ICT | CHAPTER 3

- STORAGE DEVICES AND MEDIA
- IGCSE ICT (0417)
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LEARNING OBJECTIVES

- Distinguish storage media from storage devices
- Explain magnetic, optical and solid-state storage
- Compare storage methods using speed, capacity, durability and cost
- Choose suitable storage for real-world scenarios
- Answer exam-style questions with model responses

THE BIG PICTURE

- Secondary storage is non-volatile: data remains after power is off.
- It stores the operating system, applications and user files.
- Three technologies: MAGNETIC, OPTICAL and SOLID STATE.

MEDIA vs DEVICE

- Storage medium: material on which data is stored (e.g. DVD disc).
- Storage device: hardware that reads or writes the medium (e.g. DVD drive).
- Exam tip: do not confuse the disc with the drive.

THREE STORAGE TECHNOLOGIES

- MAGNETIC — HDD and magnetic tape
- OPTICAL — CD, DVD and Blu-ray
- SOLID STATE — SSD, pen drive and memory card

MAGNETIC STORAGE

- Magnetised regions represent binary data.
- Magnetic tape is sequential/serial access.
- HDDs use rotating platters and direct access.

MAGNETIC TAPE: HOW IT WORKS

- Plastic strip coated with magnetic material.
- A read/write head detects magnetic patterns.
- Serial access: earlier data must be passed before later data.
- Access time is slow even if transfer rate can be high.

MAGNETIC TAPE: USES

- Long-term archiving of very large datasets
- Offline backups
- Batch processing such as payroll and utility bills

MAGNETIC TAPE: EVALUATION

- Advantages: high capacity; low cost per byte; stable for archives.
- Disadvantages: very slow access; awkward updating; vulnerable to strong magnetic fields.

SERIAL vs DIRECT ACCESS

- SERIAL: read through preceding records first (tape).
- DIRECT: jump to the required location (HDD and optical disc).
- A backup archive may tolerate serial access; an online booking system cannot.

HARD DISK DRIVE: INSIDE

- Platters spin while an actuator positions read/write heads.
- Data is organised into concentric tracks and sectors.
- Latency: wait for the required sector to rotate beneath the head.

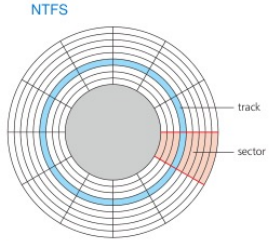
3.1.2 Hard disk drives (HDD)

Hard disk drives (HDD) are still one of the most common methods used to store data on a computer. Data is stored in a digital format on the magnetic surfaces of the hard disks (or platters, as they are usually called). A hard disk drive will very often have more than one platter depending on its capacity. A number of read/write heads can access all of the platter surfaces in the disk drive (normally each platter will have two surfaces where the data is stored). These read/write heads can move very quickly – typically they can move from the centre of the disk to the edge of the disk (and back again) 50 times a second. Data on an HDD can be read using direct access – this means, unlike magnetic tape, earlier data does not have to be read first before the required data is found. We will now look in more detail at how HDD works:



▲ **Figure 3.3** Hard disk drive – the hard disk (platter) is the media and the hard disk drive (HDD) is the storage device

- Actuators are used to move the read/write heads (voice coils are used as the actuators; these are similar to the electromagnets used in speakers – hence their name).
- A read/write arm swings the read/write head back and forth across the platter; the platter is rotating at up to 10 000 rpm (revolutions per minute).
- Each read/write head contains a tiny magnet which allows the data on the platter to be read.
- Platters are made from glass, ceramic or aluminium which are coated in iron oxide.
- There are two read/write heads per platter (one for the top surface and one for the bottom surface).
- Data is stored in concentric, circular tracks; each track is broken up into sectors (see Figure 3.4).
- A map of the sectors is stored on the HDD and is known as a file allocation table (FAT); when the computer wants to store new data, it looks at the FAT map to find out which sectors are free and then moves the read/write heads to the correct location – this greatly speeds up the writing process.



