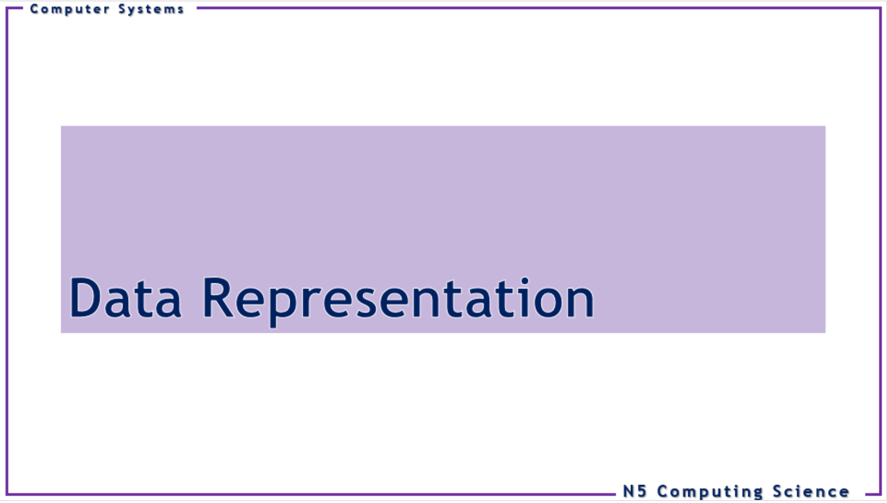
Computer Systems

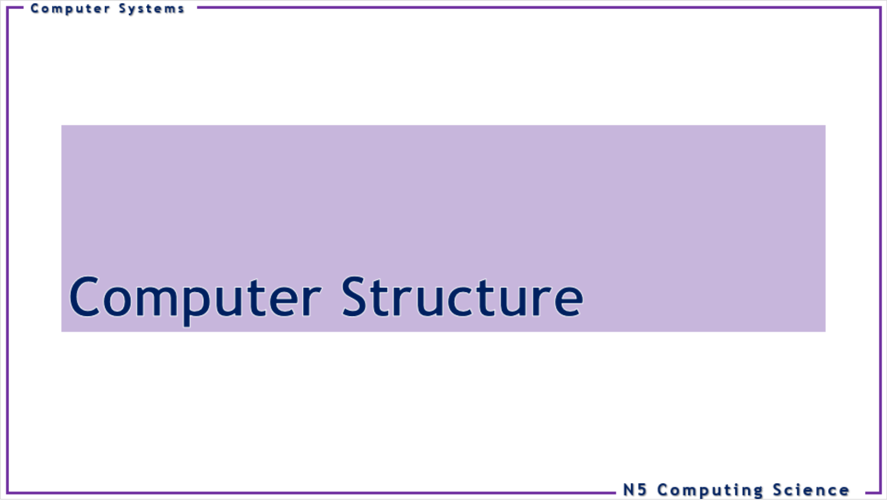
Topics



Computer Systems

Data Representation

N5 Computing Science



Computer Systems

Computer Structure

N5 Computing Science

Computer Systems

Environmental Impact

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Computer Systems

Security Precautions

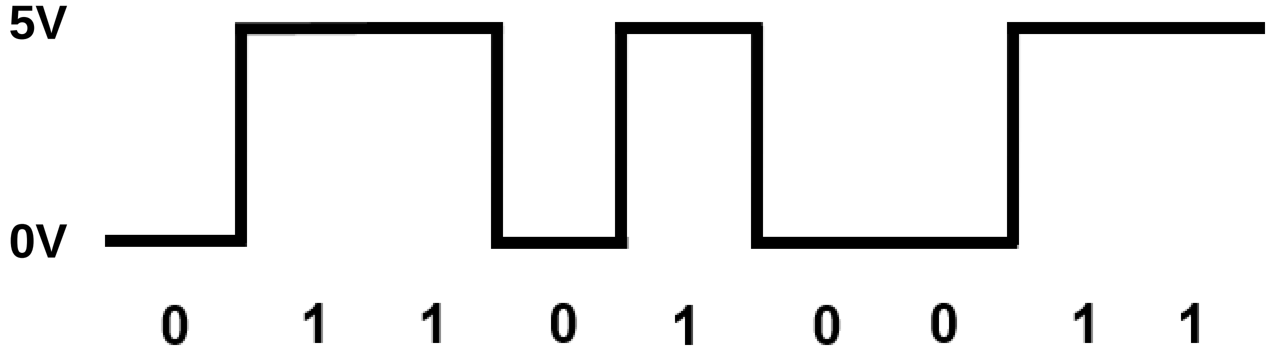
N5 Computing Science

Data Representation

Binary

Computers are digital devices that use electricity to store and send data. This data is represented in binary because electricity can only have two states: **on** or **off**.

Here is an example of a digital signal:



Computers Using Binary

Appliances that you use everyday use 1s and 0s to represent on and off

In computers:

- On is represented by a 1
- Off is represented by a 0

Each one or zero is called a “bit”. The more bits used by the Computer, the more information can be represented.

Benefits of Binary

Simplicity: computers are made up of hundreds of thousands of transistors – in fact the most recent iPhones have over 3 billion transistors in them. Transistors are simple to make but can only be turned on or off to allow electricity to pass or not.

Storage: data can be stored in lots of different ways – magnetic north/south charges on a magnetic disk or reflective/non-reflective areas of a DVD-ROM. Programs used to be written by punching holes in card, and 1s and 0s were represented by hole/no hole.

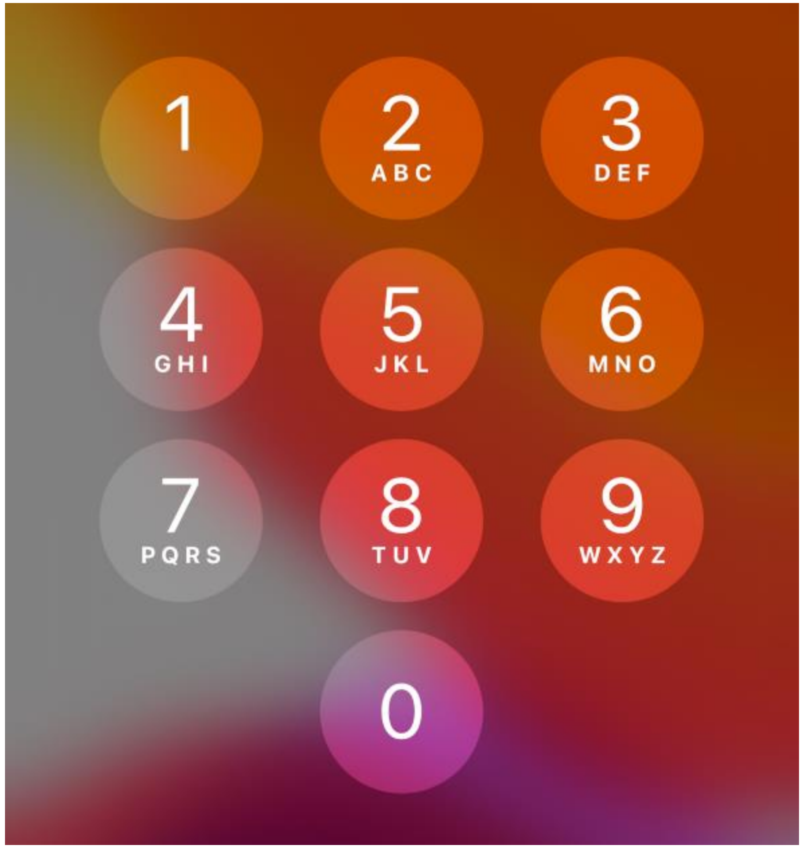
Signal degradation: electricity can drop in voltage in circuits due to resistance. Binary is resistant to this as a small drop – a full 5v or a partial 3v voltage still represents a 1 in binary.

