

Computer Systems

As it's the first page I'll start simple. Computer Science is all about computers. What, you already knew that?

A Computer is a Machine that Processes Data

- 1) The purpose of a computer is to take **data**, **process** it, then **output** it. Computers were created to help process data and complete tasks **more efficiently** than humans.
- 2) A **computer system** consists of **hardware** and **software** that work together to process data / complete tasks.
 - Hardware is the **physical** stuff that makes up your computer system, like the CPU, motherboard, monitor and printer.
 - Software is the **programs** or **applications** that a computer system runs e.g. an operating system, a word processor or video game.
- 3) There are **many types** of computer system. These range from small devices like calculators and watches, up to large **supercomputers** used by banks or for scientific applications. Computers may be **general purpose** (designed to perform **many tasks**, e.g. PCs and tablets) or **dedicated systems** (designed for **one particular** function, e.g. controlling traffic lights or an aeroplane).

External pieces of hardware like the keyboard, mouse and printer are called **peripherals**.

Embedded Systems are Computers inside a Larger System

- 1) **Embedded systems** are computers **built into other devices**, like dishwashers, microwaves and TVs. They are usually dedicated systems.
- 2) Embedded systems are often used as **control systems** — they **monitor** and **control** machinery in order to achieve a desired result. E.g. In a **dishwasher** the embedded system could control the water pumps and water release mechanisms, manage the various dishwasher cycles and control the thermostat to keep the water at an appropriate temperature.
- 3) As they're **dedicated** to a single task, embedded systems are usually easier to **design**, cheaper to **produce**, and more **efficient** at doing their task than a general purpose computer.

Computers contain Components which Work Together

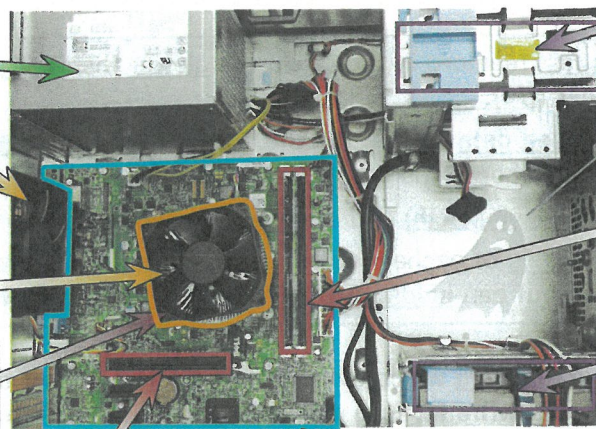
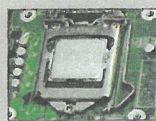
This section is all about the main hardware components of a computer. As a **genuinely fun** warm-up, let's take a look inside a typical desktop PC.

Power supply — supplies power to motherboard, optical and hard drives, and other hardware.

Case cooling fan — extracts hot air from the computer case.

CPU heat sink and cooling fan — keeps the CPU at a steady temperature (CPUs generate a lot of heat).

CPU (hidden under the heat sink) — the most important component. Does all the processing. See p2-3.



Optical drive — for read/writing of optical discs. See p7.

Ghost in the machine.

RAM sticks (computer memory) slot in here. See p4-5.

Hard Disk Drive — Internal secondary storage. See p6.

The **graphics card** slots in here. See p5.

Motherboard — The main circuit board in the computer, where the hardware is connected.

Hardware — clothes that make you look dead tough, innit...

Yes, there's a lot to take in on your first page. You should make sure you're comfortable with the components on this page before going any further, as they'll crop up a lot throughout this section.

Memory

As you'll have gathered from the last page, memory is a pretty fundamental part of a computer. It contains all the instructions that the CPU follows. Without memory, a computer wouldn't know what to do with itself.

RAM is High Speed, Volatile memory

- 1) **RAM** (or Random Access Memory) is used as the main memory in a computer. It can be read and written to. RAM is volatile.

- Volatile memory is temporary memory. It requires power to retain its data.
- Non-volatile is permanent memory — it keeps its contents even when it has no power.

