Exercise walk-through

3.1.1 Hardware devices, memory and control systems

A-Level Computer Science

You must be able to

- explain the need for input, output, primary memory and secondary storage, including removable storage
- describe the principal operation of a magnetic hard disk, solid state (flash) memory, an optical disc reader or writer, a microphone, a speaker, a touchscreen, a virtual reality headset, a laser printer and a 3D printer
- explain why a buffer is used, and how it works
- describe an embedded system with its benefits and drawbacks, and say what its RAM and ROM are used for
- explain the differences between RAM and ROM, SRAM and DRAM, and PROM, EPROM and EEPROM, for a given device
- choose sensors and actuators for a monitoring or control system, and explain the importance of feedback

1 The method

Method — Describing the principal operation of a device

A question that says **describe the principal operation** gives one mark for each correct step, in order. So:

1. name the main parts of the device;
2. say what happens to the data, step by step, with the technical words;
3. finish with the result: what is output, or what is stored.

Magnetic hard disk.

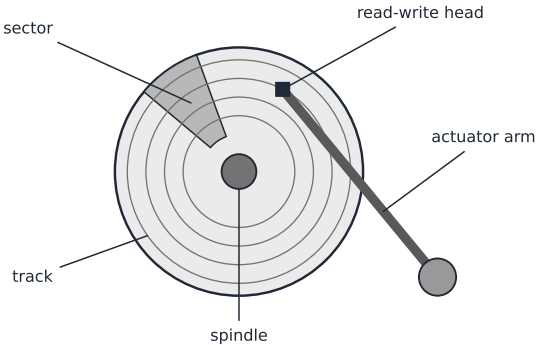
- The disk has one or more **platters** 盘片 with a magnetic coating. Each surface is divided into **tracks** 磁道 and **sectors** 扇区.
- A spindle spins the platters at high speed.
- An **actuator arm** moves the **read-write head** to the correct track, and the head waits for the correct sector to pass underneath it.

Method — Describing the principal operation of a device

- To write, the head changes the direction of magnetisation of tiny areas: one direction stores 1 and the other stores 0.
- To read, the head detects the direction of magnetisation of each area as it passes.

Method — Describing the principal operation of a device

A question that says describe the principal operation gives one mark for each correct step, in order.



Method — Solid state (flash) memory

- Data is stored in **NAND flash** memory chips, made of millions of **transistors** 晶体管 arranged in a grid of cells.
- Each cell stores a bit as electrons trapped in the transistor. The electrons stay when the power is off, so flash memory is **non-volatile**.
- A voltage moves electrons into or out of a cell to write data. Data is erased and rewritten in **blocks**, and a controller keeps track of where each file is.
- There are **no moving parts**.

	magnetic hard disk	**solid state drive**
access speed	slower: the head must move and the platter must turn	faster: no moving parts
robustness	can be damaged if it is dropped while running	more robust
power and heat	more	less
cost per GB	lower	higher
typical use	video archives and backups on a server	laptops, phones, the operating system drive

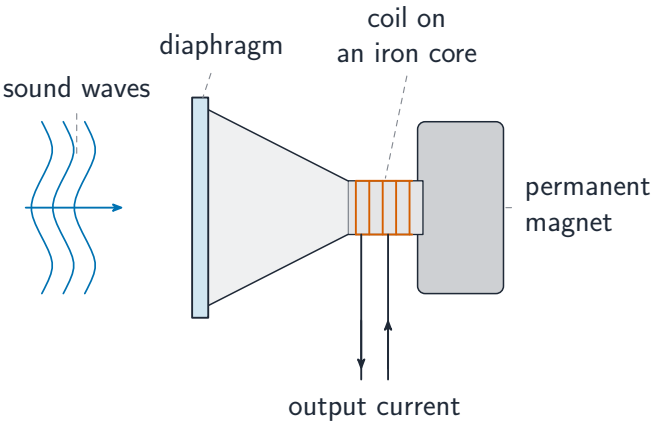
Method — Solid state (flash) memory

Removable storage, such as a USB flash drive or an optical disc, lets data be carried between computers or kept as an off-site backup.

