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EDEXCEL INTERNATIONAL GCSE (9–1)

MATHEMATICS A

Student Book 2

David Turner, Ian Potts

eBook included

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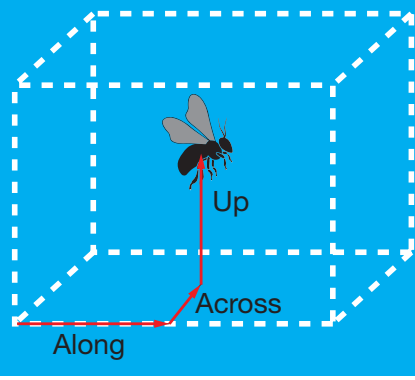
MATHEMATICS A

Student Book 2

David Turner
Ian Potts

GRAPHS 7

Every time you plot a graph you are using the Cartesian coordinate system named after René Descartes (1596–1650). The idea for the co-ordinate system came to him when he was ill. Lying in bed watching a fly buzzing around, he realised that he could describe the fly's position using three numbers: how far along one wall, how far across the adjacent wall and how far up from the floor. For a graph on a sheet of paper, only two numbers are needed.



LEARNING OBJECTIVES

- Use graphs to solve quadratic equations
- Use graphs to solve cubic equations
- Use a graphical method to solve simultaneous equations with one linear equation and one non-linear equation

BASIC PRINCIPLES

- Plot graphs of linear, **quadratic**, **cubic** and **reciprocal** functions using a table of values.
- Use graphs to solve **quadratic equations** of the form $ax^2 + bx + c = 0$
- Solve a pair of **linear simultaneous equations** graphically (recognising that the solution is the point of intersection).

USING GRAPHS TO SOLVE QUADRATIC EQUATIONS

An accurately drawn graph can be used to solve equations that may be difficult to solve by other methods.

The graph of $y = x^2$ is easy to draw and can be used to solve many quadratic equations.

EXAMPLE 1

SKILLS

PROBLEM SOLVING

Here is the graph of $y = x^2$. By drawing a suitable straight line on the graph, solve the equation $x^2 - x - 3 = 0$, giving answers **correct to** 1 d.p.

Rearrange the equation so that one side is x^2.

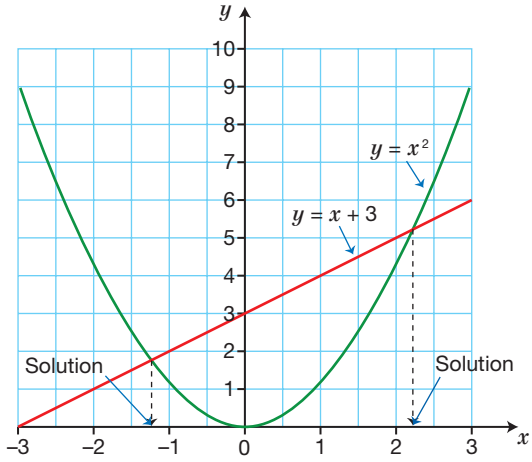
$x^2 - x - 3 = 0$

$x^2 = x + 3$

Draw the line $y = x + 3$.

Find where $y = x^2$ **intersects** $y = x + 3$.

The graph shows the solutions are $x = -1.3$ or $x = 2.3$.



EXAMPLE 2

SKILLS

PROBLEM SOLVING

Here is the graph of $y = x^2$. By drawing a suitable straight line on the graph, solve the equation $2x^2 + x - 8 = 0$, giving answers correct to 1 d.p.

Rearrange the equation so that one side is x^2.

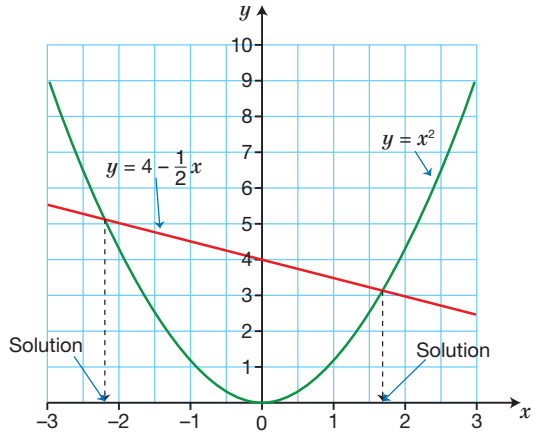
$2x^2 + x - 8 = 0$

$x^2 = 4 - \frac{1}{2}x$

Draw the line $y = 4 - \frac{1}{2}x$.