- 2) The main memory is where all data, files and programs are stored while they're being used.
- 3) When a computer boots up, the operating system is copied from secondary storage to RAM.
- 4) When software applications, documents and files are opened, they are copied from secondary storage to RAM. They stay in RAM until the files or applications are closed.
- 5) RAM is slower than the CPU cache, but way faster than secondary storage.

Secondary storage is covered on p6-7.

Virtual Memory is Secondary Storage used as extra RAM

- 1) Computers have a limited amount of RAM. As applications are opened, RAM fills with data.
- 2) When RAM is full, the computer needs somewhere else to put application data. It moves data that hasn't been used recently to a location on secondary storage (p6) known as virtual memory.
- 3) Virtual memory may be needed if there are too many applications open at once, or if a particularly memory-intensive application is being used (or both).
- 4) If the CPU needs to read data stored in virtual memory, it must move the data back to RAM. This is slow as data transfer rates are much slower on secondary storage than RAM.
- 5) Using virtual memory can make a computer slow to respond when switching between applications (while data for one application in virtual memory is swapped with the other) or when using a memory-intensive application (due to data constantly moving between virtual memory and RAM just to keep the program running).

That's RAM covered, which can mean only ROM thing...

ROM tells the CPU how to Boot Up

- 1) **ROM** ('Read Only Memory') is non-volatile memory. As it says on the tin, it can only be read, not written to.
- 2) ROM comes on a small, factory-made chip built into the motherboard.
- 3) It contains all the instructions a computer needs to properly boot up. These instructions are called the BIOS (Basic Input Output System).
- 4) As soon as the computer is powered on, the CPU reads the instructions from ROM. This tells the CPU to perform self checks and set up the computer, e.g. test the memory is working OK, see what hardware is present and copy the operating system into RAM.
- 5) Although the CPU can only read ROM, it is possible to update ('flash') the BIOS on a ROM chip.

The BIOS is a type of firmware — hardware-specific software built in to a device. Embedded systems (p1) are controlled by firmware.

Woah, woah, back off — this memory's volatile...

The memory (RAM) is where the computer puts everything it's working on. It's really, really, super important that you don't confuse memory with secondary storage. So if a computer has a 2 TB (see p12) hard drive, never say it has 2 TB of memory. Don't even think about it — it'd just be plain wrong.

Secondary Storage

"Secondary storage!", I hear you cry. "But what about primary?" It's OK, we've just covered that, as you'll see...

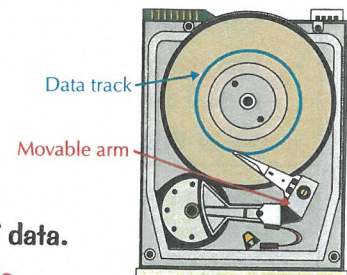
There are Two Main Tiers of Storage

- 1) **Primary storage** refers to the **memory** areas that the **CPU** can access very quickly, like CPU registers, cache, ROM and RAM. Primary storage has the **fastest** read/write speeds and is mostly **volatile** (p4).
- 2) **Secondary storage** is **non-volatile** — it's where all data (operating systems, applications and user files) are **stored** when not in use. It includes magnetic hard disk drives, solid state drives, CDs and SD cards. Read/write speeds are **much slower** compared to primary storage.

There's also tertiary storage, which is used for long term data storage (it's mainly used for archives and back-ups of massive amounts of data).

Hard Disks are High-Capacity, Reliable Storage

- 1) **Hard disk drives (HDDs)** are the traditional **internal storage** in **PCs** and **laptops** — they are often just called **hard drives**.
- 2) A hard disk drive is made up of a stack of **magnetised metal disks** that **spin** thousands of times a second.
- 3) Data is stored **magnetically** in small areas on the disk's circular **tracks**.
- 4) A **movable arm** can access these areas and **read** or **write** data.
- 5) **Portable** HDDs are popular for **backing up** and **transporting** large amounts of data.
- 6) Despite their moving parts, HDDs are generally very **long lasting** and **reliable**, although they could be damaged by large impacts like being dropped.