Representing Data in Binary

Watch this video to understand how data is represented in binary.

Positive Integers

We use the denary system in everyday life to count. Denary means that we use ten different symbols.



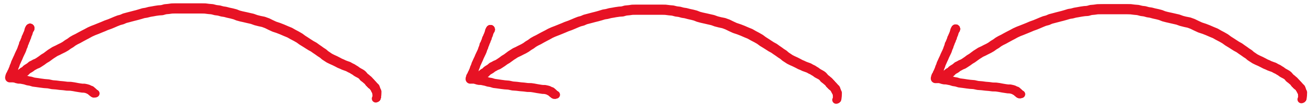
Positive Integers

The position of these symbols also tells us what value that symbol represents:

<table>
<tr><th>1000s</th><th>100s</th><th>10s</th><th>1s</th></tr>
<tr><td><b>1</b></td><td><b>4</b></td><td><b>8</b></td><td><b>7</b></td></tr>
<tr><td>1 x 1000</td><td>4 x 100</td><td>8 x 10</td><td>7 x 1</td></tr>
<tr><td colspan="4">1000 + 400 + 80 + 7 = 1487</td></tr>
</table>

Positive Integers

Each position towards the left represents a value that is ten times bigger than the one before.

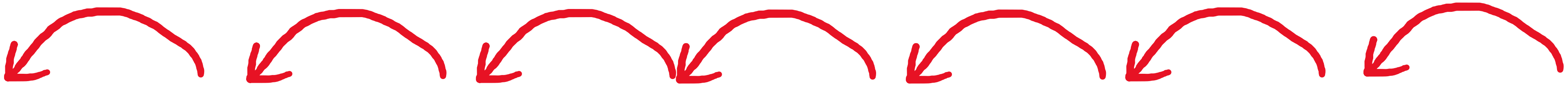


1000s	100s	10s	1s
1	**4**	**8**	**7**
1 x 1000	4 x 100	8 x 10	7 x 1
1000 + 400 + 80 + 7 = 1487			

Representing Positive Integers

We can count in the same way in binary, but we only have two symbols that we can use to represent data: **0** and **1**.

The position of these symbols still tells us what value it represents, but in binary the values increase by a factor of two as we move left.



128s	64s	32s	16s	8s	4s	2s	1s

Representing Positive Integers

Using the binary number system, we can represent positive integers.

For example, representing the number 215 in binary:

128s	64s	32s	16s	8s	4s	2s	1s
1	**1**	**0**	**1**	**0**	**1**	**1**	**1**
1x128	1x64	0x32	1x16	0x8	1x4	2x1	1x1
128 + 64 + 16 + 4 + 2 + 1 = 215							

215 (denary) = 11010111 (binary)

Converting From Denary to Binary

You need to be able to **convert a denary number to binary.**

<table>
<tr><td><b>Step 1:</b> Write the column headings</td><td>13<table><tr><th>8s</th><th>4s</th><th>2s</th><th>1s</th></tr></table></td></tr>
<tr><td><b>Step 2:</b> Put a one in the largest column that <b>fits inside the denary number</b></td><td>13<table><tr><th>8s</th><th>4s</th><th>2s</th><th>1s</th></tr><tr><td>1</td><td></td><td></td><td></td></tr></table></td></tr>
<tr><td><b>Step 3:</b> Subtract that column value from your denary number</td><td>13 – 8 = 5</td></tr>
</table>

Converting From Denary to Binary

Step 4: Repeat Steps 2 and 3 until your denary number equals 0

~~13~~ 5

8s	4s	2s	1s
1	1		

5 - 4 = 1

~~13~~ ~~5~~ 1

8s	4s	2s	1s
1	1	0	1

1 – 1 = 0

Step 5: Double check your answer by adding up the columns with a 1 in them

8 + 4 + 1 = 13 ✓

Converting From Binary to Denary

You also need to be able to **convert a binary number to denary.**

<table>
<tr><td><b>Step 1:</b> Write out your binary number</td><td><table><tr><td>1</td><td>0</td><td>1</td><td>0</td></tr></table></td></tr>
<tr><td><b>Step 2:</b> Write the column headings used in the binary system</td><td><table><tr><td>8s</td><td>4s</td><td>2s</td><td>1s</td></tr><tr><td>1</td><td>0</td><td>1</td><td>0</td></tr></table></td></tr>
<tr><td><b>Step 3:</b> Add up the columns with a 1 in the number</td><td>8x1 + 4x0 + 2x1 + 1x0
8 + 2 = 10</td></tr>
</table>

Binary number system

128s	64s	32s	16s	8s	4s	2s	1s

Each 1 or 0 is a ‘bit’. The more bits used, the more numbers that can be represented. For example:

- Using **4 bits** we can represent the numbers 0 to 15
- Using **8 bits** we can represent the numbers 0 to 255

The range of positive integers that can be represented using *n* bits is 0 to 2^n -1

Representing Text

The set of characters that can be represented by a computer is known as the **character set**, and is made up of letters, numbers and symbols.

A standardised code that is used by most systems is the Extended **American Standard Code for Information Interchange** (Extended ASCII).

Using a standardised code means that text can be exchanged across platforms easily.