Find where $y = x^2$ intersects $y = 4 - \frac{1}{2}x$.

The graph shows the solutions are $x = -2.3$ or $x = 1.8$.



KEY POINTS

- The graph of $y = x^2$ can be used to solve quadratic equations of the form $ax^2 + bx = c = 0$.
- Rearrange the equation so that $x^2 = f(x)$, where $f(x)$ is a linear **function**.
- Draw $y = f(x)$ and find the x co-ordinates of the intersection points of the curve $y = x^2$ and the line $y = f(x)$.

EXERCISE 1

10th

Draw an accurate graph of $y = x^2$ for $-4 \le x \le 4$. Use your graph to solve these equations.

1 ▶ $x^2 - 5 = 0$ **3** ▶ $x^2 + 2x - 7 = 0$ **5** ▶ $2x^2 - x - 20 = 0$

2 ▶ $x^2 - x - 2 = 0$ **4** ▶ $x^2 - 4x + 2 = 0$ **6** ▶ $3x^2 + x - 1 = 0$

EXERCISE 1*

10th

Draw an accurate graph of $y = x^2$ for $-4 \le x \le 4$. Use your graph to solve these equations.

1 ▶ $x^2 - x - 3 = 0$ **3** ▶ $x^2 - 4x + 4 = 0$ **5** ▶ $3x^2 - x - 27 = 0$

2 ▶ $x^2 + 3x + 1 = 0$ **4** ▶ $2x^2 + x - 12 = 0$ **6** ▶ $4x^2 + 3x - 6 = 0$

EXAMPLE 3

SKILLS

PROBLEM SOLVING

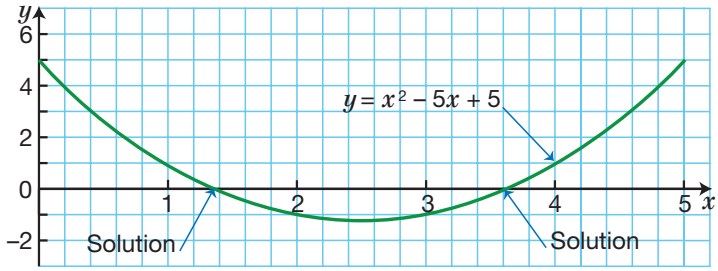
Here is the graph of $y = x^2 - 5x + 5$ for $0 \le x \le 5$.

By drawing suitable straight lines on the graph, solve these equations, giving answers to 1 d.p.

a $0 = x^2 - 5x + 5$
b $0 = x^2 - 5x + 3$
c $0 = x^2 - 4x + 4$

a Find where $y = x^2 - 5x + 5$ intersects $y = 0$ (the x-axis).

The graph shows the solutions are $x = 1.4$ and $x = 3.6$ to 1 d.p.



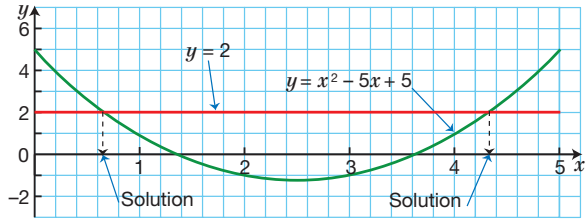
b Rearrange the equation so that one side is $x^2 - 5x + 5$

$0 = x^2 - 5x + 3$ (Add 2 to both sides)

$2 = x^2 - 5x + 5$

Find where $y = x^2 - 5x + 5$ intersects $y = 2$

The graph shows the solutions are $x = 0.7$ and $x = 4.3$ to 1 d.p.



c Rearrange the equation so that one side is $x^2 - 5x + 5$

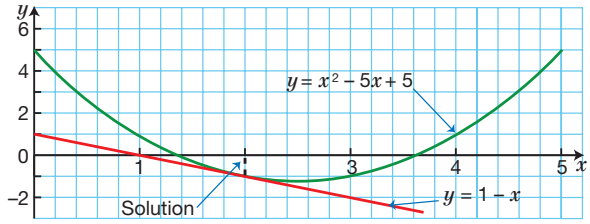
$0 = x^2 - 4x + 4$ (Add 1 to both sides)

$1 = x^2 - 4x + 5$ (Subtract x from both sides)

$1 - x = x^2 - 5x + 5$

Find where $y = x^2 - 5x + 5$ intersects $y = 1 - x$.

The graph shows the solution is $x = 2$ to 1.d.p.



Note: If the line does not cut the graph, there will be no real solutions.

KEY POINT

- The graph of one quadratic equation can be used to solve other quadratic equations with suitable rearrangement.