Solid State Drives are Fast and Reliable Secondary Storage

- 1) **Solid State Drives (SSDs)** are storage devices with **no moving parts**. SSDs are used for the **same** purpose as HDDs — for **internal / external** storage.
- 2) Most SSDs use a type of **flash memory** (a common type of **non-volatile memory**).
- 3) SSDs have **significantly faster** read/write times than HDDs. Using a SSD rather than traditional HDD can give much quicker times for **booting** up and opening **programs** and **files**.
- 4) **Hybrid drives** exist which use solid state storage for the **OS** and **programs**, and a hard disk for **data**.
- 5) Like HDDs, **portable** SSDs can be used to back up and transport data.

Other types of flash storage

USB pen drives and **memory cards** (e.g. SD cards) are **also** flash-based, solid-state storage.

They're **much slower** than SSDs and have a much shorter read/write **life**.

They're used to **expand** the storage capacity of **small devices** like cameras, smartphones and tablets (which are too small for SSDs or HDDs). Their capacity is **very high** relative to their tiny **size**.

HDDs vs SSDs — Who wins, you Decide...

Advantages of HDDs	Advantages of SSDs
<ul style="list-style-type: none"> • HDDs are cheaper. • Both are high capacity, but HDDs are higher. • HDDs have a longer read/write life than SSDs — SSDs can only be written a certain number of times before they begin to deteriorate. 	<ul style="list-style-type: none"> • SSDs are faster. • SSDs don't need defragmenting (see p10). • SSDs are more shock-proof than HDDs. • HDDs make some noise, SSDs are silent.

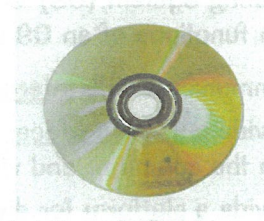
(If you decided SSD, you were correct.)

Secondary Storage

Be careful with your terminology. Storage media refers to the actual thing that holds the data, e.g. optical discs (see below). A storage device is the thing that reads/writes data to media, e.g. HDDs or optical drive.

Optical Discs are Cheap and Robust Secondary Storage

- 1) Optical discs are things like **CDs**, **DVDs** and **Blu-ray™** discs.
- 2) CDs can hold around 700 MB of data, DVDs can hold around 4.7 GB and Blu-rays can hold around 25 GB.
- 3) Optical discs come in three forms:
 - **read-only** (e.g. CD-ROM / DVD-ROM / BD-ROM)
 - **write-once** (e.g. CD-R / DVD-R / BD-R)
 - **rewritable** (e.g. CD-RW / DVD-RW / BD-RW)
- 4) Nowadays, their use is **declining**:
 - As Internet speeds have increased, **streaming** and **download** services like Netflix, Spotify® and Steam® have removed the need for optical discs.
 - Modern devices like **phones** and **tablets** don't have optical drives.
 - DVD-Rs and DVD-RWs used to be popular for backing up data, but they have **low capacity** per disc, very **slow** read/write speeds and poor **reliability** compared to flash storage devices.
- 5) They do have some **advantages** — they're very cheap (per GB), portable, and won't be damaged by **water** or **shocks** (although they are easily **scratched**).

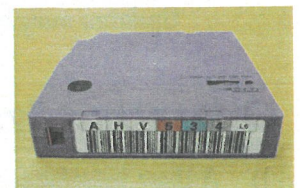


Optical discs are still useful as mirrors.
Or, bury them in flowerbeds to scare away cats.

Magnetic Tapes are used for Archiving

- 1) **Magnetic tape** has much **greater storage capacity** than HDDs. It also has an extremely **low cost** per GB.
- 2) Magnetic tapes are often used by **large organisations** in archive libraries to store **huge amounts** of data.
- 3) It comes in plastic **cassettes** (containing reels of tape). Cassettes require a special tape-drive for read/writing.
- 4) Tape is read/written **sequentially**, meaning it is read/written from the **beginning** to the **end**, or until it is stopped by the computer. This means tape is very **slow** when **finding** specific data stored on it, but has a **fast** read/write speed once it is in the correct place to begin reading/writing.