ASCII

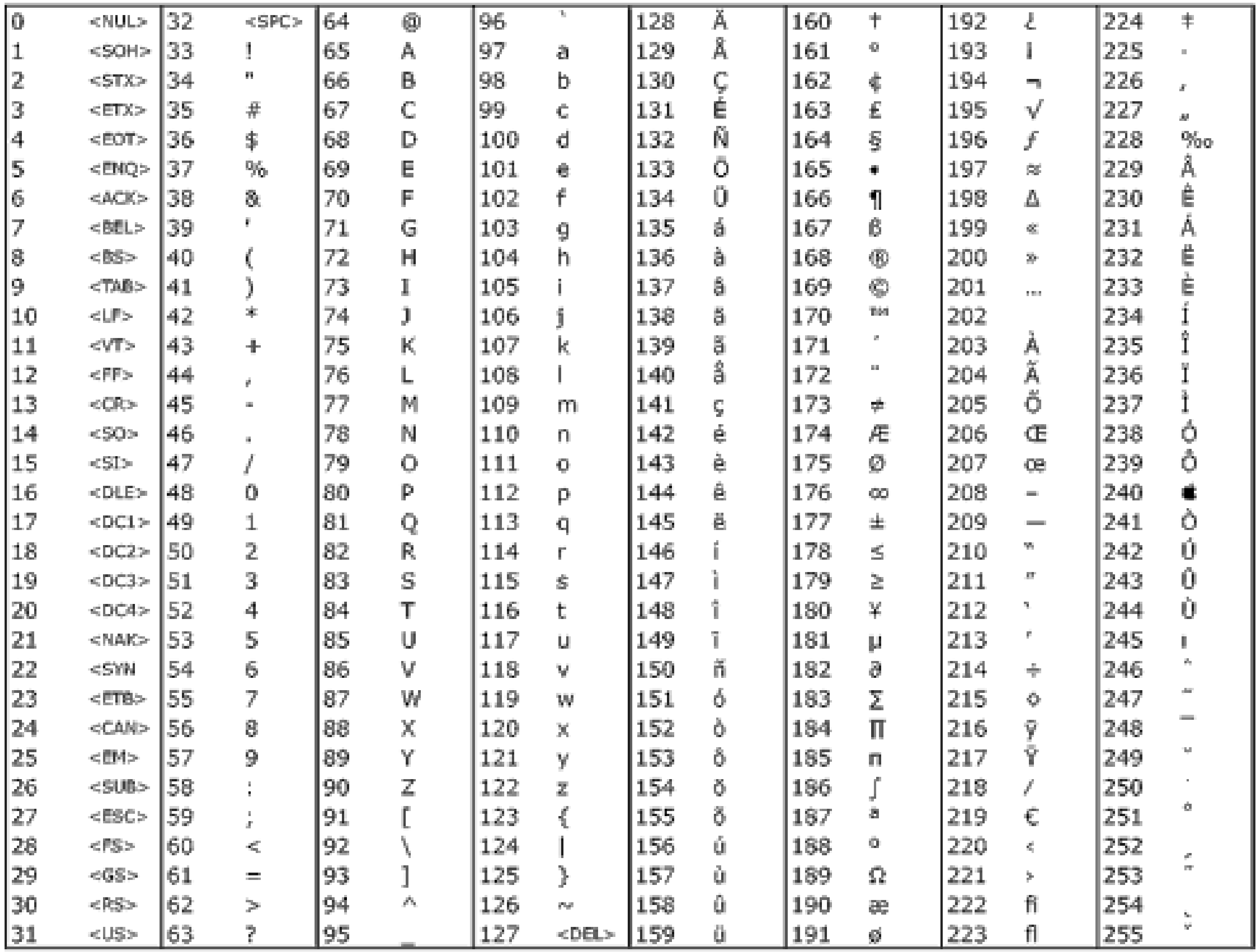
Every key on your keyboard is a **printable character** that has an ASCII code, meaning that it can be represented by a binary number.

Extended ASCII uses a unique **8-bit code** to represent each character, giving a possible 256 different characters. Each character uses 8 bits of memory.

There are some Extended ASCII codes worth remembering:

- The uppercase alphabet starts at code 65
- The lowercase alphabet starts at code 97
- Special control characters are codes 0 to 31 (non-printable)

Extended ASCII Codes



0	<NUL>	32	<SPC>	64	@	96	`	128	Ä	160	†	192	¿	224	‡
1	<SOH>	33	!	65	A	97	a	129	Å	161	°	193	¡	225	·
2	<STX>	34	"	66	B	98	b	130	Ç	162	¢	194	¬	226	‚
3	<ETX>	35	#	67	C	99	c	131	É	163	£	195	√	227	„
4	<EOT>	36	$	68	D	100	d	132	Ñ	164	§	196	ƒ	228	‰
5	<ENQ>	37	%	69	E	101	e	133	Ö	165	•	197	≈	229	Â
6	<ACK>	38	&	70	F	102	f	134	Ü	166	¶	198	∆	230	Ê
7	<BEL>	39	'	71	G	103	g	135	á	167	ß	199	«	231	Á
8	<BS>	40	(	72	H	104	h	136	à	168	®	200	»	232	Ë
9	<TAB>	41	)	73	I	105	i	137	â	169	©	201	…	233	È
10	<LF>	42	*	74	J	106	j	138	ä	170	™	202		234	Í
11	<VT>	43	+	75	K	107	k	139	ã	171	´	203	À	235	Î
12	<FF>	44	,	76	L	108	l	140	å	172	¨	204	Ã	236	Ï
13	<CR>	45	-	77	M	109	m	141	ç	173	≠	205	Õ	237	Ì
14	<SO>	46	.	78	N	110	n	142	é	174	Æ	206	Œ	238	Ó
15	<SI>	47	/	79	O	111	o	143	è	175	Ø	207	œ	239	Ô
16	<DLE>	48	0	80	P	112	p	144	ê	176	∞	208	–	240	
17	<DC1>	49	1	81	Q	113	q	145	ë	177	±	209	—	241	Ò
18	<DC2>	50	2	82	R	114	r	146	í	178	≤	210	“	242	Ú
19	<DC3>	51	3	83	S	115	s	147	ì	179	≥	211	”	243	Û
20	<DC4>	52	4	84	T	116	t	148	î	180	¥	212	‘	244	Ù
21	<NAK>	53	5	85	U	117	u	149	ï	181	µ	213	’	245	ı
22	<SYN>	54	6	86	V	118	v	150	ñ	182	∂	214	÷	246	ˆ
23	<ETB>	55	7	87	W	119	w	151	ó	183	∑	215	◊	247	˜
24	<CAN>	56	8	88	X	120	x	152	ò	184	∏	216	ÿ	248	¯
25	<EM>	57	9	89	Y	121	y	153	ô	185	π	217	Ÿ	249	˘
26	<SUB>	58	:	90	Z	122	z	154	ö	186	∫	218	⁄	250	˙
27	<ESC>	59	;	91	[	123	{	155	õ	187	ª	219	€	251	˚
28	<FS>	60	<	92	\	124	|	156	ú	188	º	220	‹	252	¸
29	<GS>	61	=	93	]	125	}	157	ù	189	Ω	221	›	253	˝
30	<RS>	62	>	94	^	126	~	158	û	190	æ	222	ﬁ	254	˛
31	<US>	63	?	95	_	127	<DEL>	159	ü	191	ø	223	ﬂ	255	ˇ

ASCII Control Characters

Control characters are characters that do not print anything on screen when you press the key on the keyboard. These control characters include **delete**, **backspace** and **escape**.

Most of these characters are the first 32 codes, using ASCII values 0-31. The exception is delete, which is ASCII code 127.

Representing Images

Computers use two different ways of storing images:

- as a grid of pixels (bitmapped graphics)
- as a series of instructions describing shapes and lines (vector graphics)

You need to be able to describe and compare both ways.

Bitmapped Images

A bit mapped graphic is a grid of pixels, where the computer stores the colour of each individual pixel.