EXERCISE 2

1 ▶ Draw the graph of $y = x^2 - 3x$ for $-1 \leq x \leq 5$.

Use your graph to solve these equations.

a $x^2 - 3x = 0$ **c** $x^2 - 3x = -1$ **e** $x^2 - 3x - 3 = 0$

b $x^2 - 3x = 2$ **d** $x^2 - 3x = x + 1$ **f** $x^2 - 5x + 1 = 0$

2 ▶ Draw the graph of $y = x^2 - 4x + 3$ for $-1 \leq x \leq 5$.

Use your graph to solve these equations.

a $x^2 - 4x + 3 = 0$ **c** $x^2 - 5x + 3 = 0$

b $x^2 - 4x - 2 = 0$ **d** $x^2 - 3x - 2 = 0$

3 ▶ Find the equations solved by the intersection of these pairs of graphs.

a $y = 2x^2 - x + 2$, $y = 3 - 3x$

b $y = 4 - 3x - x^2$, $y = 2x - 1$

4 ▶ Using a graph of $y = 3x^2 + 4x - 2$, find the equations of the lines that should be drawn to solve these equations.

a $3x^2 + 2x - 4 = 0$

b $3x^2 + 3x - 2 = 0$

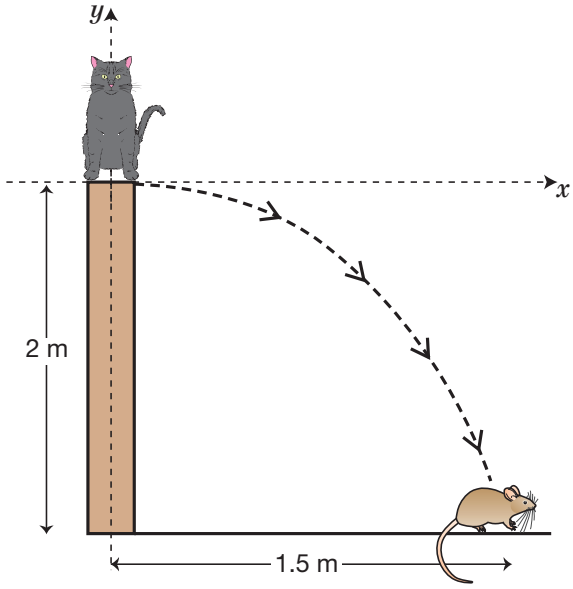
c $3x^2 + 7x + 1 = 0$

5 ▶ Romeo is throwing a rose up to Juliet's balcony. The balcony is 2 m away from him and 3.5 m above him. The equation of the path of the rose is $y = 4x - x^2$, where the origin is at Romeo's feet.

a Find by a graphical method where the rose lands.

b The balcony has a 1 m high wall. Does the rose pass over the wall?

6 ▶ A cat is sitting on a 2 m high fence when it sees a mouse 1.5 m away from the foot of the fence The cat leaps along the path $y = -0.6x - x^2$, where the origin is where the cat was sitting and x is measured in metres. Find, by a graphical method, whether the cat lands on the mouse.



EXERCISE 2*

1 ▶ Draw the graph of $y = 5x - x^2$ for $-1 \leq x \leq 6$.

Use your graph to solve these equations.

a $5x - x^2 = 0$ **b** $5x - x^2 = 3$ **c** $5x - x^2 = x + 1$ **d** $x^2 - 6x + 4 = 0$

2 ▶ Draw the graph of $y = 2x^2 + 3x - 1$ for $-3 \leq x \leq 2$.

Use your graph to solve these equations.

a $2x^2 + 3x - 1 = 0$ **b** $2x^2 + 3x - 4 = 0$ **c** $2x^2 + 5x + 1 = 0$

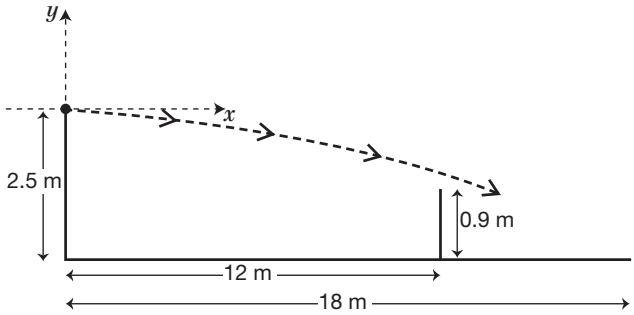
3 ▶ Find the equations solved by the intersection of these pairs of graphs.

