AQA Computer Science A-Level

4.7.4 External hardware devices

Advanced Notes

Specification:

4.7.4.1 Input and output devices:

Know the main characteristics, purposes and suitability of the devices and understand their principles of operation.

Devices that need to be considered are:

- barcode reader
- digital camera
- laser printer
- RFID

4.7.4.2 Secondary storage devices:

Explain the need for secondary storage within a computer system.

Know the main characteristics, purposes, suitability and understand the principles of operation of the following devices:

- hard disk
- optical disk
- solid-state drive (SSD)

Compare the capacity and speed of access of various media and make a judgement about their suitability for different applications.

Input and output devices

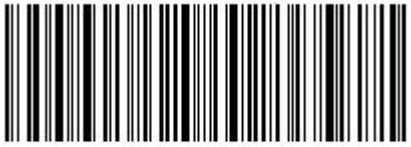
In order to make use of data, computers must be able to use various devices which allow the computer to have data input and output.

Barcodes and barcode readers

When you buy something in a supermarket, the chances are that a barcode reader is used by the computer to identify what it is you're buying.

Barcodes are printed diagrams that consist of light and dark portions. They contain information which can be read by a computer using a barcode reader. There are two main types of barcode: 1D and 2D.

1D



2D

2D barcodes can contain more information in the same amount of space as a 1D barcode but require more processing in order for the information to be extracted.

Barcode readers consist of a laser light source, a lens, photodiodes and a mirror. The mirror directs light from the laser onto a printed barcode. The light reflected by the barcode passes through the lens and is incident on the photodiode which turns light into electrical charge. This electrical charge can be measured and processed to form a digital signal representing the content of a barcode.

Light portions of a barcode reflect the most light while dark sections absorb incident light. The pattern of light and dark stripes in a barcode corresponds to binary 1s and 0s.

Barcodes can have error detection and prevention methods such as parity bits and check digits built in, allowing computers to tell whether a barcode has been read correctly. If a barcode fails to scan correctly, perhaps because the barcode is dirty, the reader will continue to scan until the barcode is read successfully. Barcode readers can scan barcodes 1000s of times a second, so the time delay caused by rescanning is hardly perceptible to humans.

Synoptic Link

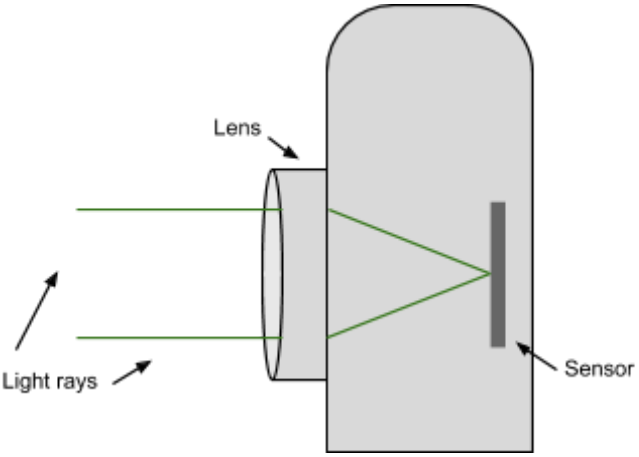
Parity bits and **check digits** are ways to check for errors in data transmission.

These are covered in **information coding systems** under **fundamentals of data representation**.

Digital cameras

Digital cameras consist of a lens that focuses light onto a sensor. The path of light between the lens and the sensor is regulated by a shutter.

Two sensors commonly used in digital cameras are CMOS (complementary metal oxide semiconductor) and CCD (charge coupled device) which both convert incident light into electrical charge. Charge builds up in cells, each of which represents a pixel in the image. Once the photograph has been taken, the charge in each of the cells is measured and converted to a digital value which is then processed by the camera and stored as a digital image.

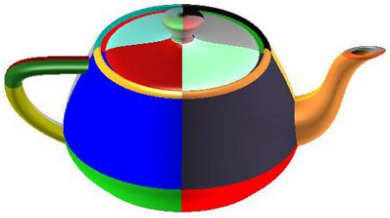


In colour cameras, there are multiple cells for each pixel, each of which has a filter that only allows in certain wavelengths of light. This lets the camera build up a separate image for the intensity of each colour of light which can then be combined to form a full colour photograph.

