# 3 Storage devices and media

In this chapter you will learn about:

- backing storage
- why back up data?
- types of access used by secondary storage devices
- types of internal and external secondary storage devices:
  - magnetic
  - optical
  - solid state.

## 3.1 Backing up of data

This chapter covers many forms of secondary storage and compares the advantages and disadvantages of each type. In Chapter 1 you learnt about the primary memory, known as RAM and ROM. We will consider a number of storage devices later but first it is important to consider why we need to back up data using these devices and also how data is accessed.

### 3.1.1 What is backing up of data?

Backing up refers to the copying of files/data to a different medium (disk, tape, flash drive, etc.) in case of a problem with the main secondary storage device. Backing up files and data on a regular basis is seen as good computing practice and many computer systems can be set to back up files automatically on a regular basis. An example would be the use of magnetic tapes to back up internet servers on a regular basis, or cloud storage companies using magnetic tape or hard disk drives to back up clients' data on a regular basis.

The backups are often stored in a different place to the main storage. This is in case of fire or some other situation that could lead to irretrievable loss of key data/files.

### 3.1.2 Why back up data?

There are various reasons why backups are made. Some of the more common reasons are considered below.

- To safegauard against loss of data due to the failure of the original secondary storage device; this could be due to hardware failure (e.g. head crash on a hard drive unit), problems caused by files being overwritten accidentally (or otherwise) or possible corruption of files (for example, caused by power surges).
- To safeguard against damage caused by hackers. This may not be their intention (they may only want to gain access to the information for other purposes, for example to find personal information such as bank account details). However, the very act of hacking in to files could cause problems such as corruption or data loss.
- Backups are also made in case the files need to be used elsewhere; this protects the originals against possible corruption or loss.
- Backups don't necessarily guard against the effect of a virus. The virus could attach itself to the files, which could mean that the backups are also affected. If the computer was 'cleaned' of the virus and then the backup files reloaded, there is a real risk that the virus could infect the computer system again. The best protection is not to get a virus in the first place.

## 3.2 Types of access

A number of secondary storage devices are discussed in Section 3.3. The way data is stored and read by each of these devices is very different, however.

This section briefly describes the two main methods of accessing data. It is important to understand three new terms here:

- field
- record
- file.

Suppose we are storing data about 20 cars in a car showroom. Data about each car – such as its colour, engine size, type of fuel, number of doors and whether it's new or used – are stored in an allocated space known as a **field**. All of the data about car 1, for example, is known as the **record** for that car. Putting all the data together for all 20 cars produces a **file** like this.

| field 1 | field 2 | field 3 | field 4 | field 5 | field 6 | |
|---|---|---|---|---|---|---|
| car 1 | red | 1.5 litres | petrol | 3 doors | new | record 1 |
| car 2 | blue | 1.3 litres | petrol | 5 doors | used | record 2 |
| car 3 | green | 2.2 litres | diesel | 5 doors | used | record 3 |
| … | … | … | … | … | … | |
| car 20 | white | 1.6 litres | petrol | 2 doors | new | record 20 |

**Figure 3.1** Data for 20 cars in a showroom

### 3.2.1 Serial access

When using **serial access** it is necessary to start at the beginning of the file and then access each record in turn until the required record is found. In the example above, to find the record for car 15, it is necessary to first read all of the preceding records (that is, 1 to 14) until the required record is located.

It is primarily used on magnetic tape systems and is essentially a very slow form of data access. It is used in applications where speed of access, or where the order in which the data is accessed, isn't important (for example in utility billing, clearing bank cheques or producing pay slips).