a $y = 6x^2 - 4x + 3$, $y = 3x + 5$ **b** $y = 7 + 2x - 5x^2$, $y = 3 - 5x$

4 ▶ Using a graph of $y = 5x^2 - 9x - 6$, find the equations of the lines that should be drawn to solve these equations.

a $5x^2 - 10x - 8 = 0$ **b** $5x^2 - 7x - 5 = 0$

5 ▶ Jason is serving in tennis. He hits the ball from a height of 2.5 m and the path of the ball is given by $y = -0.05x - 0.005x^2$, where the origin is the point where he hits the ball.



a The net is 0.9 m high and is 12 m away. Does the ball pass over the net?

b For the serve to be allowed it must land between the net and the service line, which is 18 m away. Is the serve allowed?

6 ▶ A food parcel is dropped by a low-flying aeroplane flying over sloping ground. The path of the food parcel is given by $y = 40 - 0.005x^2$ and the slope of the ground is given by $y = 0.2x$. Use a graphical method to find the co-ordinates of the point where the food parcel will land. (Use $0 \leq x \leq 100$)

USING GRAPHS TO SOLVE OTHER EQUATIONS

EXAMPLE 4

SKILLS

PROBLEM SOLVING

Here is the graph of $y = x^3$.

By drawing suitable straight lines on the graph, solve these equations, giving the answers to 1 d.p.

a $x^3 + 2x - 4 = 0$ **b** $x^3 - 3x + 1 = 0$

a Rearrange the equation so that one side is x^3.

$x^3 + 2x - 4 = 0$ (Add 4 to both sides)

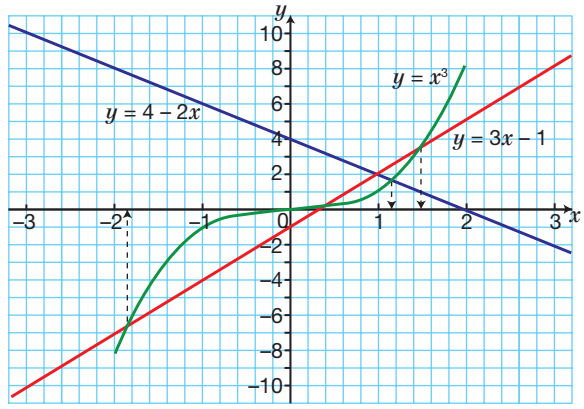
$x^3 + 2x = 4$ (Subtract $2x$ from both sides)

$x^3 = 4 - 2x$

Find where $y = x^3$ and $y = 4 - 2x$ intersect.

The graph shows that there is only one solution.

The graph shows the solution is $x = 1.2$ to 1 d.p.



b Rearrange the equation so that one side is x^3.

$x^3 - 3x + 1 = 0$ (Subtract 1 from both sides)

$x^3 - 3x = -1$ (Add $3x$ to both sides)

$x^3 = 3x - 1$

Find where $y = x^3$ and $y = 3x - 1$ intersect.

The graph shows that there are three solutions.

The graph shows the solutions are $x = -1.9$, $x = 0.4$ or $x = 1.5$ to 1 d.p.

EXERCISE 3

10th

1 ▶ **a** Draw the graph of $y = x^3$ for $-3 \le x \le 3$.

b Use your graph to solve these equations.

i $x^3 - 3x = 0$ **ii** $x^3 - 3x - 1 = 0$ **iii** $x^3 - 2x + 1 = 0$

2 ▶ **a** Copy and complete this table of values for $y = x^3 - 5x + 1$, giving values to 1 d.p.

x	–3	–2.5	–2	–1.5	–1	–0.5	0	0.5	1	1.5	2	2.5	3
y		–2.1		5.1		3.4		–1.4		–3.1		4.1	

b Draw the graph of $y = x^3 - 5x + 1$ for $-3 \le x \le 3$.

c Use your graph to solve these equations.

i $x^3 - 5x + 1 = 0$ **ii** $x^3 - 5x - 2 = 0$ **iii** $x^3 - 7x - 1 = 0$

3 ▶ **a** Copy and complete this table of values for $y = \frac{6}{x}$.

x	–3	–2.5	–2	–1.5	–1	–0.5	0.5	1	1.5	2	2.5	3
y		–2.4		–4		–12		6				2

b Draw the graph of $y = \frac{6}{x}$ for $-3 \le x \le 3$ where $x \neq 0$.

c Use your graph to solve these equations.

i $\frac{6}{x} - 5 = 0$ **ii** $\frac{6}{x} - 2x - 1 = 0$

4 ▶ The graph of $y = x^3 + 3x - 4$ has been drawn. What lines should be drawn on this graph to solve the following equations?