Red light intensity

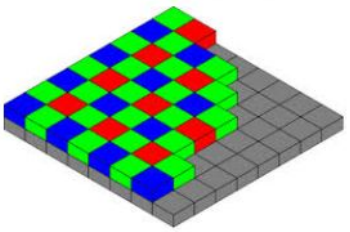
Green light intensity

Blue light intensity



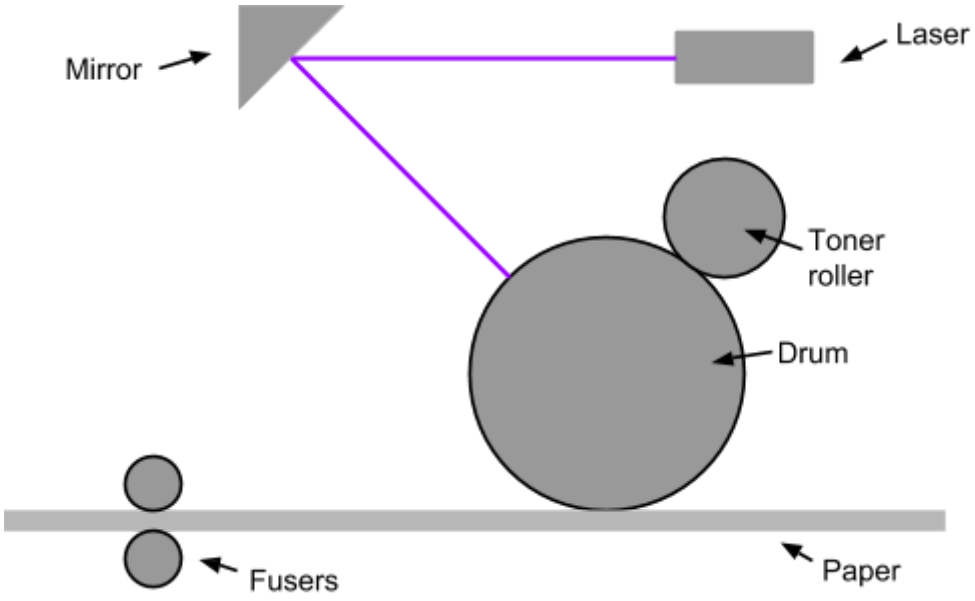
Red, green and blue combined

A Bayer filter is a special colour filter used in digital cameras that has the same number of green filters as red and blue combined. Using a Bayer filter produces an image that is a closer approximation of what the human eye, which is most sensitive to green light, sees.



Laser printer

A laser printer is an output device that produces images on paper from digital signals. Laser printers, which print whole pages at a time, consist of a laser light source, a mirror, a drum, a toner roller and fusers.



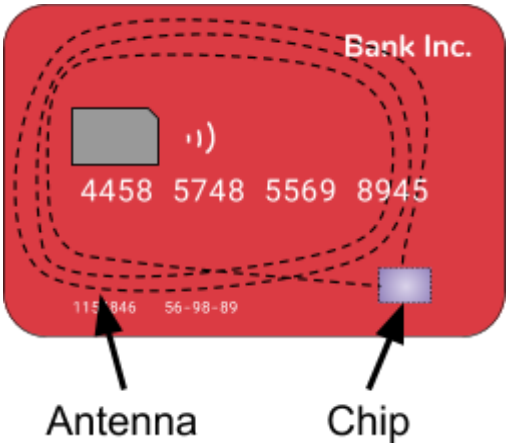
When a document is printed, the drum is positively charged all over before the laser is directed at its surface by the mirror. Areas on which the laser is incident are discharged, leaving behind an impression of the page in electrical charge on the drum.

The toner roller dispenses negatively charged toner (a type of plastic powder) onto the drum. As opposite charges attract, toner is attracted to the positively charged portions of the drum. The toner is then applied to the paper by the drum before the paper is heated by fusers, fixing the toner to the paper.

Colour printers apply the same process with four different colours of toner: cyan, yellow, magenta and black (CYMK) to achieve full colour prints.