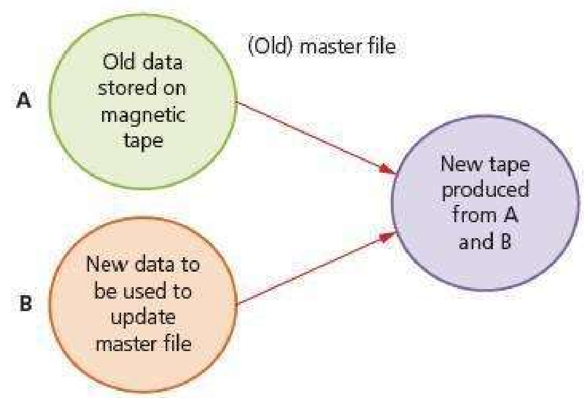



**Figure 3.2** Updating a magnetic tape

When the original magnetic tape (called the **master file**) needs **updating**, an additional tape (called a **transaction file**) is required. The transaction file contains all the new data to allow the master file to be updated (although the transaction file is very often another tape, the new data could in fact be stored on a different medium). The updated tape is referred to as the new master file. When using tapes, it is essential that the records on both master file and transaction file are sorted in the same order (for example, sorted by customer number if it is a billing application – the field used to sort the records is often referred to as a **key field**).

This is an example of how a master file (MF) can be updated using a Transaction File (TF). The scenario here is a book shop that sells books. All of the books held in stock are stored on the MF in ISBN order – the ISBN acts as the key field for each record (each different book title will have its own record made up of the ISBN, title of book, author, genre, cost price and selling price). All the changes during the day will be stored on the TF – if a book sells, if new books come in, if a book is out of print, and so on. At the end of each day, the

MF is updated using the new data stored on the TF. The basic steps in the update process are shown below:

- at the end of the day, the TF is sorted in the same order as the MF (this will be done using the ISBN which is known here as the key field)
- a new master file (NMF) is created to store the updated records of the books in the shop
- the first record in the TF is then read and the first record in the MF is also read
  - the two records are compared with each other
  - if the key field on the MF < the key field on the TF, then no transactions took place and the MF record is written to the NMF; a new MF record is now read
  - if the key field on the MF = the key field on the TF, then a transaction took place and the new record from the TF is written to the NMF; the next record from both the MF and TF are now read
  - if the transaction file indicates a deletion then the record is simply not written to the NMF and a new record from each file is read
  - if the key field on the MF is greater than the key field on the TF, then the record doesn't yet exist and a new record is created on the NMF and the record is written from the TF to the NMF; a new TF record is now read
- the process is repeated until the end of the MF
- finally, any remaining records on the TF are written to the NMF.

**Example**

The Master File (MF) contains the following records with key fields shown:

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 6 | 8 | 9 |

The Transaction File (TF) contains the following records with key fields shown:

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 2 | 4 | 5 | 7 | 8 | 10 |

The first record from each file is read. The key fields both match, so the record with key field 1 is written from the TF to the new master file (NMF):

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | |

The second record is then read from the MF and TF; again the keys are equal so the record on TF with key field 2 is now written to the NMF:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | | | | | | | | |

The third record is then read from the MF and TF; this time the key fields are different (3 and 4). The MF key < the TF key, so the MF record with key 3 is now written to the NMF:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | | | | | | | |

The next record from the MF is read. This time they are both 4 so the record on the TF is written to the NMF:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | | | | | | |

The next records form both MF and TF are read (6 and 5). The MF key is greater than the TF key, so a new record is created with key field 5. The new record is written to the NMF from the TF:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | | | | | |

The next record on the TF is read. Again they are different (6 and 7). The MF key < TF key, so the MF record with key 6 is now written to the NMF:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | | | | |

This process continues until all the records have been checked and the final NMF emerges:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

### Exercise 3a

Continue the above exercise for the remainder of records to see if you arrive at the above NMF. What would happen if two of the records on the TF (with key fields of 4 and 8) needed deletion to be carried out? What would be the final NMF?

## 3.2.2 Direct access

Direct access is used with magnetic disks, optical media and solid state media. The computer uses the key field to calculate where data should be stored. It is then able to access the data directly from the calculated position. Consequently, access is much faster than with serial access. When updating files using direct access, the old records/data are simply written over by the new records/data. It is not necessary to sort records into any specific order first.

It is used in applications where data access speed is vital (for example, in real-time operations such as controlling a chemical plant or online systems such as booking air tickets or automatic stock control).