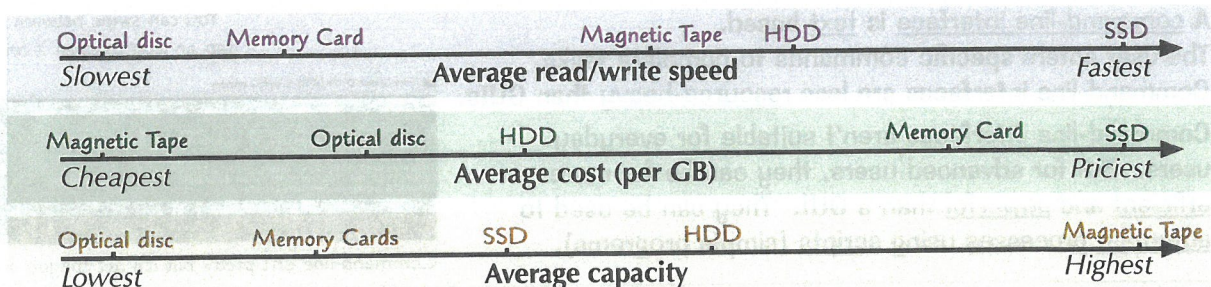
Magnetic tapes are most suitable for businesses who do large, frequent back-ups.



A 6.5 TB magnetic tape cassette.

A quick Summary...

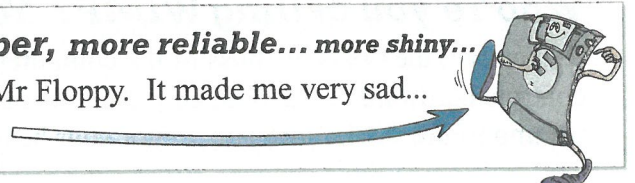
It can get pretty confusing with all this 'thingy is faster than thingy which is cheaper than thingy but holds less than thingy'. So here's a summary of relative **speeds**, **costs** and **capacities**.



Harder, Better, Faster, Stronger... cheaper, more reliable... more shiny...

Poor old optical discs. I remember when this happened to Mr Floppy. It made me very sad...

Here's Mr Floppy with his remarkable 1.44 MB of storage.



Units

Just like you have units like centimetres, metres and kilometres for measuring distance, computers need units for measuring digital information. You'll need to learn all of the unit names on this page and their sizes.

Bits are the Smallest Measure of Data

- Computers use 1s and 0s to represent the flow of electricity. 1 is used to show that electricity is flowing, and 0 shows that it is not flowing.
- All the data we want a computer to process must be converted into binary code (1s and 0s).
- Each 1 or 0 in a binary code is a bit (binary digit). For example, 1010 is 4 bits.
- The table below shows the size of other units of data:

A byte is big enough to store one character (like x, e, M or £).
See p18 for more info.

Most files (like songs, pictures and documents) are measured in kB or MB.

High definition videos and complex applications are often measured in gigabytes.

Secondary storage capacity is measured in gigabytes or terabytes.

Name	Size
Bit (b)	A single binary digit (1 or 0)
Nibble	4 bits
Byte (B)	8 bits
Kilobyte (kB)	1000 bytes
Megabyte (MB)	1000 kilobytes
Gigabyte (GB)	1000 megabytes
Terabyte (TB)	1000 gigabytes
Petabyte (PB)	1000 terabytes

You might see each unit defined to be 1024 (not 1000) times bigger than the previous unit. The main reason is that 1024 is a power of 2 which is helpful when dealing with binary data.

- Each bit can take one of two different values (either 1 or 0). This means that a nibble (4 bits) can take $2^4 = 16$ different values, and a byte (8 bits) can take $2^8 = 256$ different values.

You can Convert between Different Units

Converting between units of data is usually pretty straightforward — just watch out when you have to switch between bits and bytes.



EXAMPLE:

Ashley has downloaded some images to her computer. Each image is 300 kilobytes.

- a) How many bits are in each image?