▲ **Figure 3.4** Hard disk platter (showing tracks and sectors)

While hard disk drives have much faster data access times than magnetic tape, there are still small delays. Many applications require the read/write heads to constantly seek the correct blocks of data; this means a large number of head movements. The effects of **latency** then become very significant. (Latency is defined as the time it takes for a specific block of data on a data track to rotate around to the read/write head). Users will sometimes notice the effect of latency, especially if many different applications are open, when they see messages such as: 'Please wait' or, at its worst, 'not responding'. HDDs can be either fixed or portable.

HDD: USES

- Operating system, software and everyday files
- Network file servers
- Online and real-time systems
- Portable HDDs for backups and file transfer

HDD: ADVANTAGES & RISKS

- Advantages: large capacity, relatively fast access, fast transfers.
- Risks: moving parts, noise, physical damage and head crashes.
- Portable drives are especially vulnerable to being dropped.

ACCESS TIME vs TRANSFER RATE

- Access time = time to locate the requested data.
- Transfer rate = rate at which data is moved once transfer begins.
- A tape can have slow access but a high transfer rate.

OPTICAL STORAGE: HOW IT WORKS

- A laser reads data along a spiral track.
- Pits and lands affect reflected light.
- The disc does not touch the laser head.
- Optical media include CD, DVD and Blu-ray.

CD / DVD FORMATS

- ROM: factory-recorded, read-only.
- R: recordable once.
- RW: rewritable multiple times.
- Choose based on whether the data should change.

CD-R / DVD-R

- Uses: distributing recordings and storing files for later use.
- Advantages: inexpensive write-once medium; finalised data cannot be overwritten.
- Disadvantages: mistakes cannot be corrected by rewriting the disc.

CD-RW / DVD-RW

- Uses: repeated recording, backups and some CCTV applications.
- Advantages: can rewrite data multiple times.
- Disadvantages: accidental overwriting and relatively higher media cost.

CD-ROM / DVD-ROM

- Read-only media used for distributing software, music, films and games.
- Useful where users must not alter the original content.
- Generally slower to access than hard disks.

DUAL-LAYER DVD

- Two recording layers increase capacity.
- The laser focuses at different depths to read each layer.
- A single-layer DVD holds about 4.7 GB (as in the source).

BLU-RAY vs DVD

- Blu-ray uses a blue laser (405 nm).
- DVD uses a red laser (650 nm).
- Shorter wavelength permits smaller pits and higher capacity.
- Source comparison: Blu-ray single layer ~27 GB; dual layer ~50 GB.

Comparison of the capacity and interactivity of DVDs and Blu-ray discs

- A standard single-layer DVD has a storage capacity of 4.7 GB (enough to store a two-hour standard definition movie).
- A single-layer Blu-ray disc has a storage capacity of 27 GB (enough to store a two-hour high definition movie or 13 hours of standard definition movies).
- A dual-layer Blu-ray disc has a storage capacity of 50 GB (enough to store 4.5 hours of high definition movies or 20 hours of standard definition movies).
- Blu-ray devices allow greater interactivity than DVD devices. For example with Blu-ray, it is possible to:
  - record high definition television programmes
  - skip quickly to any part of the disc
  - create playlists of recorded movies and television programmes
  - edit or re-order programmes recorded on the disc
  - automatically search for empty space on the disc to avoid over-recording
  - access websites and download subtitles and other interesting features.

Finally, Table 3.1 summarises the main differences between CDs, DVDs and Blu-ray discs.

Table 3.1 Comparison of CD, DVD and Blu-ray

Disk type	Laser colour	Wavelength of laser light	Disk construction	Track pitch (distance between tracks)
CD 700mb ROM(R)(RW)	red	780 nm	single 1.2 mm polycarbonate layer	1.60 μm
DVD (dual-layer) 4.7gb R/RW	red	650 nm	two 0.6 mm polycarbonate layers	0.74 μm
Blu-ray (single-layer) 25gb	blue	405 nm	single 1.2 mm polycarbonate layer	0.30 μm
Blu-ray (dual-layer) 50gb	blue	405 nm	two 0.6 mm polycarbonate layers	0.30 μm

(NOTE: nm = 10^{-9} metres and μm = 10^{-6} metres.)

(Blu-ray can currently go up to six-layer technology, but this is outside the scope of this book.)