# 3.3 Secondary storage media

Dating right back to the advent of the personal computer, all systems have come equipped with some form of secondary storage. When a user loads data into a computer, the information is stored temporarily in the RAM – if the computer was turned off, this data would be lost. Secondary storage devices ensure that data is stored permanently so that it can be used again at a later date. This section will consider the various types of secondary storage and the media used.

Throughout the chapter, you will notice that the term byte is used to measure the size of memory or storage. Typically, storage sizes or file sizes are measured in kilobytes (kB), megabytes (MB), gigabytes (GB) and terabytes (TB) as shown in Table 3.1.

**Table 3.1** File sizes

| Storage size | Number of bytes | Number of bytes as power of 10 |
|---|---|---|
| 1 KB | 1000 bytes | $10^3$ bytes |
| 1 MB | 1 000 000 bytes | $10^6$ bytes |
| 1 GB | 1 000 000 000 bytes | $10^9$ bytes |
| 1 TB | 1 000 000 000 000 bytes | $10^{12}$ bytes |

Note that this is different to memory sizes as used internally in the computer, where:
1 KB = 1024 ($2^{10}$) bytes, 1 MB = 1 048 576 ($2^{20}$) bytes, 1 GB = 1 073 741 824 ($2^{30}$) bytes and 1 TB = 1 099 511 627 776 ($2^{40}$) bytes. These values are all powers of 2.

This section reviews the various types of secondary storage devices available. These are either internal or external (that is, plug-in devices) to the computer.

Devices fall into the three different types of storage media:

- magnetic
- optical
- solid state.

## 3.3.1 Magnetic storage media

Magnetic storage media depend on the magnetic properties of certain materials (iron and nickel alloys being the most common). Magnetic material is coated on the surface of a disk or tape that can be magnetised in such a way as to represent a 1 or a 0. Many hard disk drives are made up of more than one disk and these disks are known as **platters**. Each platter is made from glass, ceramic or aluminium coated in a nickel alloy that can be magnetised. In the case of tape, plastic that is coated in a magnetic material is used to store the data.

### Fixed/internal hard disk drive (HDD)

**Fixed hard disk drives** are available on all computers and are the main method used for data storage. On a PC this is usually a fixed hard disk with read/write heads allowing data to be written to or read from the disk surface. The disk surface is coated in a magnetic film that allows data to be stored by altering the magnetic properties to represent binary 1s or 0s (the fundamental units of computer memories). The hard disks usually store the **disk operating system (DOS)** and other systems software, as well as applications software and files. Applications software (such as spreadsheets and word processors) also needs a hard drive to allow them to quickly retrieve and save data.

Uses

- To store the operating system, systems software and working data/files.
- Storing applications software that needs fast retrieval and storage of data.
- Used in real-time systems (for example, robots, control of a chemical plant where data for the process is stored to allow real-time operations) and in online systems (for example, booking airline tickets or automatic stock control using EFTPOS, which allows immediate updating of the stock files).
- Used in file servers for computer networks.

**Advantages**

- They have a very fast data transfer rate and fast access times to data.
- They have very large memory capacities.

**Disadvantages**

- Can be easily damaged if the correct shut down procedure is not carried out; this can lead to a head crash which would result in a loss of data.
- They have many moving parts when compared to, for example solid state drives (SSDs).
- Their read/write operation can be quite noisy compared to SSDs.

### Portable hard disk drives

These devices work in much the same way as fixed hard disk drives but are usually connected to the computer via the **USB (universal serial bus)** port and can be disconnected and used on different computers. The disks are generally capable of storing more data than the equivalent optical disk (CD, DVD and so on).

**Uses**

- They can be used as backup systems to prevent loss of data.
- They can be used to transfer data/files/software between computers.

**Advantages**

- The data access time and data transfer rate is very fast.
- They have a large memory capacity.
- They can be used as a method of transferring information between computers.

**Disadvantages**

- They can be easily damaged if dropped or subjected to a strong magnetic field; as with fixed hard disk drives, an incorrect shut-down procedure could also lead to loss of data.