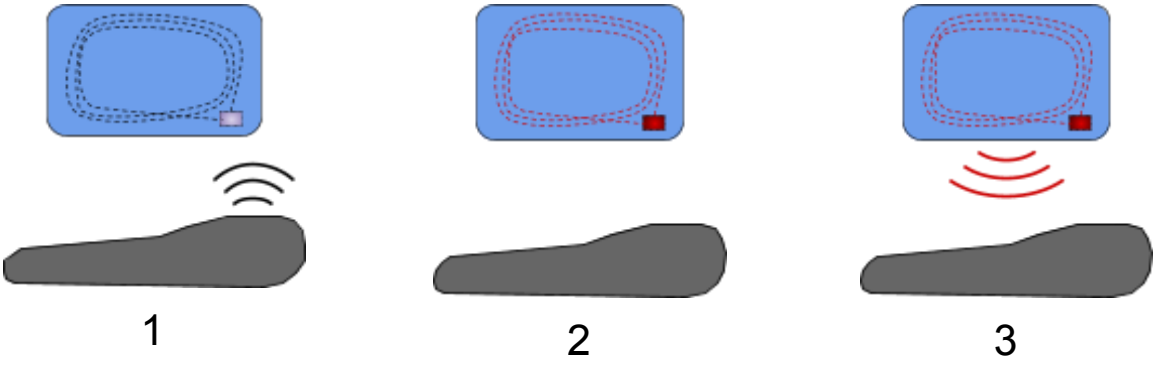
RFID

RFID, which stands for radio frequency identification, is a method of transferring information wirelessly between a tag and a reader. RFID is used in contactless credit and debit cards as well as in some hotel room cards.



Inside an RFID tag is a chip which contains a small amount of memory. The chip is attached to a coil of wire which acts as an antenna.

Most RFID tags are passive, meaning that they induce enough power wirelessly from the reader to operate the chip. However, active tags (which contain a small power supply like a battery) also exist. Active tags can be used much further away from readers than passive tags which must be held within a few centimeters of their reader.



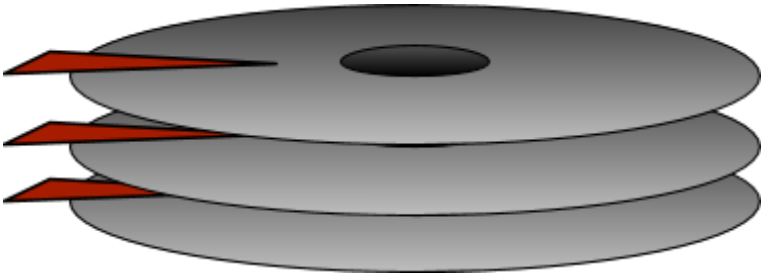
When an RFID tag is scanned, the reader emits radio waves which are picked up by the tag's antenna (stage 1). The power induced in the tag's antenna from these waves is enough to power the chip (stage 2) which then uses its antenna to emit its own radio wave (stage 3), which contains the information held on the chip. This wave is picked up by the reader which decodes the information and returns the information to a computer.

Secondary storage devices

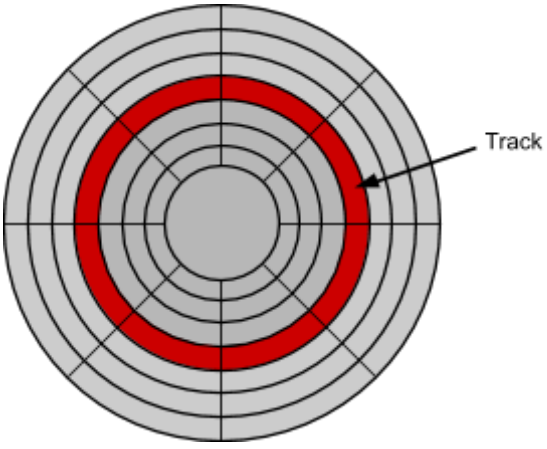
A computer's primary storage is memory such as RAM and ROM. Secondary storage, which is used to store files and applications, includes hard disk drives (HDDs), solid-state drives (SSDs) and optical disks.

Hard disk drives

A hard disk drive consists of a number of circular platters which are made from a magnetic material. Above each platter hovers an actuating arm on which is a read/write head.



The actuating arm allows the read/write head, which changes the magnetic polarity of parts of the platter, to access all portions of each platter.



Data is written in concentric tracks, each of which is further divided into sectors. The platter rotates thousands of times per minute, allowing for good read and write speeds.

Hard disk drives typically come in capacities of between 500GB and 5TB. Adding more platters and decreasing the width of tracks are two ways in which hard disk drives can be kept the same size while increasing their capacity.

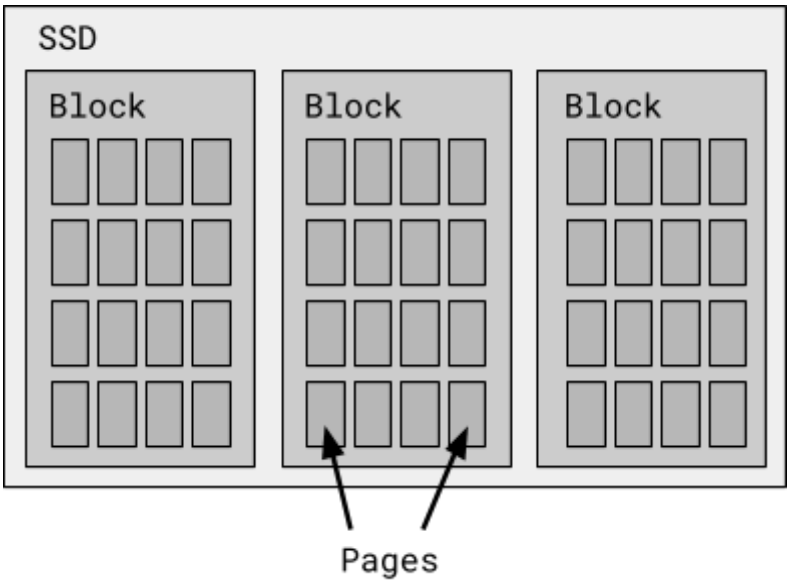
Because of the number of moving parts in hard disk drives, they are susceptible to damage from movement. This makes them unsuitable for use in portable devices like phones and tablets.