a $x^3 + 3x + 1 = 0$ **b** $x^3 + x - 4 = 0$ **c** $x^3 - 3x + 4 = 0$

5 ▶ The graph of $y = \frac{4}{x} + x^2$ has been drawn. What lines should be drawn on this graph to solve the following equations?

a $\frac{4}{x} + x^2 - 6 = 0$ **b** $\frac{4}{x} + x^2 + 2x - 7 = 0$ **c** $\frac{4}{x} + x + 1 = 0$

EXERCISE 3*

10th 11th

1 ▶ **a** Draw the graph of $y = 3x^2 - x^3 - 1$ for $-2 \le x \le 3$.

b Use your graph to solve these equations.

i $3x^2 - x^3 - 1 = 0$ **ii** $3x^2 - x^3 - 4 = 0$ **iii** $3x^2 - x^3 - 4 + x = 0$

2 ▶ **a** Draw the graph of $y = x^4 - 4x^2 + 2$ for $-3 \le x \le 3$.

b Use your graph to solve these equations.

i $x^4 - 4x^2 + 1 = 0$ **ii** $x^4 - 4x^2 - 2x + 3 = 0$ **iii** $2x^4 - 8x^2 + x + 2 = 0$

3 ▶ Draw the graph of $y = \frac{12}{x^2}$ for $-5 \le x \le 5$ where $x \neq 0$.

a Use your graph to solve these equations.

i $\frac{12}{x^2} - x - 2 = 0$ **ii** $\frac{12}{x^2} + x - 5 = 0$ **iii** $12 - x^3 + x^2 = 0$

4 ▶ The graph of $y = 3x^3 + 6x^2 - 5x + 3$ has been drawn. What lines should be drawn on this graph to solve the following equations?

a $3x^3 + 6x^2 - 1 = 0$ **b** $3x^3 + 6x^2 - 2x + 5 = 0$ **c** $x^3 + 2x^2 - 2x + 1 = 0$

5 ▶ The graph of $y = x^2 + \frac{16}{x}$ has been drawn. What lines should be drawn on this graph to solve the following equations?

a $x^3 - x^2 + 16 = 0$ **b** $x^3 - 3x^2 - 8x + 16 = 0$

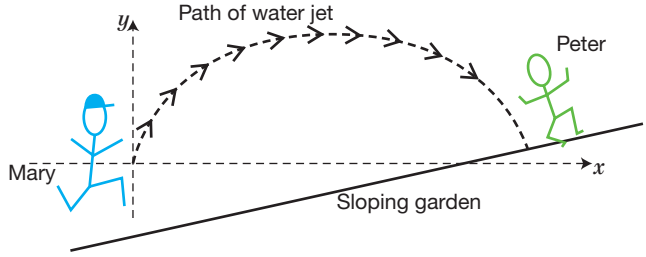
USING GRAPHS TO SOLVE NON-LINEAR SIMULTANEOUS EQUATIONS

You can use a graphical method to solve a pair of **simultaneous equations** where one equation is linear and the other is non-linear.

ACTIVITY 1

SKILLS
MODELLING

Mary is watering her garden with a hose. Her little brother, Peter, is annoying her so she tries to spray him with water.



The path of the water jet is given by

$y = 2x - \frac{1}{4}x^2$

The slope of the garden is given by

$y = \frac{1}{4}x - 1$

Peter is standing at (8, 1).

The origin is the point where the water leaves the hose, and units are in metres.

Copy and complete these tables.

x	0	2	4	6	8	10
$2x$			8			
$-\frac{1}{4}x^2$				–9		
$y = 2x - \frac{1}{4}x^2$		3				

x	0	4	8
$\frac{1}{4}x$			2
$y = \frac{1}{4}x - 1$	–1		

On one set of axes, draw the two graphs representing the path of the water and the slope of the garden.

Does the water hit Peter? Give a reason for your answer.

Mary changes the angle of the hose so that the path of the water is given by $y = x - 0.1x^2$.

Draw in the new path. Does the water hit Peter this time?

In Activity 1, the simultaneous equations $y = 2x - \frac{1}{4}x^2$ and $y = \frac{1}{4}x - 1$ were solved graphically by drawing both graphs on the same axes and finding the x co-ordinates of the points of intersection.

Some non-linear simultaneous equations can be solved algebraically and this is the preferred method as it gives accurate solutions. When this is impossible then graphical methods must be used.

EXAMPLE 5

Solve the simultaneous equations $y = x^2 - 5$ and $y = x + 1$ graphically.