Uses of Blu-ray discs

- Home video consoles.
- Storing and playing back movies (one high definition movie of two hours duration uses up 25 GB of memory).
- Computers can use this technology for data storage or backing up hard drives.
- Camcorders can use this media (in cartridge form) to store movies.

OPTICAL MEDIA COMPARISON

- CD: red laser, 780 nm
- DVD: red laser, 650 nm
- Blu-ray: blue laser, 405 nm
- As wavelength decreases, track spacing and pit size can decrease.

BLU-RAY: APPLICATIONS

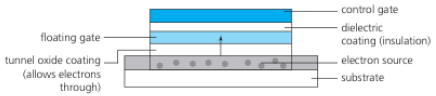
- High-definition film storage and playback
- Video-game consoles
- Data backups and camcorder recording
- Advantages: high capacity and faster optical access.

SOLID-STATE STORAGE

- Stores binary data electronically in NAND flash cells.
- No moving mechanical parts.
- Non-volatile, compact and usually very fast.

FLOATING GATE MEMORY

- Control gate voltage changes the charge stored in a floating gate.
- Insulation traps the charge so data persists without power.
- The stored charge represents a bit value.



▲ **Figure 3.8** Floating gate and control gate (solid-state memory)

A dielectric coating separates the two transistors, which allows the floating gate transistor to retain its charge (which is why the memory is non-volatile). The floating gate transistor has a value of 1 when it is charged and a value of 0 when it is not. To program one of these 'intersection cells' a voltage is applied to the control gate and electrons from the electron source are attracted to it. But due to the dielectric coating, the electrons become trapped in the floating gate. Therefore, we have control over the bit value stored at each intersection. (Note: After about 12 months, this charge can leak away which is why a solid-state device should be used at least once a year to be certain it will retain its memory contents).

3.3.2 Solid-state drives (SSD)

Uses of SSDs

Solid-state drives have revolutionised computers over the last few years, and they are rapidly taking over from HDDs as the main type of backing storage. As the name suggests, they use solid-state media and can be used in the same way as an HDD (that is, as a storage device to store files, applications, operating system, and so on). They have enabled laptop computers to become thinner and much lighter. They have given rise to the development of smartphones and tablets; without solid-state technology, these devices simply would not exist.

Advantages of SSDs

So, when developing a new computer or electronic device (such as a phone or tablet), what are the main benefits of using an SSD rather than an HDD? The main benefits of SSDs are:

- they are more reliable (no moving parts to go wrong)
- they are considerably lighter (which makes them suitable for laptops)
- they do not have to 'get up to speed' before they work properly
- they have a lower power consumption
- they run much cooler than HDDs (both these points again make them very suitable for laptop computers)
- because of no moving parts, they are very thin
- SSD data access time is only 0.1 milliseconds compared to 10 milliseconds for HDD
- data transfer speed for SSDs is also much faster than for HDDs.

SOLID-STATE DRIVE (SSD)

- Stores operating systems, applications and files like an HDD.
- No spinning platter or moving read/write head.
- Common in laptops, tablets and many modern computers.

WHY CHOOSE AN SSD?

- Faster data access and transfer
- Lighter, thinner and quieter
- Lower power consumption and heat
- More resistant to mechanical shock

SSD LIMITATIONS

- Flash cells have finite write endurance.
- Cost per gigabyte may be higher than HDD.
- Endurance depends on workload and drive technology.

HDD vs SSD — EXAM COMPARISON

- HDD: moving parts, higher mechanical risk, slower random access.
- SSD: no moving parts, faster access, lower power use.
- HDD may be selected for economical high-capacity storage.

USB PEN DRIVES

- Small, portable flash storage that connects via USB.
- Uses: moving files, small backups and security dongles.
- Advantages: compact, robust and unaffected by magnetic fields.

Disadvantages of SSDs

The main drawback of SSDs is the longevity of the technology (although this is becoming less of an issue). Most solid-state storage devices are conservatively rated at only 20 GB write operations per day over a three-year period – this is known as **SSD endurance**. For this reason, SSD technology is still not used in all servers, for example, where a huge number of write operations take place every day. However, the durability of these solid-state systems is being addressed by a number of manufacturers to improve them, and they are rapidly becoming more common in applications such as servers and **cloud storage** devices.