- First, convert to bytes by multiplying by 1000: $300 \text{ kB} = 300 \times 1000 = 300\,000 \text{ Bytes}$
- There are 8 bits in a byte, so multiply by 8: $300\,000 \text{ Bytes} = 300\,000 \times 8 = 2\,400\,000 \text{ bits}$

- b) She wants to copy 400 of these images onto her USB flash drive, which has 0.15 GB of free space left. Does she have enough space to store them all?

- Work out the total size of all the images: $400 \times 300 = 120\,000 \text{ kB}$
- Now convert this to GB — first, divide by 1000 to get it in MB, then again to get it in GB: $120\,000 \text{ kB} = 120\,000 \div 1000 = 120 \text{ MB}$
 $120 \text{ MB} = 120 \div 1000 = 0.12 \text{ GB}$
So **yes**, she has enough space.

0101010

This page has me in bits...

Keep working your way through that unit table until the size order is clear in your head — it might just show up on your exam. A bit is smaller than a nibble, and a nibble is less than a full byte. I know, hilarious.

Binary Numbers

As computers only understand 1s and 0s, all data must be converted into binary to be processed. Binary can be used to represent all numbers in our standard number system.

Counting in Binary is a bit like Counting in Denary

- 1) In our standard number system we have ten different digits (0, 1, 2, 3, 4, 5, 6, 7, 8, 9). This is called denary, decimal or base-10.
- 2) Binary only uses two different digits (0 and 1) — we call this base-2.
- 3) Counting in binary is similar to counting in denary, but the place values from right to left increase by powers of 2 (e.g. 8, 4, 2, 1), instead of powers of 10 (e.g. 1000, 100, 10, 1).
- 4) The following table shows the binary equivalents of the denary numbers 0-15:

0 = 0	4 = 100	8 = 1000	12 = 1100
1 = 1	5 = 101	9 = 1001	13 = 1101
2 = 10	6 = 110	10 = 1010	14 = 1110
3 = 11	7 = 111	11 = 1011	15 = 1111

- 5) Most binary numbers are given as 8-bit numbers, e.g. 01101011, which can represent the denary numbers 0-255. The bit with the largest value (the left-most bit) is called the most significant bit, and the bit with the smallest value (the right-most bit) is called the least significant bit.

Binary Numbers are easier to Convert using Tables

Drawing a table with binary place values in the first row makes binary to denary conversion easier.

EXAMPLE:

Convert the 8-bit binary number 00110101 to a denary number.

- 1) Draw up a table with binary place values in the top row. Start with 1 at the right, then move left, doubling each time.

128	64	32	16	8	4	2	1
0	0	1	1	0	1	0	1

Each column is just a power of 2. i.e. $2^3, 2^2, 2^1, 2^0$.

- 2) Write the binary number 00110101 into your table.

- 3) Add up all the numbers with a 1 in their column: $32 + 16 + 4 + 1 = 53$

So 00110101 is 53 in denary.

This works with all binary numbers — just draw as many columns as you need, doubling each time.

Convert Denary to Binary by Subtracting

When converting from denary to binary, it's easier to draw a table of binary place values, then subtract them from largest to smallest. Have a look at this example:

EXAMPLE:

Convert the denary number 79 into an 8-bit binary number.

- 1) Draw an 8-bit table.
- 2) Move along the table, only subtracting the number in each column from your running total if it gives a positive answer.
- 3) Put a 1 in every column that gives a positive answer, and a 0 in the rest.

128	64	32	16	8	4	2	1
0	1	0	0	1	1	1	1

$$\begin{array}{r}
 79 - 128 = -49 \\
 79 - 64 = 15 \\
 15 - 32 = -17 \\
 15 - 16 = -1 \\
 15 - 8 = 7 \\
 7 - 4 = 3 \\
 3 - 2 = 1 \\
 1 - 1 = 0
 \end{array}$$

So 79 converted to an 8-bit binary number is 01001111.

There are other methods to convert denary to binary, so just choose the one you are most comfortable with.

The latest additions to the Nairy family — Brian, and brother Dean...

There are a couple of different conversions on this page, and you'll need to be comfortable with it all before carrying on. Remember that to read each digit from smallest to largest, read from right to left like with denary numbers. The value of each digit in binary is double the value of the digit to its right.