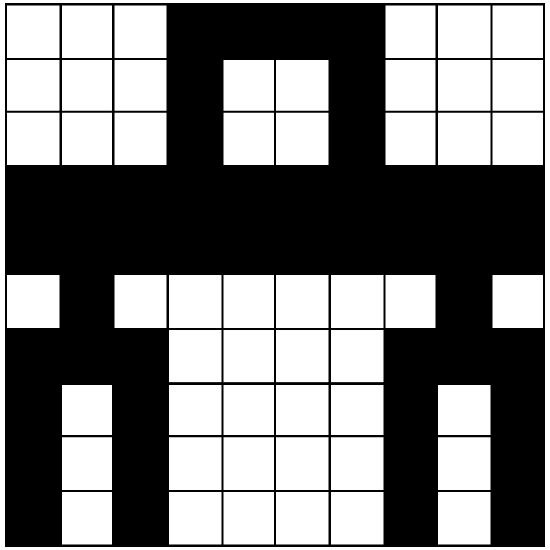
There are two definitions you need to know for bitmapped images:

- resolution
- colour depth

Resolution

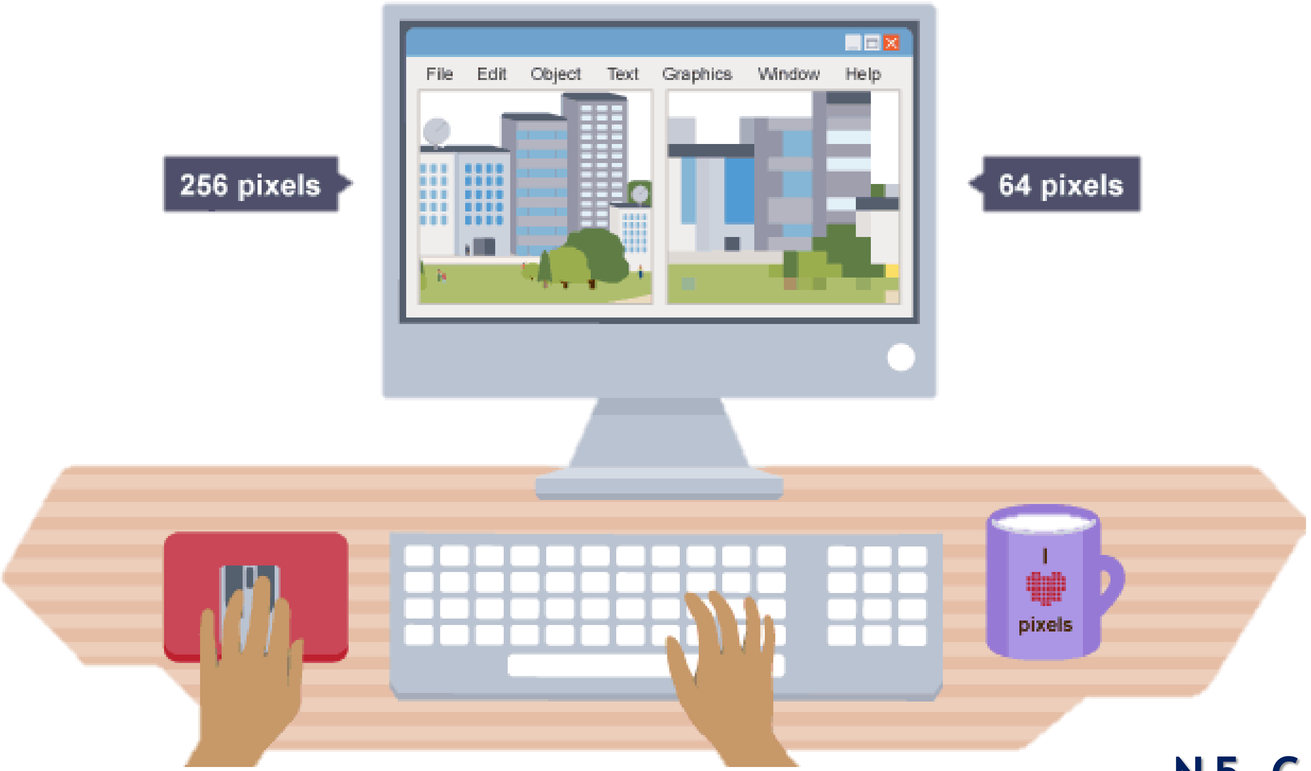
Resolution is the number of pixels that make up the image. The resolution is calculated by multiplying the number of pixels horizontally by the number of pixels vertically.

In this image there are 10 pixels horizontally and 10 pixels vertically, so the resolution is 100 pixels.



Resolution

The resolution impacts the quality of the image – the more pixels, the better quality image, however the bigger the file size.



Colour Depth

Colour depth is the number of bits allocated to each pixel to represent colour.

For example, a 2-bit colour depth would allow four different values: 00, 01, 10, 11.

Binary Code	Colour
00	White
01	Light Grey
10	Dark Grey
11	Black

Colour Depth

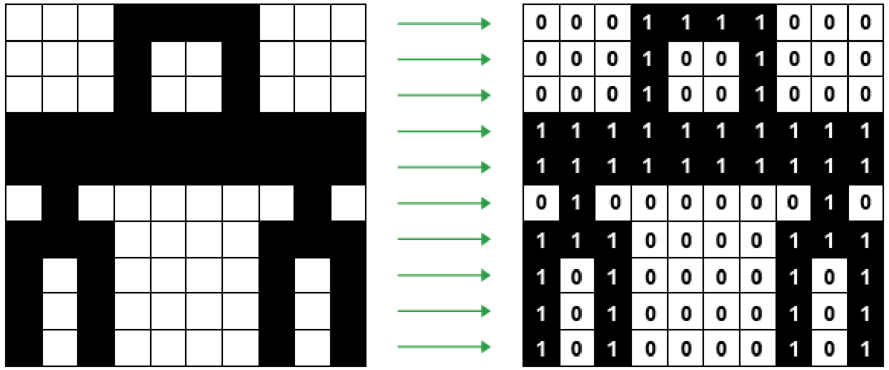
The greater the colour depth, the more colours are available.

Colour Depth	Available Colours
1-bit	2
2-bit	4
3-bit	8
4-bit	16
8-bit	256

Bitmapped Images

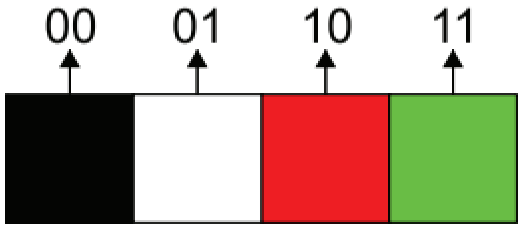
When you know the resolution and colour depth, you can create a grid to show the binary value of each pixel and see how the image is stored in memory.

Here is how an image with a 1-bit colour depth would be mapped.



0	0	0	1	1	1	1	0	0	0
0	0	0	1	0	0	1	0	0	0
0	0	0	1	0	0	1	0	0	0
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
0	1	0	0	0	0	0	0	1	0
1	1	1	0	0	0	0	1	1	1
1	0	1	0	0	0	0	1	0	1
1	0	1	0	0	0	0	1	0	1
1	0	1	0	0	0	0	1	0	1

If the image has a higher colour depth, each pixel would be represented by multiple bits.