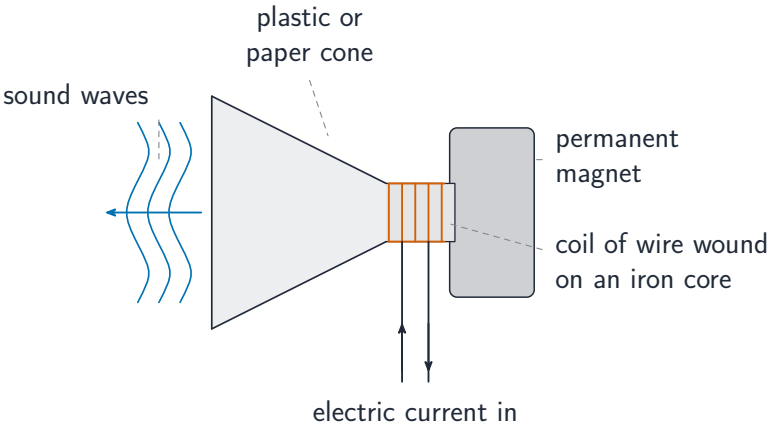
Method — Sound in and sound out

- **Microphone:** sound waves make the **diaphragm** 膜片 vibrate. The diaphragm moves a coil backwards and forwards near a permanent magnet, which produces a varying electric current. This is an **analogue** signal, and an **ADC** converts it to binary for the computer.
- **Speaker:** a **DAC** converts the digital sound into a varying current. The current flows through a coil, which becomes an **electromagnet**. As the current changes, the coil is attracted to and repelled by the permanent magnet, so the cone vibrates and makes sound waves.

Method — Sound in and sound out



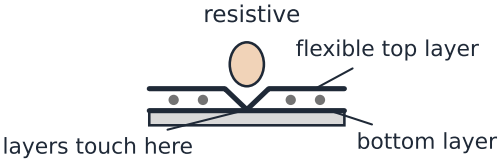
Method — Sound in and sound out

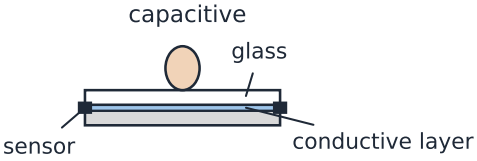


Method — Touchscreens

	resistive	**capacitive**
layers	two flexible conductive layers with a small gap	glass over a conductive layer that holds an electrostatic field
a touch	pressure pushes the layers together and completes a circuit at that point	the finger draws a little charge, so the current changes at that point
finding the position	the microprocessor measures the voltage where the layers touch	sensors at the corners measure the change, and the microprocessor calculates the position
in use	works with gloves or any stylus; cheaper	needs a bare finger; supports multi-touch; clearer image

Method — Touchscreens





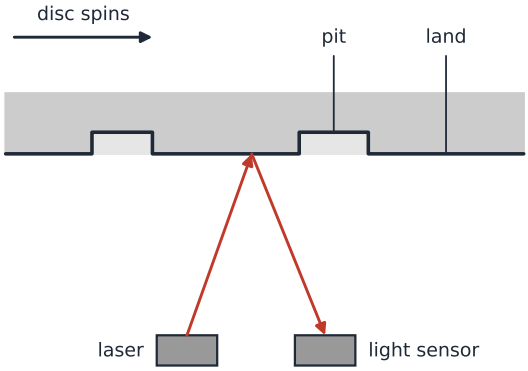
Method — Optical discs, VR headsets and printers

- **Optical disc reader:** the disc spins. A **laser** shines on the reflective surface, which has **pits** 凹坑 and **lands** 平面 along a spiral track. A light sensor detects the reflected light. The reflection changes at the edge of a pit, and these changes are read as binary data.
- **Optical disc writer:** a stronger laser changes the surface (it burns a dye layer), so that some areas reflect light differently.
- **Virtual reality headset:** two small screens, or one screen split in two, show a slightly different image to each eye, so the scene looks **3D**. Lenses focus the images. **Sensors** 传感器 such as a **gyroscope** 陀螺仪 and an **accelerometer** 加速度计 detect the movement of the head, and the processor changes the images so that the view follows the head.

Method — Optical discs, VR headsets and printers

- **Laser printer** and **3D printer:** see sheet 3.1. A laser draws the page as charge on a drum, and toner is transferred and fused; a 3D printer builds the object layer by layer from a sliced design.

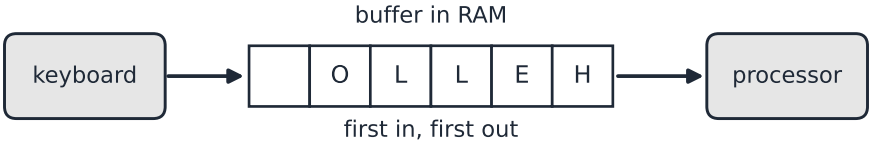
Method — Optical discs, VR headsets and printers



Method — Buffers

- A **buffer** is a temporary area of memory (RAM) that holds data while it moves between two devices or processes that work at different speeds.
- **Keyboard buffer:** key presses are stored in order until the processor is ready, so no key press is lost while the computer is busy.
- **Streaming video:** the next part of the video is downloaded into a buffer before it is played, so the video plays smoothly even when the download rate changes.
- A buffer works as a **queue** 队列: first in, first out.