Solid-state drives

Solid-state drives (SSDs) consist of NAND flash memory cells and a controller that manages the structure of data on the drive.

NAND flash memory is non-volatile, meaning that an SSD's contents are retained even when there is no power being supplied. The memory cells are formed of floating gate transistors which store information by trapping electrical charge.

Data is stored on SSDs in pages, which are combined to form blocks.



Unlike hard disk drives, SSDs are not capable of overwriting data. Instead, an SSD's controller must completely erase the entirety of a page before writing new information to it.

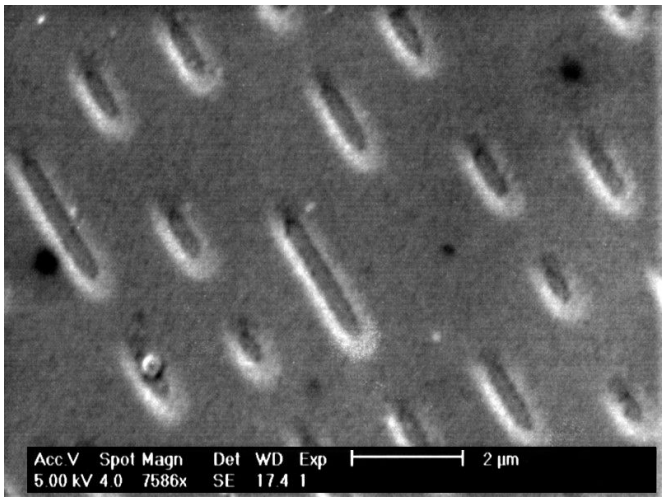
Because SSDs don't have any moving parts, they are capable of far higher read and write speeds than HDDs and are suitable for use in portable devices like phones and tablets.

Optical disks

Optical disks include CDs, DVDs and Blu-rays. They store information which can be read optically by a laser. Optical disks can be either read-only, recordable or rewritable depending on what they are to be used for.

Different types of optical disk vary slightly but all follow the same basic principles of operation.

The image below shows a microscope view of the surface of a read-only optical disk. The stripes in the image are called pits, and the areas surrounding them called lands. Pits are burnt into the disk by a high-power laser which permanently deforms the surface.



Unlike hard-disk drives which use tracks and sectors, optical disks have just one continuous track which spirals from the center of the disk to the outside edge.

When a low-power laser beam is passed over the flat surface of an optical disk, it reflects back onto a photodiode. However, when the laser is incident on a pit, the light from the beam is scattered in different directions rather than reflected back at the photodiode. The resulting pattern of reflections and scatters can be converted into a digital signal of binary 1s and 0s.

On recordable and rewritable optical disks, a pattern of reflections and scatters is created not by pits and lands but by an opaque dye on the disk's surface. Where there is no dye, the disk reader's laser beam is reflected off of the optical disk's surface. Where there is dye, the laser beam is absorbed by the dye and not reflected at all.

Recordable optical disks use a special photosensitive dye which changes from opaque to transparent under a high-power laser which is used to write information to the disk. The dye remains unaffected by the low-power laser used to read the disk.

Comparison of secondary storage devices

	Hard-disk drive	Solid-state drive	Optical disk
Typical capacity	High capacity. Typically between 500GB and 5TB.	Relatively low capacity. Typically under 1TB.	Very low capacity. Blu-rays have the highest capacity at 25GB.
Read / write speeds	Good speeds. ≈ 100MB/s	Very high speeds. ≈ 500MB/s	Relatively low speeds. ≈ 30MB/s
Latency	High	Very low	High
Portability	Bulky, heavy and easily damaged by movement.	Lightweight and rarely damaged by movement.	Very small and lightweight, can be damaged by scratches and dirt.
Power consumption	High	Low	High
Suitability	Good for desktop PCs and servers.	Good for laptops, phones and tablets.	Good for sharing and distributing small volumes of data.