3.3.3 Pen drives

Pen drives (memory sticks) are small portable devices that make use of solid-state technology.

They connect to the computer through a USB port. Their main advantage is that they are very small, lightweight portable devices which make them very suitable as a method for transferring files between computers. They can also be used as small backup devices for music or photo files, for example. Pen drives are examples of USB flash drives which draw their power from the computer via the USB connection. Some devices combine the functionality of a **portable media player** with USB flash storage; such devices require a battery to play music on the go.



▲ **Figure 3.9** Pen drive/memory stick

Note: The terms pen drive (memory stick) and flash drive are often incorrectly used to mean the same thing. Essentially, any device that uses solid-state technology can be referred to as a flash drive; a pen drive (memory stick) is a flash drive with a USB connector. In other words, a pen drive is a type of flash drive with a particular purpose. However, flash drives can be used inside many devices to carry out a number of different tasks. These devices may be acting as the controller for a microwave oven, for example, which is certainly a very different task to a pen drive.

Uses of memory sticks/pen drives

- Transporting files between computers or using as a backing store.
- Used as a security device to prevent software piracy (known as a dongle).

Advantages of memory sticks/pen drives

- Very compact and portable media.
- Very robust.
- Does not need additional software to work on most computers.
- They are not affected by magnetic fields.

Disadvantages of memory sticks/pen drives

- Cannot write protect the data/files by making it 'read-only'.
- Easy to lose (due to the small physical size).
- The user needs to be very careful when removing a memory stick from a computer – incorrect removal (for example, while it is still doing a read/write operation) will corrupt the data on the memory stick and make it useless.

PEN DRIVE: RISKS

- Easy to lose or steal due to small size.
- Removing during writing can corrupt files.
- Use safe-eject procedures and keep backups.

MEMORY CARDS

- SD: common in cameras, audio players and portable devices.
- XD: removable camera storage.
- CFast: higher-end photo and video equipment.

3.3.4 Memory cards

A memory card makes use of solid-state technology. They can be inserted into a device which can read the card or allow data to be written to the card. The cards come in various memory sizes. There are many available memory card formats, for example:

- SD cards (**s**ecure **d**igital card)
- XD cards (e**x**treme **d**igital card)
- CFast card (**c**ompact**fast** card).

The XD card is a type of removable memory card designed for use in digital cameras. They can be written to or read from the camera or other suitable XD card reader (the card readers can often be attached to a computer to allow the memory card to be read directly).

The SD card is a type of very small card with a very high-capacity memory. SD cards are primarily used in portable devices such as digital video recorders, digital cameras, audio players, smartphones and tablets.

A CFast card is a memory card format which was developed to allow solid-state technology to be used in a very small portable device. It has no moving mechanical parts and does not need a battery to retain data. CFast cards are primarily used as removable memory for higher-end digital photo and video cameras.

Uses of memory cards

- Storing photos on digital cameras.
- Used as mobile phone memory cards.
- Used in MP3 players to store music files.
- Used as a backing store in hand-held computer devices.

Advantages of memory cards

- Very compact – can be easily removed and used in another device or for transferring photos directly to a computer or printer.
- Because they are solid-state memories (and have no moving parts) they are very durable.
- They can hold large amounts of data.
- Digital devices, such as compact cameras and smartphones, are able to read and write to memory cards, allowing the user to transport large collections of photographs, songs or information with them.

Disadvantages of memory cards

- Expensive per gigabyte of memory when compared to hard disk drives.
- Have a lower storage capacity than hard disks.
- Have a finite life regarding number of times they can be read from or written to.
- Memory cards, specifically the micro SD card, are the smallest storage devices available; this means they are more likely to be lost, stolen or damaged.
- Not all computers come with memory card readers built in; users will often be required to purchase a card reader or USB converter to view the data on a memory card.

MEMORY CARD: EVALUATION

- Advantages: compact, removable, durable, high capacity for size.
- Disadvantages: easy to lose, limited write life, may require a reader.
- Choose a card compatible with the device.

THE FUTURE OF STORAGE

- Many laptops no longer include CD/DVD drives.
- Flash storage is widely used to transfer files.
- Cloud access and streaming reduce dependence on physical discs.