## Magnetic tapes

A **magnetic tape** is a very thin strip of plastic that has been coated in a magnetic layer. They are read and written to by a read/write head. The data is stored in magnetic areas that represent 1s and 0s. Data is read from the tape using serial access (see earlier description). This type of storage is useless in a real-time or online applications (due to the very slow data access speeds) and is best suited to offline or batch processing.


**Uses**

- In applications where batch processing is used, for example, clearing bank cheques, utility billing (gas, electricity, water) and producing pay slips; in these applications there is no need for any specific processing order and speed of data access is not essential.
- Used as a backup media since all the data needs to be stored.
- Used in long-term archiving of data; magnetic tapes have huge data storage capacities and are known to be very stable, which makes them ideal for long-term storage.

**Advantages**

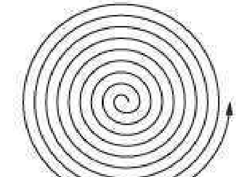
- They are generally less expensive (per byte) than the equivalent hard disk.
- It is a very robust technology (they don't deteriorate very much over time).
- They have a huge data storage capacity.
- The **data transfer rate** is actually fast (this should not be confused with data access time, which is very slow for magnetic tapes).

**Disadvantages**

- Very slow **data access times** (need to read all the earlier records on the tape until the required record is found – see Section 3.2).
- When updating, another tape is needed (see description in Figure 3.2 on page 45) to store the final updated version.
- They are affected by magnetic fields; a strong magnet can corrupt data stored on the tape.

## 3.3.2 Optical storage media

### CD/DVD disks



CDs and DVDS are described as optical storage devices. Laser light is used to read data and to write data on the surface of the disk. Both CDs and DVDs use a thin layer of metal alloy or light-sensitive organic dye to store the data.

As can be seen from the diagram, they use a single spiral track that runs from the centre of the disk to the edge.

The data is stored in 'pits' and 'bumps' on the spiral track. A red laser is used to read and write the data. CDs and DVDs can be designated as follows:

- R – write once only
- ROM – can only be read
- RW – can be written to or read from many times.

DVD technology is slightly different to that used in CDs. One of the main differences is the use of **dual-layering**, which considerably increases the storage capacity. Basically, this means that there are two individual recording layers. The two layers of a standard DVD are joined together with a transparent (polycarbonate) spacer; a very thin reflector is also sandwiched between the two layers. Reading and writing of the second layer is done by a red laser focusing at a fraction of a millimetre difference compared to the first layer.

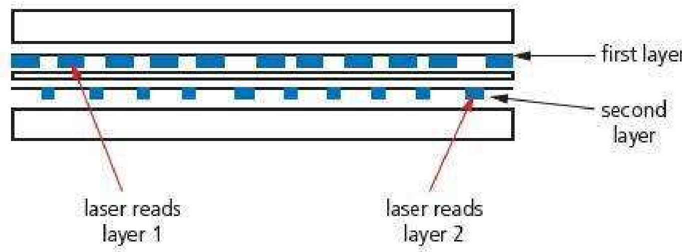



**Figure 3.3** Dual-layering in a DVD

Standard, single-layer DVDs still have a larger storage capacity than CDs because the 'pit' size and track width are both smaller. This means that more data can be stored on the DVD surface. DVDs use lasers with a wavelength of 650 nanometres; CDs use lasers with a wavelength of 780 nanometres. The shorter the wavelength of the laser light, the greater the storage capacity of the medium.

### CD-ROM and DVD-ROM

These optical disks are read-only memory (ROM), which means they cannot be written over and can only be read. The data is stored as a series of **pits** (equivalent to a binary value of 1) and **lands** (equivalent to the binary value of 0) in the metallic optical layer. The 'pits' are formed by a laser beam etching the surface at the manufacturing stage. Only a single track exists which spirals out from the centre of the disk.

The 'pits' and 'lands' are read by a low-powered laser beam that follows the data stream and reads from the centre outwards in a spiral. The light reflects differently off a 'pit' than it does off a 'land' and this is interpreted as 1s and 0s (that is, data) – hence the term digital media.

