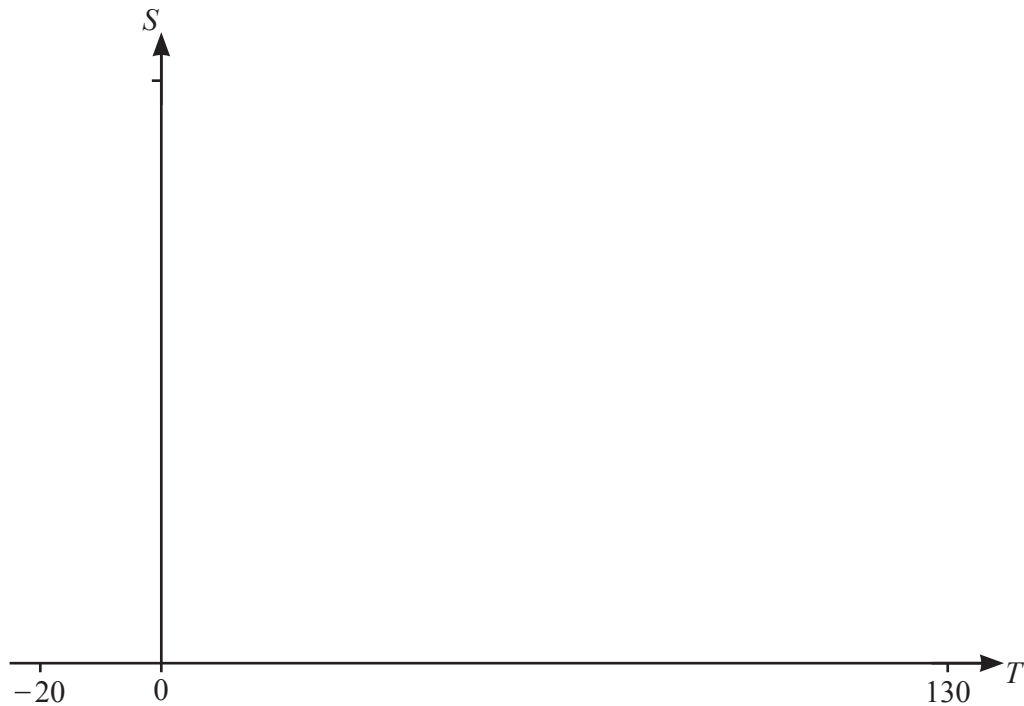
Give your answer correct to 3 decimal places.

..... [3]

- (b) Use **part (a)** and your answer to **Question 6(b)(ii)** to write down another model for S in terms of T and H .

..... [1]

- (c) For places where humans live, air temperatures are usually between -40°C and 50°C but can reach above 100°C near volcanic eruptions and wildfires.



On the axes, sketch the graph of your model when $H = 25$.

[3]

- (d) There is a loud explosion in a desert at exactly 12 18.
The temperature is 45°C and the humidity is 25%.
The explosion is heard 100 km away.

Find the time when the explosion is heard.
Give your time correct to the nearest second.

..... [6]

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