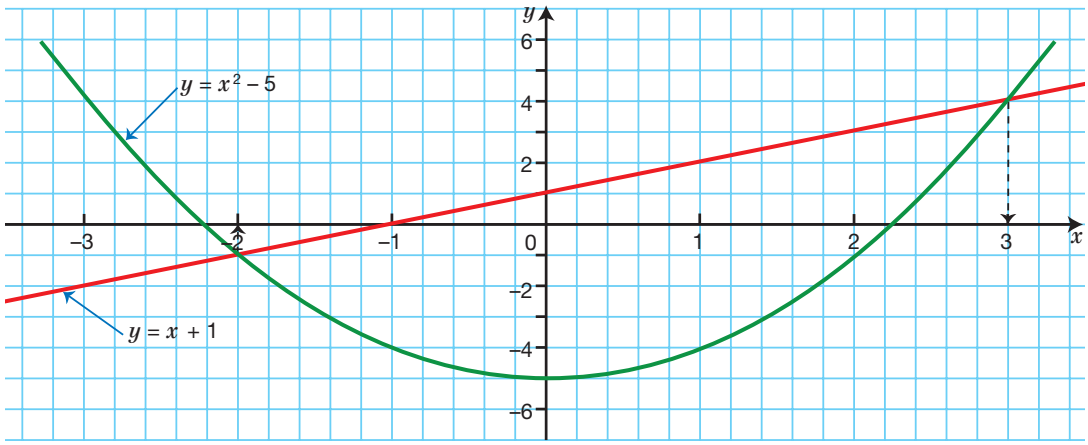
SKILLS

PROBLEM SOLVING

Construct a tables of values and draw both graphs on one set of axes.

x	–3	–2	–1	0	1	2	3
$x^2 - 5$	4	–1	–4	–5	–4	–1	4

x	–3	0	3
$x + 1$	–2	1	4



The co-ordinates of the intersection points are (–2, –1) and (3, 4) so the solutions are $x = -2$, $y = -1$ or $x = 3$, $y = 4$.

KEY POINT

- To solve simultaneous equations graphically, draw both graphs on one set of axes. The co-ordinates of the intersection points are the solutions of the simultaneous equations.

EXERCISE 4

Solve the simultaneous equations graphically, drawing graphs from $-4 \leq x \leq 4$.

1 ▶ $y = 4 - x^2$, $y = 1 + 2x$

2 ▶ $y = x^2 + 2x - 1$, $1 + 3x - y = 0$

3 ▶ $y = x^2 - 4x + 6$, $y + 2 = 2x$

4 ▶ $x^2 + y = 4$, $y = 1 - \frac{x}{4}$

5 ▶ $y = \frac{4}{x}$, $y + 1 = x$

6 ▶ $y = x^3 + 2x^2$, $y - 1 = \frac{1}{2}x$

EXERCISE 4*

Solve the simultaneous equations graphically.

1 ▶ $y = x^2 - x - 5$, $y = 1 - 2x$

2 ▶ $y = 2x^2 - 2x - 4$, $y = 6 - x$

3 ▶ $y = 10x^2 + 3x - 4$, $y = 2x - 2$

4 ▶ $(x + 1)^2 + y = 6$, $y = x + 3$

5 ▶ $y = x^3 - 4x^2 + 5$, $y = 3 - 2x$

6 ▶ $y = \frac{10}{x} + 4$, $y = 5x + 2$

EXERCISE 5

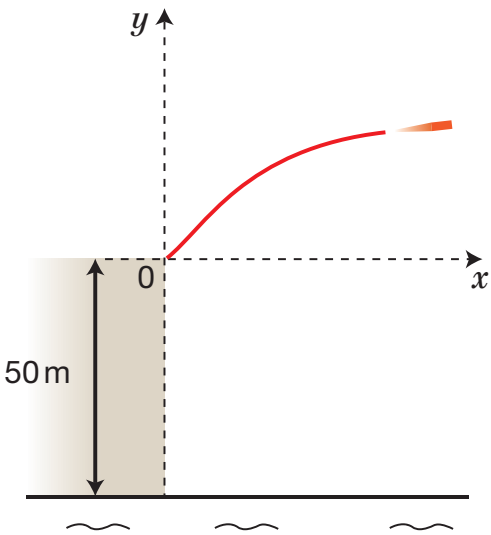
REVISION

1 ▶ An emergency rocket is launched out to sea from the top of a 50 m high cliff.

Taking the origin at the top of the cliff, the path of the rocket is given by

$y = x - 0.01x^2$

Use a graphical method to find where the rocket lands in the sea.