Uses

- CD-ROMs are used to store music files, software, computer games and reference software (such as an encyclopaedia).
- DVD-ROMs have much larger storage and are used to store films, computer data and ever-more sophisticated computer/arcade games.
- CD-ROMs and DVD-ROMs are used in applications where there is a real need to prevent the deletion or overwriting of important data.

**Advantages**

- They hold far more data than floppy disks (one CD/DVD could replace several floppy disks in some applications).
- They are less expensive than hard disk drive systems.

**Disadvantages**

- The data transfer rate/data access time is slower than for hard disks.

## CD-R and DVD-R

The letter R here means the disk is recordable *once* only; it becomes a CD-ROM or DVD-ROM once it has been finalised (this means that the CD/DVD cannot have any additional data written to it). This is the last step in the CD/DVD process; finalising is also used as an alternative word for the 'closing' of a CD-R, in which Table of Contents (TOC) data are written on the disc to enable the computer to read the CD/DVD.

A thin layer of an organic dye (DVDs also use an additional silver alloy or gold reflector) is used as the recording media. A laser beam produces **heated spots** and **unheated spots**. On reading the disk, a laser beam is capable of distinguishing between the two types of spots and effectively reads the data stream from the centre outwards in a spiral action. This data is then interpreted as 1s and 0s.

**Uses**

- Home recordings of music (CD-R) and films (DVD-R).
- Used to store data to be kept for later use or to be transferred to another computer.

**Advantages**

- Cheaper than RW disks.
- Once burned (and finalised) they are like a ROM.

**Disadvantages**

- If finalised, the CD-R/DVD-R can only be recorded on once; if an error in the data has occured then the disk has to be discarded since it can no longer be written to.
- Not all CD/DVD players can read CD-R/DVD-R.

## CD-RW and DVD-RW

The RW means these disks are a rewritable media and can be written over several times. Unlike CD-R/DVD-R, they don't become ROMs. The recording layer uses a special phase-changing metal alloy (often GeSbTe [Germanium-Antimony-Terbium alloy]; a number of different methods are used to produce these alloys). The alloy can switch between crystalline phase and amorphous phase (non-crystalline), thus changing its reflectivity to light depending on the laser beam power. **Spots** are produced that can be read by a laser and then interpreted as 1s and 0s. The system allows data to be written, erased and rewritten many times.

**Uses**

- Used to record television programmes (like a video recorder), which can be recorded over time and time again.
- Not as wasteful as R format as more files/data can be added to at a later stage (with CD-R/DVD-R it is only possible to do a write operation once if you have already finalised the disc).
- Used in CCTV systems.

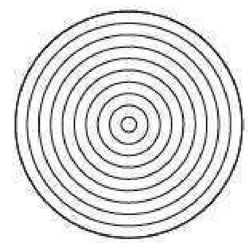
**Advantages**

- Can be written over many times.
- Can use different file formats each time it is used.

**Disadvantages**

- Can be relatively expensive.
- It is possible to accidentally overwrite data.

## DVD-RAM



**DVD-RAM** uses a very different technology to CDs and DVDs. They have the following features:

- instead of a single, spiral track, they use a number of concentric tracks
- the use of concentric tracks allows simultaneous read and write operations to take place
- they allow numerous read and write operations (up to 100 000 times) and have great longevity (over 30 years), which makes them ideal for archiving
- DVD-RAMs can be written to and read from many times.

The recording layer is made from a similar phase-changing material as used in RW technology. When writing, a laser heats the phase-changing alloy on the disk to about 500 °C to 700 °C changing the reflective properties from shiny to dull (i.e. **pits**). If the disk needs to be erased, a laser heats the surface to about 200 °C to return the disk to its original shiny state. A low-power laser is used to read the written marks on the surface. The shiny and dull marks ('pits') represent data to a computer where they are interpreted.

**Uses**

- In recording devices such as satellite receivers to allow simultaneous recording and playback.
- Used in camcorders to store movies.