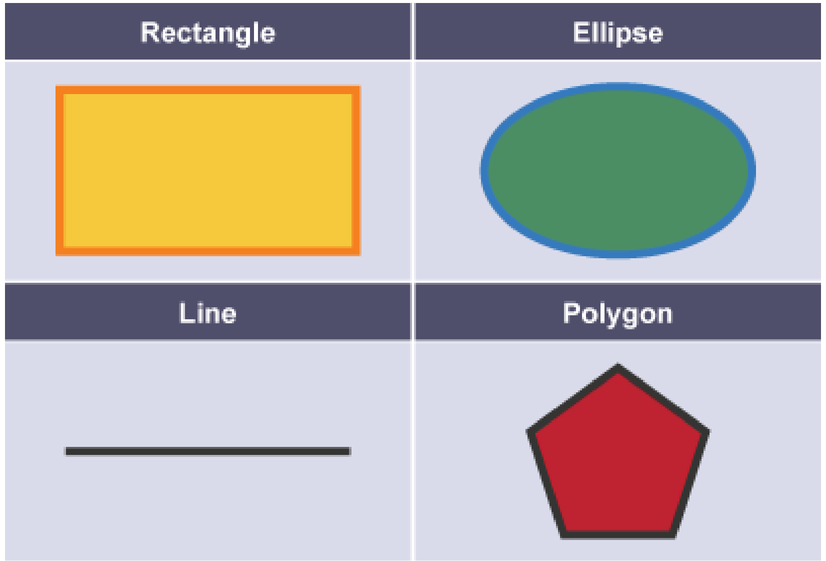
Vector Images

Instead of storing information about every single pixel, vector graphics store a list of shapes and attributes. When the image is opened, the computer will generate the shapes by looking at their attributes.

Vector Objects

There are many types of object (shapes) in vector graphics, but at National 5 you should know the following four:

- Polygons (irregular shapes with multiple points/sides)
- Lines
- Ellipses
- Rectangles



Vector Attributes

Attributes help to describe the shape. There are many attributes that can be used to describe objects, but at National 5 level you should know the following attributes:

Line colour: defines the colour of the outer line of an object.

Fill colour: defines the colour inside an object.

X and Y coordinates: the start position is the top left-hand corner of the drawing area (0,0). The X value defines how far to the right the object should be placed and the Y value defines how far down the object should be placed.

Vector vs Bitmap

	Advantages	Disadvantages
Bitmapped Graphics	• Can represent highly detailed images e.g. photos • Can edit images at pixel level e.g. removing red-eye from photos • There are lots of standard file formats • Can create a wide range of irregular shapes and patterns	• Large file sizes – even blank pixels need to be saved • Resizing results in pixilation • You cannot change objects once they have been drawn
Vector Graphics	• Small file size – you only store data for the objects created • Resizing does not result in pixilation • Objects can be changed after they have been drawn	• Cannot represent highly detailed images e.g. photos • Cannot edit image at pixel level • Cannot create a wide range of irregular shapes and patterns

Computer Structure

Computer Architecture

All computers perform the same tasks:

- take **input** from a device that converts real-life information into binary
- **process** that data in the processor
- **output** the results using a device that will take the binary data and turn it back into real-life information

Computer Instructions

All processes carried out by the computer are broken down into **instructions** – in fact the programs that you write are lists of instructions for the computer to execute.

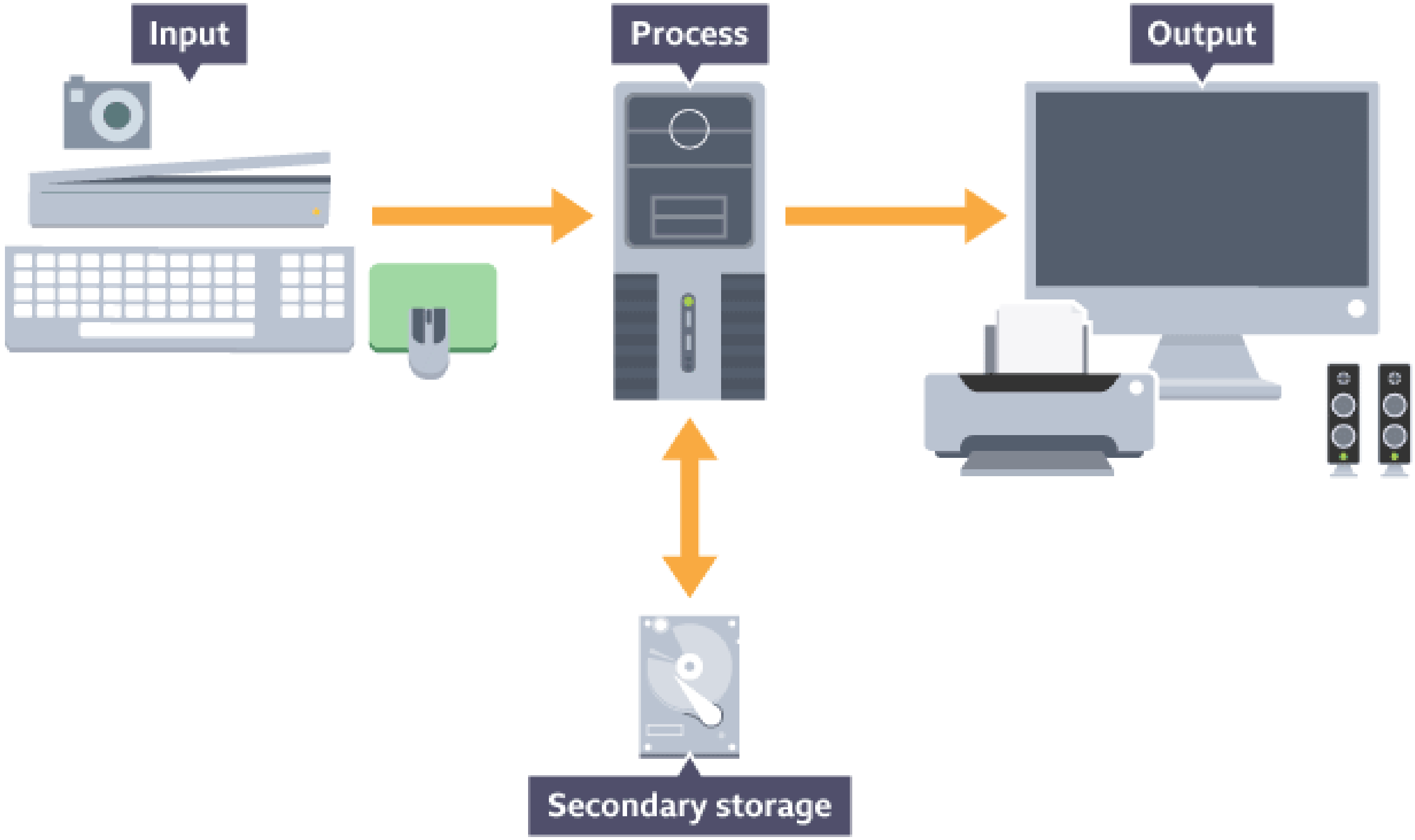
Each instruction is a sequence of 0s and 1s (called **machine code**) that describes an operation that the computer needs to perform, such as “add”.