CHOOSING THE RIGHT STORAGE

- Long-term bulk archive → magnetic tape
- Fast laptop startup → SSD
- Cheap high-capacity local storage → HDD
- Removable camera storage → SD / CFast card
- Write-once distribution → optical R or ROM

REVISION: COMMON EXAM TRAPS

- Media ≠ device
- Access time ≠ transfer rate
- Serial access ≠ direct access
- SSD ≠ RAM (SSDs are non-volatile)
- Blu-ray ≠ DVD (laser wavelength differs)

EXAM PRACTICE 1 • OPTICAL [4]

- Choose the medium: lower-quality audio; highest capacity; RAM format used for recording; high-definition movies.

EXAM MODEL ANSWER 1 • OPTICAL [4]

- CD; Blu-ray; DVD (DVD-RAM); Blu-ray.

EXAM PRACTICE 2 • CLASSIFY [4]

- Classify: SSD, Blu-ray, pen drive, portable HDD.

EXAM MODEL ANSWER 2 • CLASSIFY [4]

- SSD — solid state
- Blu-ray — optical
- Pen drive — solid state
- Portable HDD — magnetic

EXAM PRACTICE 3 • EXPLAIN [6]

- (a) What is optical media? [2]
- (b) Give four reasons SSDs are replacing HDDs. [4]

EXAM MODEL ANSWER 3 • EXPLAIN [6]

- (a) Storage medium that uses laser light to read/write data; information is stored as optical marks such as pits and lands.
- (b) Faster access; lower power use; no moving parts; lighter/thinner (any four distinct valid points).

EXAM PRACTICE 4 • MATCH [6]

- Match these: pits and lands; dual-layering; solid-state memory; pen drive; memory cards; serial access.

EXAM MODEL ANSWER 4 • MATCH [6]

- DVD data regions → pits and lands
- Two recording layers → dual-layering
- Floating/control gates → solid-state memory
- USB flash device → pen drive
- SD/XD/CFast → memory cards
- Previous records read first → serial access

EXAM PRACTICE 5 • FILL THE GAPS [10]

- Fill ten blanks using the word bank on PDF page 15.

EXAM MODEL ANSWER 5 • FILL THE GAPS [10]

- 1 Direct access 2 Media 3 Platters 4 Latency
- 5 Data transfer rate 6 Data access time
- 7 Blu-ray discs 8 Three-year period
- 9 SSD endurance 10 Memory sticks

EXAM PRACTICE 6 • TRUE / FALSE [10]

- Decide True or False for the ten statements on PDF page 15.

EXAM MODEL ANSWER 6 • TRUE / FALSE [10]

- 1 T 2 F 3 F 4 F 5 T
- 6 T 7 T 8 F 9 T 10 F
- Note: statement 10 is false as written in the source distinction: a pen drive is a type of flash drive, not an interchangeable term for every flash drive.

EXAM PRACTICE 7 • COMPARE [10]

- (a) Three Blu-ray vs DVD differences; one use of each.
- (b) Three HDD vs SSD differences; one use of each.

EXAM MODEL ANSWER 7 • COMPARE [10]

- Blu-ray: blue 405 nm laser; greater capacity; smaller pits / closer tracks. DVD: red 650 nm laser.
- Uses: Blu-ray HD movie; DVD standard movie.
- SSD: no moving parts, faster access, less power; HDD: moving parts, slower access, more power.
- Uses: HDD large-capacity file server; SSD laptop boot drive.

EXAM PRACTICE 8 • TECHNOLOGY [8]

- (a) Why are HDDs less dominant as main backing storage? [4]
- (b) Why do modern laptops omit CD/DVD drives? [4]

EXAM MODEL ANSWER 8 • TECHNOLOGY [8]

- (a) SSDs are faster, lighter, thinner and use less power; no moving parts improves reliability.
- (b) USB flash drives, cloud storage, streaming and software downloads reduce optical disc needs; removing the drive makes laptops thinner/lighter.

CHAPTER 3 • QUICK RECAP

- Magnetic: HDD and tape
- Optical: CD, DVD and Blu-ray
- Solid state: SSD, USB flash and memory cards
- Always justify a storage choice using the application.