2 ▶ Draw the graph of $y = x^2 - 2x - 1$ for $-2 \leq x \leq 4$. Use the graph to solve these equations.

a $x^2 - 2x - 1 = 0$

b $x^2 - 2x - 4 = 0$

c $x^2 - x - 3 = 0$

3 ▶ The graph of $y = 3x^2 - x + 1$ has been drawn. What lines should be drawn to solve the following equations?

a $3x^2 - x - 2 = 0$

b $3x^2 + x - 4 = 0$

4 ▶ **a** Find the equation that is solved by finding the intersection of the graph of $y = 2x^2 - x + 2$ with the graph of $y = 2x + 3$.

b Find the equation of the line that should be drawn on the graph of $y = 2x^2 - x + 2$ to solve the equation $2x^2 - 4x = 0$.

5 ▶ The graph of $y = 2x^3 + 3x - 5$ has been drawn. What lines should be drawn on this graph to solve the following equations?

a $2x^3 + 3x - 9 = 0$

b $2x^3 - 2x - 5 = 0$

c $2x^3 + 6x - 7 = 0$

6 ▶ Solve the simultaneous equations $y = 1 + 3x - x^2$ and $y = 3 - x$ graphically. Plot your graphs for $-1 \leq x \leq 4$ and give your answers to 1 d.p.

EXERCISE 5*

10th

11th

REVISION

1 ▶ Draw the graph of $y = 5 + 3x - 2x^2$ for $-2 \leq x \leq 4$. Use the graph to solve these equations.

a $2 + 3x - 2x^2 = 0$

b $7 + x - 2x^2 = 0$

c $2 + 2x - x^2 = 0$

2 ▶ The graph of $y = 4x^2 + 2x - 4$ has been drawn. What lines should be drawn to solve the following equations?

a $4x^2 - x - 3 = 0$

b $2x^2 + 3x - 5 = 0$

3 ▶ The graph of $y = 6x^3 - 3x^2 + 12x - 18$ has been drawn. What lines should be drawn to solve the following equations?

a $6x^3 - 3x^2 - 18 = 0$

b $6x^3 - 3x^2 + 16x - 38 = 0$

c $2x^3 - x^2 + x - 1 = 0$

4 ▶ **a** Find the equation that is solved by the intersection of the graph of $y = 2x^3 - 6x^2 - 5x + 7$ with the graph of $y = 2 + 3x - 5x^2$.

b Find the equation of the line that should be drawn on the graph of $y = 2x^3 - 6x^2 - 5x + 7$ to solve the equation $2x^3 - 5x + 5 = 0$.

5 ▶ Solve the simultaneous equations $y = x^3$ and $y = 4 - 4x^2$ graphically.

6 ▶ The area of a rectangle is 30 cm^2 and the **perimeter** is 24 cm. If x is the length of the rectangle and y is the width, form two equations for x and y and solve them graphically to find the dimensions of the rectangle.

EXAM PRACTICE: GRAPHS 7

1 **a** Draw the graph of $y = x^2 - 2x$ for $-2 \leq x \leq 4$, by copying and completing the table below.

x	–2	–1	0	1	2	3	4
y	8		0				8

b By drawing suitable lines on your graph, solve

i $x^2 - 2x = 1 - x$

ii $x^2 - 4x + 2 = 0$ **[8]**

2 If the graph of $y = 3x^2 - 3x + 5$ has been drawn, find the equations of the lines that should be drawn to solve these equations.

a $3x^2 - 4x - 1 = 0$

b $3x^2 - 2x - 2 = 0$

c $3x^2 + x - 3 = 0$ **[6]**

3 If the graph of $y = 5x^3 - x^2 + 4x + 1$ has been drawn, find the equations of the lines that should be drawn to solve these equations.

a $5x^3 - x^2 + 1 = 0$

b $5x^3 - x^2 + 6x - 3 = 0$ **[4]**

4 **a** Draw the graph of $y = 4 + 2x - x^2$ for $-2 \leq x \leq 4$, by copying and completing the table below.

x	–2	–1	0	1	2	3	4
y			4				–4

b Use this graph to solve the simultaneous equations
$y = 4 + 3x - x^2$ and $x + 2y = 6$, giving your answers to 1 d.p. **[7]**

[Total 25 marks]

CHAPTER SUMMARY: GRAPHS 7

USING GRAPHS TO SOLVE QUADRATIC EQUATIONS

The graph of $y = x^2$ can be used to solve quadratic equations of the form $ax^2 + bx = c = 0$.