Basic Computer Architecture

Watch this video to understand basic computer architecture.

Basic Computer Architecture

We will be looking at each of these components in more detail.



Input and Output Devices

Input and output devices are often known as peripheral devices.

Input Devices	Output Devices
Keyboard	Monitor
Touchscreen	Headphones
Webcam	Speakers
Microphone	Projector
Mouse	3D Printer

Memory

Memory, sometimes referred to as **main memory**, holds the data and programs that are in use by the computer.

In general, the more memory a device has, the more programs can be run at once, and the better the computer performs.

Memory vs Backing Storage

When talking about memory, this is not referring to storage devices that are used to store your files

Backing storage is used to store your files, and can include hard disks, USB sticks or even cloud storage.

Files from backing storage can be loaded into main memory if they are going to be used by the computer.

Memory

Most computers contain a mix of different types of memory, both of which you need to know for National 5:

- ROM (Read-Only Memory)
- RAM (Random Access Memory)

ROM is a small part of main memory, with a few basic programs needed to start up a computer.

RAM is the largest part of main memory and is used to hold more complex programs, like the operating system, programs currently in use and any user data.

ROM

Read Only Memory (ROM) is used to store a small part of the operating system, called the bootstrap loader.

When the computer is switched on, the bootstrap loader checks the backing storage devices to find the operating system. Once it’s found it is loaded into RAM.

ROM is described as non-volatile, which means that the data held on ROM is not lost when the computer is switched off.

RAM

Random Access Memory (RAM) is used to store all programs that are currently is use, including the operating system.

RAM is described as volatile, which means all data and programs held in RAM are lost when the computer is switched off. As RAM cannot store its contents without power, programs and data are stored permanently on backing storage devices, such as hard drives.

You can add RAM to you machine to improve the performance of the computer. Increasing RAM allows more programs to be run at the same time.

RAM vs ROM

RAM	ROM
RAM stores the programs and associated data of the programs currently in use	ROM stores a small part of the operating system called the bootstrap loader
The data in RAM is read/write so it can be changed	ROM is read-only and cannot be changed
All data stored in RAM is lost when then computer is switched off	Data on ROM is not lost when the computer is switched off

RAM vs ROM

This video by BBC Bitesize helps to explain the differences between RAM and ROM – note that you do not need to know about virtual memory for National 5.

Central Processing Unit

The processor in a computer is also called the **central processing unit** (CPU). The CPU is the main component of any computer.

The CPU is made up of smaller parts, and is responsible for:

- fetching and executing instructions from memory
- performing arithmetic calculations
- performing logical operations
- controlling read, write and clock lines

CPU Clock

All of the operations inside the CPU are synchronised by an electrical pulse called the **clock**. The clock speed gives an indication of how quickly the processor can complete tasks.

Modern CPUs have a clock speed of over 1GHz, meaning that over a billion instructions can be carried out every second.

Central Processing Unit

The CPU is made up of 3 components:

- control unit
- arithmetic and logic unit
- registers

Control Unit

The control unit is responsible for co-ordinating processes:

- responding to input and output devices
- managing the clock signal to keep actions in time
- fetching instructions and data from the main memory
- decoding instructions and deciding which part of the processor to send them to
- executing instructions

Arithmetic Logic Unit

The **arithmetic logic unit** (ALU) performs all mathematical or logical decisions:

- performs comparisons on numeric values e.g. answer > 2
- makes decisions based on logic e.g. AND, OR and NOT
- performs all mathematical calculations

Registers

Registers are small, fast, memory locations on the CPU.

Registers can only store a few bytes, so data that is not immediately needed will be transferred to main memory (RAM) until it is required.

Registers

Registers store information that is necessary for processes to execute successfully. This information could include:

- memory addresses of data or instructions that are needed
- the current instruction being decoded
- data that will be needed by the ALU to carry out calculations
- the results of calculations

Machine Code

Machine code is the language that a computer understands (e.g. 1s and 0s).

Machine code is very difficult for humans to read and understand, so when we program we use a high-level programming language instead.

A high-level programming language, such as Python, is English-based so that it's easy for humans to understand and to identify and fix issues. However, we then need to translate this high-level source code into machine code that can be understood and run by the computer.

Environmental Impact

Energy Use in Devices

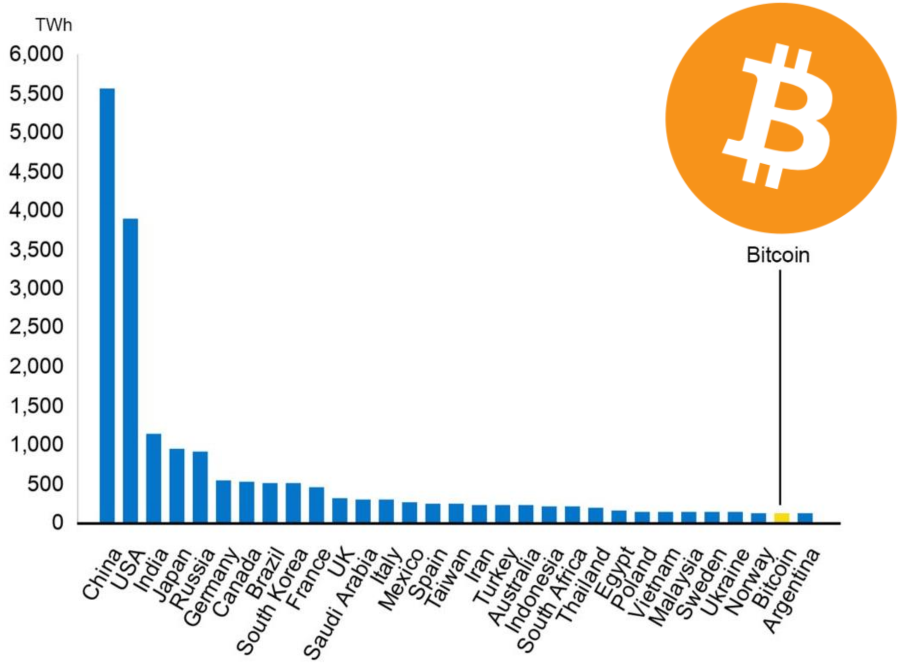
As of 2017, it is estimated that two billion computer systems are in use in the world. While one individual device may not need much energy to operate, two billion systems require vast amounts of electricity.

Some devices such as desktop PCs and consoles plug directly into mains electricity, and battery-powered devices such as smartphones need to be charged frequently.

Energy Use in Devices

"Mining" for the cryptocurrency is power-hungry, involving heavy computer calculations to verify transactions.