Method — Buffers



Method — Embedded systems and their memory

An **embedded system** is a microprocessor-based computer inside a larger device, with a **dedicated** 专用的 function, for example the controller of a washing machine.
Random Access Memory (RAM) is volatile and can be read and written; **Read Only Memory (ROM)** is non-volatile. A range of devices use both, for example:

memory	**what it holds in a washing machine**	**why**
ROM or EEPROM	the program (firmware) for the wash cycles	**non-volatile**: kept when the machine is switched off; EEPROM lets the maker update it electrically
RAM	the chosen wash, the current water temperature and the time left	**volatile** working data that changes during the wash

Method — Embedded systems and their memory

- **Benefits:** small, low power, cheap to mass-produce, reliable, and ready as soon as it is switched on.
- **Drawbacks:** hard to upgrade or repair, limited to one task, and a connected device can be hacked if it is not updated.
- **Static RAM (SRAM) or Dynamic RAM (DRAM)?** SRAM uses flip-flops, is faster and needs no refreshing, so it is used for **cache**. DRAM uses a transistor and a **capacitor 电容器** for each bit, is cheaper and holds more data per chip, so it is used for **main memory**, but it must be refreshed. Which one a device uses depends on what it needs: speed, or a lot of memory at a low cost.
- **Programmable ROM (PROM)** can be programmed once. **Erasable Programmable ROM (EPROM)** is erased with ultraviolet light, out of the device. **Electrically Erasable Programmable ROM (EEPROM)** is erased electrically, while it stays in the device.

Method — Sensors, actuators and feedback

sensor	**detects**	**example system**
temperature	how hot or cold something is	an incubator, a fridge
pressure	force on an area	a car tyre, a floor mat in a burglar alarm
infra-red	heat radiation, or a broken beam	a security light, a hand dryer
sound	noise level	a noise meter in a library

Method — Sensors, actuators and feedback

- A **monitoring system** reads the sensors and only records or reports the data, for example by sounding an alarm.
- A **control system** also sends signals to **actuators** 执行器 (motors, pumps, heaters, valves) that change the conditions.
- **Feedback** 反馈: the output affects the next input. The sensors measure the effect of each change, so the processor can keep the conditions near the target.

2 Practice

Practice 2.1 ▪ 2 marks

Explain why a computer needs both primary memory and secondary storage.

Solution 2.1

Method: Embedded systems and their memory — p.19

Worked steps

- primary memory holds the programs and data the processor is using now, and the processor can access it directly and quickly B1
- secondary storage keeps programs and data when the power is off (non-volatile), and it holds much more B1

Practice 2.2 ▪ 3 marks

Describe how data is read from a magnetic hard disk.

Solution 2.2

> Method: Describing the principal operation of a device — p.4

Worked steps

any **three** of:

- the platter spins on the spindle B1
- the actuator arm moves the read-write head to the correct track B1
- the head waits for the correct sector to pass under it B1
- the head detects the direction of magnetisation of each area, which gives the 1s and 0s B1

Practice 2.3 ▪ 2 marks

Give **two** reasons why a laptop uses a solid state drive instead of a magnetic hard disk.

Solution 2.3

Method: Solid state (flash) memory — p.7

Worked steps

any **two** of:

- faster access to data, because there are no moving parts B1
- more robust if the laptop is dropped B1
- uses less power, so the battery lasts longer B1
- lighter and thinner B1

Practice 2.4 ▪ 3 marks

Describe how a **capacitive** touchscreen detects where it is touched.

Solution 2.4

Method: Touchscreens — p.12

Worked steps

- the glass has a conductive layer with an electrostatic field B1
- a finger draws a little charge, so the current changes at the point of touch B1
- sensors at the corners measure the change, and the microprocessor calculates the position B1

Practice 2.5 ▪ 2 marks

A video streaming app stores the next part of a video in a buffer. Explain why.

Solution 2.5

Method: Buffers — p.17

Worked steps

- the download rate over the internet can change, but the video must play at a steady rate B1
- the buffer holds data downloaded ahead of playback, so the video does not stop and wait B1

Practice 2.6 ▪ 3 marks

Identify the most suitable type of sensor for each system.

Practice 2.6 (a) ▪ 1 mark

a light that switches on when a person walks past at night

Solution 2.6 (a)

Method: Sensors, actuators and feedback — p.21

Worked steps

an **infra-red** (motion) sensor B1

Practice 2.6 (b) ▪ 1 mark

an alarm that sounds when a car tyre is under-inflated

Solution 2.6 (b)

Worked steps

a **pressure** sensor B1

Practice 2.6 (c) ▪ 1 mark

a display that warns when a library is too noisy

Solution 2.6 (c)

Worked steps

a **sound** sensor B1

3 Exam-style

Exam-style 3.1 ▪ 6 marks

A video call app uses a microphone and a speaker.