**Advantages**

- They have a long life (estimated 30 years minimum life).
- It is possible to do a rewrite operation over 100 000 times (compare this to the RW format, which only allows about 1000 rewrites).
- Writing on DVD-RAMs is very reliable – they have in-built verification software, so the accuracy of the data is ensured.
- Very fast access if the files are fairly small.
- No need to **finalise** the disk.
- Very large capacity (about 10 GB if double-sided format I is used).
- They offer the ability to read data at the same time as data is being written.

### Disadvantages

- Not as compatible as R or RW format; many systems won't recognise the DVD-RAM format.
- Relatively expensive (about four times the cost of a DVD-RW disk).
- They have been superseded by newer technologies such as solid state memories.

## Blu-ray discs


**Blu-ray discs** are another example of optical storage media. However, they are fundamentally different to DVDs in their construction and in the way they carry out read-write operations.

The main differences are:

- a blue laser, rather than a red laser, is used to carry out read and write operations; the wavelength of blue light is only 405 nanometres (compared to 650 nanometres for red light)
- using blue laser light means that the 'pits' and 'bumps' can be much smaller; consequently, Blu-ray can store up to five times more data than a normal DVD
- Blu-ray uses a single 1.1 mm-thick polycarbonate disk; normal DVDs use a sandwich of two 0.6 mm thick disks
- using two sandwiched layers can cause **birefringence** (light is refracted into two separate beams causing reading errors); because Blu-ray uses only one layer, the disks don't suffer from birefringence
- Blu-ray discs automatically come with a secure encryption system, which helps to prevent piracy and copyright infringement.

Table 3.2 summarises the main differences between CDs, DVDs and Blu-ray.

**Table 3.2** Comparison of CDs, DVDs and Blu-ray

| Disk type | Laser colour | Wavelength of laser light | Disk construction | Track pitch (distance between tracks) |
|---|---|---|---|---|
| CD | red | 780 nm | single 1.2 mm polycarbonate layer | 1.60 μm |
| DVD | red | 650 nm | two 0.6 mm polycarbonate layers | 0.74 μm |
| Blu-ray | blue | 405 nm | single 1.1 mm polycarbonate layer | 0.30 μm |

Note: nm = $10^{-9}$ metres; μm = $10^{-6}$ metres.

### Uses

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

**Advantages**

- Very large storage capacity, therefore ideal for storing high-definition movies.
- Very fast data transfer rate.
- The data access speed is also greater than with other optical media.
- Blu-ray discs automatically come with a secure encryption system, which helps to prevent piracy and copyright infringement.

**Disadvantages**

- Relatively expensive.
- Encryption problems (which are used to stop piracy) when used to store video.
- There are fewer movie titles on Blu-ray format, which is reducing its impact on the home movie market.

All these optical storage media are used as backup systems (for photos, music and multimedia files). This also means that CDs and DVDs can be used to transfer files between computers. Manufacturers often supply their software using CDs and DVDs. When the software is supplied in this way, the disk is usually in a read-only format.

The most common use of DVD and Blu-ray is the supply of movies or games. The memory capacity of CDs isn't big enough to store most movies.

## The future of optical media

In recent times both the CD and DVD are showing signs of becoming obsolete. Many computer systems now come with USB connectors only and no DVD or CD drive. The main method of transferring files between devices has become flash memory. Many people now store all their music in the following ways:

- on hard disk drive systems (set up as sound systems, as shown in the photo)
- in MP3 format on:
  - a computer/tablet
  - their mobile/smartphone
  - a portable music player (such as an iPod)
- using the 'cloud' to store all their files so they can access their music from anywhere in the world
- by 'streaming' their music from the internet; provided the user has an internet connection they can access music through a laptop computer, mobile phone, tablet or any other receiving device.


It is a similar story for movies, where streaming is becoming increasingly common. Many television sets are now set up as 'smart' televisions – this means it is now possible to simply stream movies or television programmes on demand without the need for any DVD or Blu-ray players. In effect, the television set has become the central computer with a link to the internet using wireless connection.