In February 2021, Cambridge University reported that mining Bitcoin uses more energy per year than many countries, including Argentina. In fact, if Bitcoin was a country it would be in the top 30 energy users worldwide.



Energy Use in Devices

In general, the larger the computer system the more energy it will consume, i.e. desktop PCs use more energy than laptops, laptops more than tablets and tablets more than smartphones.

The main problem with the electricity being consumed by computers is that almost all of the world relies on the burning of fossil fuels to generate electricity. As a user, you should consider ways to reduce unnecessary energy use to reduce your carbon footprint.

Reducing Your Energy Consumption

There are a number of ways to reduce the amount of electricity a computer consumes. In National 5, the three areas to consider are:

1. Monitor settings
2. Power down options
3. Standby settings

Monitor Settings

There are many things you can do with your monitor to reduce power consumption, or extend the battery life of a mobile device before you have to charge it again:

- Reduce the brightness of the monitor
- Switch on low-power mode, which often reduces the number of background processes running

Monitor Settings

There are other things you can do with your monitor to reduce power consumption:

- Avoid using a screensaver instead of going in to standby mode, as screensavers use just as much energy
- Choose an energy efficient device, one that usually displays the energy efficient logo

energy
ENERGY STAR

Power Down Options

Devices, particularly PCs and laptops, include power settings to help users reduce unnecessary energy consumption.

Users can change these settings to:

- power down the monitor after a set period of inactivity
- power down the desktop or laptop after a set period of inactivity (see the Standby Options slides)
- control settings for individual components, for example turning off wi-fi and Bluetooth adapters, which constantly use energy to send and receive data, and scan for other devices to connect to.

Standby Options

Most PCs will offer standby settings within the settings to help reduce power consumption. The two main options are:

- sleep
- hibernate

At National 5 you should know the difference between sleep mode and hibernate.

Sleep Mode

Sleep mode can be set to activate after a period of inactivity, or can also be triggered using a button or by closing a laptop or tablet cover.

In sleep mode:

- the screen is put into standby mode
- hard disks and backing storage devices are powered down
- RAM continues to be powered unless the battery is low (in this case the computer will hibernate)

Sleep mode uses more power than hibernate, but allows the user to resume working quickly as data being used is still in RAM.

Hibernate

Hibernate can be triggered in the same way as sleep mode.

In hibernate:

- the screen is put into standby mode
- the contents of RAM are copied onto backing storage, then the whole system is powered down, including hard disks and backing storage devices

Hibernate uses less power than sleep mode, but it will take longer to start up again, as the system has to reload the previous state back into RAM so that you can resume where you left off.

Stand By or Power Off?

It is often better to use standby or hibernate settings instead of shutting a system down, as powering on a PC can cause a surge in power to components.

While modern computer components are more reliable, in general it is better to minimise the number of times components receive a surge in power.

For this reason, standby or hibernate is a better option if you are going to use the system again after a short period of inactivity.

Security Precautions

Security Precautions

There are a number of security risks to computers, the data that they store and the data that is sent across the internet.

These risks include viruses, cyber attacks, and unauthorised malicious access to computer networks. Unauthorised access can be gained by hacking, or via social engineering such as phishing.

The video on the next slide explains these risks.

Security Risks

Watch this video to learn about the risks that are faced online.

Security Precautions

There are precautions that you can take to protect your computer or network from these risks. At National 5 you need to know about two precautions:

- Firewalls
- Encryption of data

Encryption

Encryption protects data even if it is accessed by a malicious or unauthorised entity. Data needs to be encrypted in two states:

- **in transit** (while it is being sent across the internet)
- **at rest** (while it is being stored in databases or data warehouses)

Data in Transit

We saw that the internet is public, and that packets are sent from router to router with no pre-determined path – it is possible that unauthorised entities can intercept and have access to the data.

We have to make sure that data cannot be read and understood by anyone other than the intended recipient.

Data at Rest

Hackers will often gain access to computer systems with the intention of stealing data from databases or data warehouses.

Data should be encrypted so that even if hackers steal the data, they cannot read and understand it, or sell it for profit.

How Does Encryption Work?

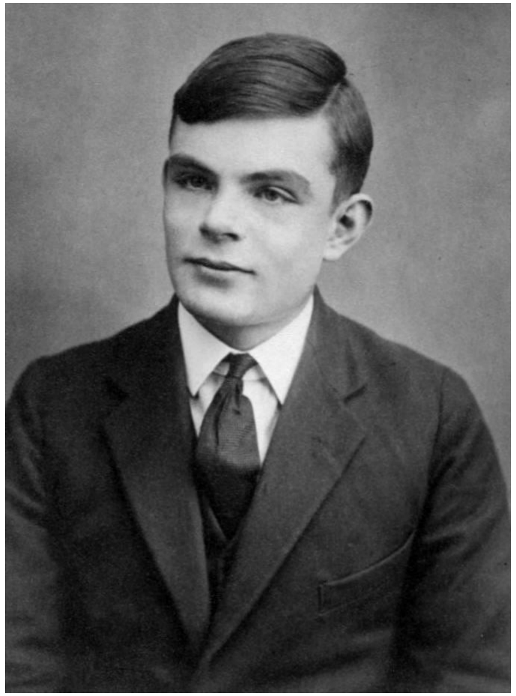
Watch this video up to 5:45 to see how encryption works.

Encryption Through History

Encryption has been used throughout history, particularly to keep military strategies secret. The Caesar's Cipher was named after Julius Caesar and is the method he supposedly used to send instructions to his army.

During World War II, the German military used encryption for the same purpose, using the Enigma machine to encrypt communications.

Alan Turing and his team worked to break Enigma and helped the allied forces to victory.



Types of Encryption

There are two types of encryption:

- Symmetric encryption
- Asymmetric encryption

These encryption techniques use a **key** to scramble the data and create **ciphertext**, which looks like nonsense and is impossible to understand.

There is some incredibly complex maths involved in encryption, which you are not expected to know for National 5.