Exam-style 3.1 (a) ▪ 3 marks

Describe the principal operation of a microphone.

Solution 3.1 (a)

Method: Describing the principal operation of a device — p.4

Worked steps

any **three** of:

- sound waves make the diaphragm vibrate B1
- the diaphragm moves a coil backwards and forwards near a permanent magnet B1
- this produces a varying electric current B1
- the analogue signal is converted to digital by an ADC B1

Exam-style 3.1 (b) ▪ 3 marks

Describe the principal operation of a speaker.

Solution 3.1 (b)

Worked steps

any **three** of:

- a DAC converts the digital sound into a varying current B1
- the current flows through a coil, which becomes an electromagnet B1
- the coil is attracted to and repelled by the permanent magnet as the current changes B1
- so the cone vibrates and produces sound waves B1

Exam-style 3.2 ▪ 5 marks

A museum keeps copies of its old films on Blu-ray discs.

Exam-style 3.2 (a) ▪ 3 marks

Describe how data is read from an optical disc.

Solution 3.2 (a)

Worked steps

any **three** of:

- the disc spins, and a laser shines on its surface **B1**
- the surface has pits and lands along a spiral track **B1**
- a light sensor detects the reflected light **B1**
- the change in reflection at the edge of a pit is read as binary data **B1**

Exam-style 3.2 (b) ▪ 2 marks

The museum also stores the films on magnetic hard disks in an archive computer. Give **two** reasons why magnetic hard disks are suitable for this archive.

Solution 3.2 (b)

Worked steps

any **two** of:

- films are large files, and magnetic storage has a lower cost per GB B1
- very large capacities are available B1
- the archive computer does not move, so being less robust does not matter B1
- fast access is not needed for an archive B1

Exam-style 3.3 ▪ 4 marks

A trainee surgeon practises operations using a virtual reality headset. **Describe** how the headset gives a 3D view that follows the movement of the surgeon's head.

Solution 3.3

Method: Optical discs, VR headsets and printers — p.14

Worked steps

any **four** of:

- two screens, or one split screen, show a slightly different image to each eye B1
- so the brain sees the scene in 3D B1
- lenses focus the images for the eyes B1
- sensors such as a gyroscope and an accelerometer detect the movement of the head B1
- the processor updates the images so the view changes as the head moves B1

Exam-style 3.4 ▪ 4 marks

A student types quickly while the computer is busy running a large program.

Exam-style 3.4 (a) ▪ 3 marks

Explain how a keyboard buffer makes sure that no key presses are lost.

Solution 3.4 (a)

Worked steps

each key press is stored in the buffer, in RAM, in the order it was typed B1

- the processor takes the key presses from the buffer when it is ready B1
- first in, first out, so the characters are processed in order and none is lost while the processor is busy B1

Exam-style 3.4 (b) ▪ 1 mark

State **one** reason why DRAM, not SRAM, is used for the computer's main memory.

Solution 3.4 (b)

Worked steps

DRAM is cheaper and holds more data per chip, so a large main memory is affordable B1

Exam-style 3.5 ▪ 10 marks

A smart thermostat controls the heating in a house. Its controller is an embedded system.

Exam-style 3.5 (a) ▪ 2 marks

Explain why the controller is an embedded system.

Solution 3.5 (a)

Method: Embedded systems and their memory — p.19

Worked steps

it is a microprocessor-based system inside a larger device B1

- it has one dedicated task: controlling the heating B1

Exam-style 3.5 (b) ▪ 2 marks

Give **one** benefit and **one** drawback of using an embedded system in the thermostat.

Solution 3.5 (b)

Worked steps

benefit, e.g. small, cheap, low power or reliable B1

- drawback, e.g. hard to upgrade or repair, limited to one task, or can be hacked if it is not updated B1

Exam-style 3.5 (c) ▪ 2 marks

The thermostat's program is stored in EEPROM, not in PROM. **Explain** why.

Solution 3.5 (c)

Worked steps

PROM can be written only once, so the program could never be changed B1

- EEPROM can be erased and rewritten electrically while it is in the thermostat, so the program can be updated B1

Exam-style 3.5 (d) ▪ 3 marks

The thermostat has a temperature sensor, a processor and a relay that switches the boiler on and off. **Explain** why this is a control system, and how feedback is used.

Solution 3.5 (d)

Worked steps

the processor switches the boiler on or off through the relay (an actuator), so it changes the conditions instead of only recording them B1

- the sensor measures the temperature again after each change B1
- the processor compares the new reading with the target and decides whether to switch again, which keeps the temperature near the target B1

Exam-style 3.5 (e) ▪ 1 mark

State **one** item of data the thermostat stores in RAM.

Solution 3.5 (e)

Worked steps

e.g. the current temperature reading, or the target temperature set by the user

B1