Floppy disks met the same fate in the early twenty-first century. How often do you see floppy disks? It is very likely that CDs and DVDs will meet the same fate and be replaced by one of the systems described above or something entirely new.

## Exercise 3b

Using this student book and the internet, do some research to find out all the different ways to store music files and movie files.

Draw a table similar to the one shown below to list all the advantages and disadvantages of each of the methods you have identified.

| Storage method | Advantages | Disadvantages |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |

## 3.3.3 Solid state storage media

### Solid state drives (SSD)

**Solid state drives (SSD)** are rapidly taking over from HDDs. They have no moving parts and all data is retrieved at the same rate no matter where it is stored. They don't rely on magnetic properties; the most common type of solid state storage devices store data by controlling the movement of electrons within NAND* chips. The data is stored as 0s and 1s in millions of tiny transistors within the chip. This effectively produces a non-volatile rewritable memory.

*NAND flash memory is a type of non-volatile storage that does not require power to retain data. NAND flash memory stores data in an array of memory cells made from floating-gate transistors which are insulated from each other by an oxide layer. NAND is a type of logic gate and is basically one of the building blocks of many electronic circuits including solid state storage devices.

However, a number of solid state storage devices sometimes use **electronically erasable programmable read-only memories (EEPROM)** technology. The main difference is the use of NOR* chips rather than NAND. This makes them faster in operation; however, devices using EEPROM are considerably more expensive than those that use NAND technology. EEPROM also allows data to be read or erased in single bytes at a time. Use of NAND only allows blocks of data to be read or erased. This makes EEPROM technology more useful in certain applications where data needs to be accessed or erased in byte-size chunks.

*NOR flash memory is also a type of non-volatile storage; a NOR gate is a type of logic gate that makes up many electronic circuits. NOR gates work in a different way to NAND gates, but the differences are outside the scope of this student book. Essentially, solid state memories made from NOR gates allow faster read/write operations than those made from NAND gates, but the storage devices cost much more to manufacture – consequently, most solid state storage devices use NAND gate technology.

Because of the cost implications, the majority of solid state storage devices use NAND technology. The two are usually distinguished by the terms **flash** (uses NAND) and **EEPROM** (uses NOR).

So, what are the main advantages of using SSD rather than HDD? The main advantages of SSDs are summarised below:

- they are more reliable (no moving parts to go wrong)
- they are considerably lighter (which makes them suitable for laptops)
- they don't 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 there are no moving parts, they are very thin
- data access is considerably faster than HDD.

The main drawback of SSD is the questionable longevity of the technology. 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 not used in internet servers, for example, where a huge number of write operations take place every day. However, this issue is being addressed by a number of manufacturers to improve the durability of these solid state systems.

## Memory sticks/pen drives

**Memory sticks/pen drives** can store several gigabytes of data and use the solid state technology described above. They are usually connected to a computer through the USB port and power to operate them is drawn from the host computer. They are extremely small and very portable. Most operating systems recognise these storage media, which means no additional software is needed to operate them.

Some expensive software now uses these storage methods (sometimes referred to as portable flash drives) as a form of security. They plug into the computer using the USB port and are known as **dongles**. The software installed on a computer sends out a request (in encrypted form) to the dongle asking for an encrypted validation key. Thus a person trying to carry out **software piracy** would have to break the code on the dongle first before they could use the software. Some systems go one stage further and have key bits of software stored on the dongle in encrypted form. The software looks for these pieces of encrypted code to enable it to run. This gives an added security benefit to the software.

### Uses

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

### Advantages

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

**Disadvantages**

- Can't write-protect the data/files.
- Easy to lose (due to their 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, rendering it useless.

## Flash memory cards

These are a form of electrically **erasable programmable read-only memory (EEPROM)** and are examples of solid state memories.


**Uses**

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

**Advantages**

- Very compact and can be easily removed and used in another device or for transferring photos directly to a computer or printer.
- Since they are solid state memories, they are very robust.

**Disadvantages**

- Expensive per gigabyte of memory when compared to hard drive disks.
- Have a finite life regarding the number of times they can be read from or written to.
- Have a lower storage capacity than hard disks.