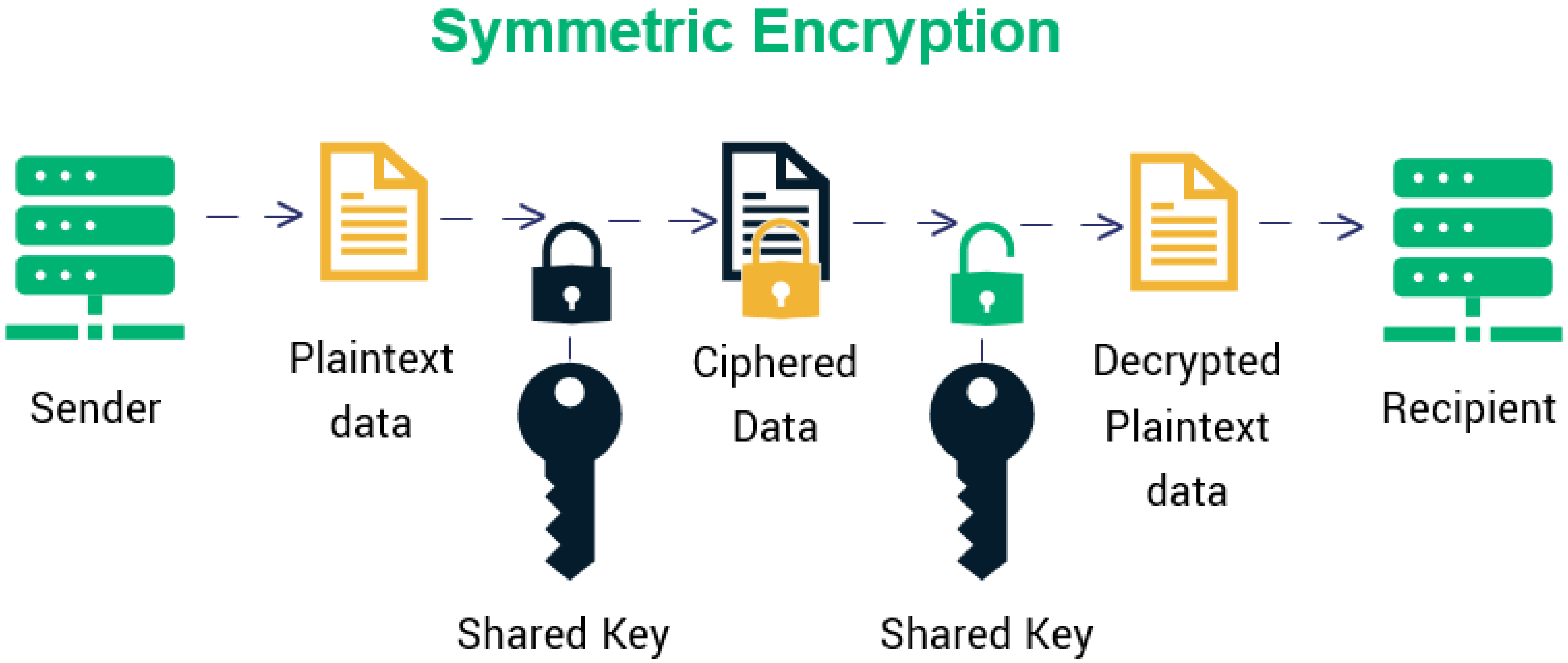
Symmetric Encryption

Symmetric encryption is when a **single, secret, shared key** is used to encrypt and decrypt data.

The two entities that are communicating must exchange the key, but it can be difficult to keep the key secret when it’s being sent across the internet, so symmetric encryption is usually only used to keep **data secure at rest.**

Symmetric encryption is faster and more efficient than asymmetric encryption, so it is usually used for **encrypting large amounts of data**, e.g. databases.

Symmetric Encryption



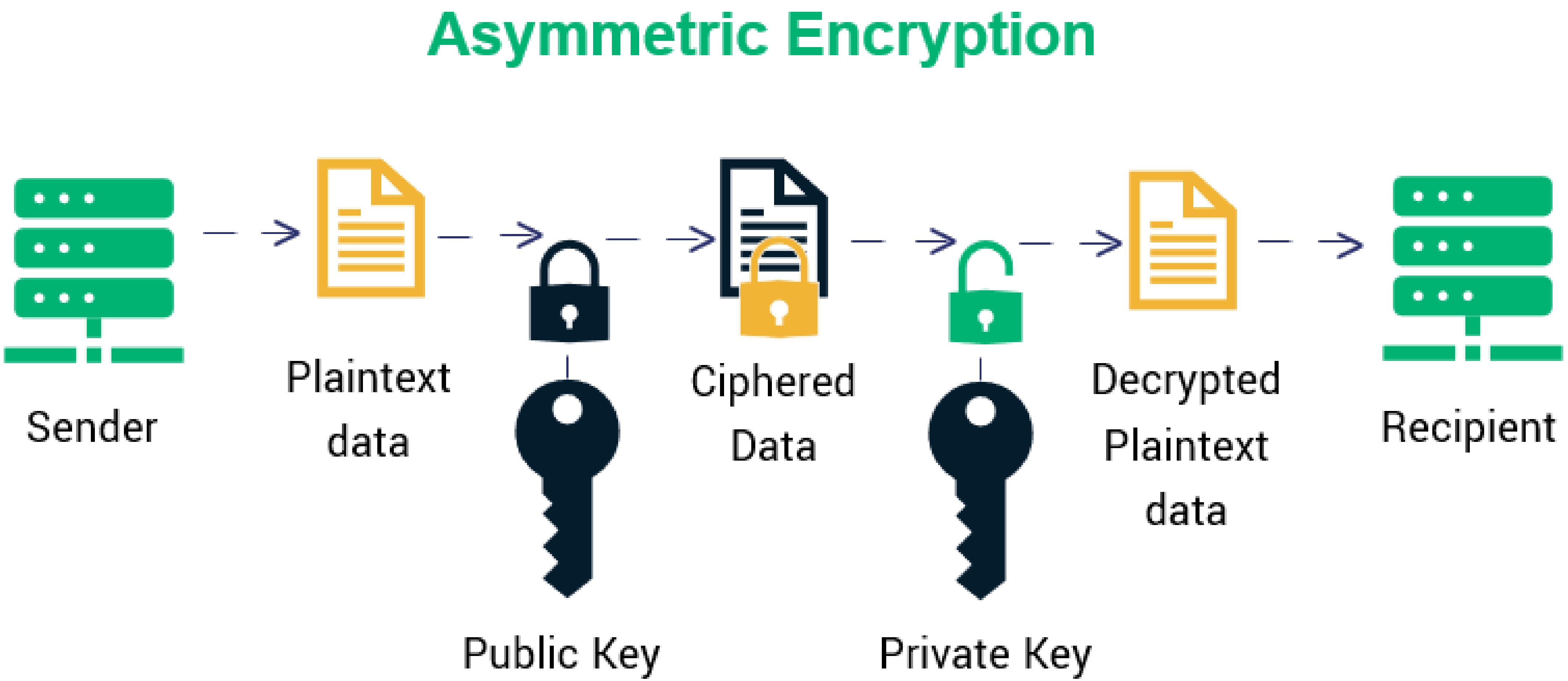
Asymmetric Encryption

Asymmetric encryption uses a public key **to encrypt data** and a separate, secret, private key **is used to decrypt**.

There is no need to exchange a secret key, so asymmetric encryption is considered much more secure and is usually used to keep **data secure in transit**.

Asymmetric decryption is a slow process compared to symmetric cryptography, so it is used for **encrypting smaller amounts of data**, e.g. IP packets.

Asymmetric Encryption



How is Your Data Protected?

Your data is regularly encrypted when you use the internet.

Whenever you see https or a padlock in the address bar of your browser, your details are encrypted before they are sent – you should check for this before you enter any personal data or bank details.

Your messages are often encrypted so that only the intended recipient can read them – this means that Facebook cannot read your WhatsApp messages.

SAMSUNG
last seen today at 14:10
55% 14:45
TODAY
Messages to this chat and calls are now secured with end-to-end encryption. Tap for more info.