Rearrange the equation so that $x^2 = f(x)$, where $f(x)$ is a linear function.

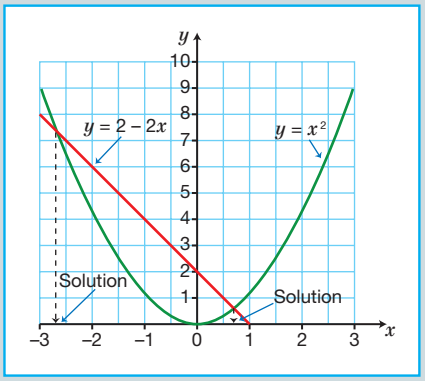
Draw $y = f(x)$ and find the x co-ordinates of the intersection points of the curve $y = x^2$ and the line $y = f(x)$.

To solve $x^2 + 2x - 2 = 0$, rearrange the equation so that one side is x^2

$x^2 = 2 - 2x$

Draw the line $y = 2 - 2x$ and find where it intersects $y = x^2$.

The graph shows the solutions are $x \approx -2.7$ or $x \approx 0.7$



USING GRAPHS TO SOLVE OTHER EQUATIONS

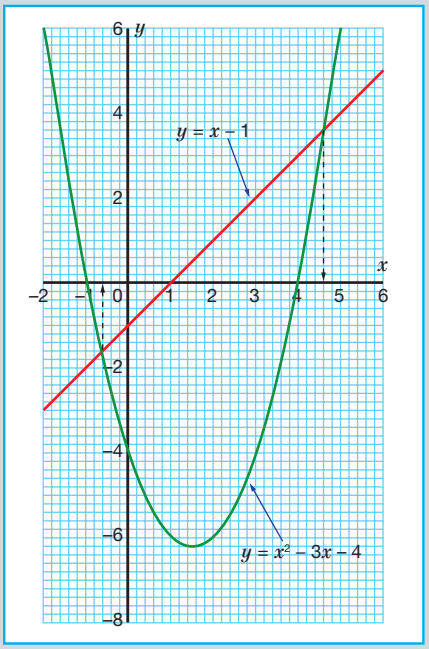
The graph of one quadratic equation can be used to solve other quadratic equations with suitable rearrangement.

If the graph of $y = x^2 - 3x - 4$ has been drawn, then the x co-ordinates of the intersection with $y = x - 1$ will solve
$x^2 - 3x - 4 = x - 1$ or $x^2 - 4x - 3 = 0$

The graph show that the solutions are $x \approx -0.6$ and $x \approx 4.6$.

The graph of one cubic equation can be used to solve other cubic equations with suitable rearrangement.

If the graph of $y = x^3 - 2x^2 + 4x - 3$ has been drawn, then the x co-ordinates of the intersection with $y = 2x - 5$ will solve $x^3 - 2x^2 + 4x - 3 = 2x - 5$ or $x^3 - 2x^2 + 2x + 2 = 0$.

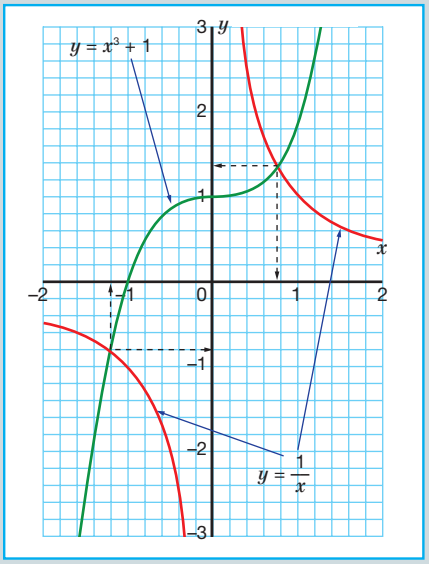


USING GRAPHS TO SOLVE NON-LINEAR SIMULTANEOUS EQUATIONS

To solve simultaneous equations graphically, draw both graphs on one set of axes. The co-ordinates of the intersection points are the solutions of the simultaneous equations.

To solve $y = x^3 + 1$ and $y = \frac{1}{x}$ simultaneously draw both graphs.

The graphs show the solutions are approximately (–1.2, –0.8) and (0.7, 1.4).



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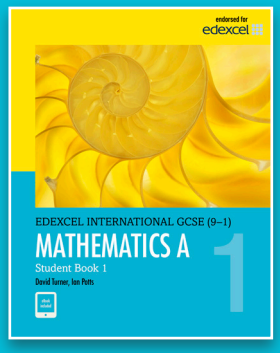

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