

3.1.1 Hardware devices, memory and control systems

Name: _____ Class: _____ Date: _____ **Total: 44 marks**

KEY WORDS buffer 缓冲 • embedded system 嵌入式系统 • touchscreen 触摸屏 • sensor 传感器
• feedback 反馈

Objective

Build the skills to answer exam questions that **describe how hardware devices work**, and that apply memory and control ideas to a real device: **magnetic hard disks** 磁性硬盘, **solid state** 固态 (flash) memory, **microphones** 麦克风 and **speakers** 扬声器, **touchscreens** 触摸屏, **optical disc** 光盘 readers and writers, **virtual reality headsets** 虚拟现实头戴设备, laser and 3D printers, **buffers** 缓冲, **embedded systems** 嵌入式系统, and monitoring and control systems. This sheet covers syllabus 3.1.

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 Worked examples

Study these first. Each one shows a **method** that a question later on this sheet needs.

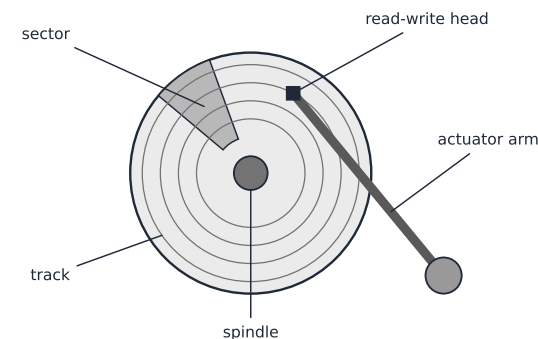
■ Describing the principal operation of a device

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.
- 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.

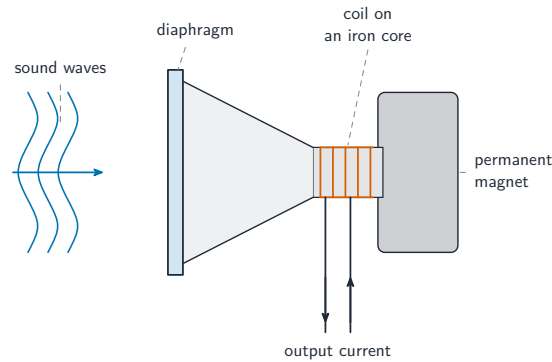
■ Solid state (flash) memory

- 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**.

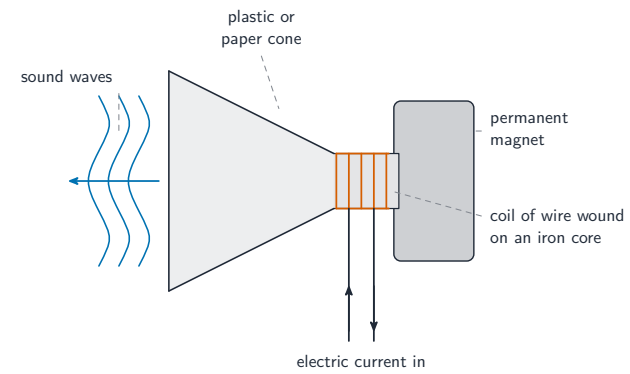
	magnetic hard disk	solid state drive
access speed	slower: the head must move and the platter must turn	faster: no moving parts
robustness	can be damaged if it is dropped while running	more robust
power and heat	more	less
cost per GB	lower	higher
typical use	video archives and backups on a server	laptops,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

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.

■ Sound in and sound out

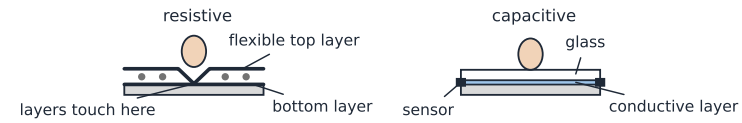


- **Microphone:** sound waves make the **diaphragm** 膜片 vibrate. The diaphragm moves a coil backwards and forwards near a permanent magnet, which produces a varying electric current. This is an **analogue** signal, and an **ADC** converts it to binary for the computer.



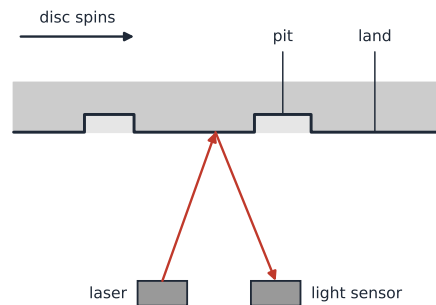
- **Speaker:** a DAC converts the digital sound into a varying current. The current flows through a coil, which becomes an **electromagnet**. As the current changes, the coil is attracted to and repelled by the permanent magnet, so the cone vibrates and makes sound waves.

■ Touchscreens



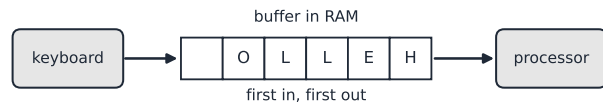
	resistive	capacitive
layers	two flexible conductive layers with a small gap	glass over a conductive layer that holds an electrostatic field
a touch	pressure pushes the layers together and completes a circuit at that point	the finger draws a little charge, so the current changes at that point
finding 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

■ 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.
- **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.

■ 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.

■ 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

- **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.

■ 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

- 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

Now use the methods above.

2.1 Explain why a computer needs both primary memory and secondary storage. [2]

2.2 Describe how data is read from a magnetic hard disk. [3]

2.3 Give **two** reasons why a laptop uses a solid state drive instead of a magnetic hard disk. [2]

2.4 Describe how a **capacitive** touchscreen detects where it is touched. [3]

2.5 A video streaming app stores the next part of a video in a buffer. Explain why. [2]

2.6 Identify the most suitable type of sensor for each system.

(a) a light that switches on when a person walks past at night [1]

(b) an alarm that sounds when a car tyre is under-inflated [1]

(c) a display that warns when a library is too noisy [1]

3 Exam-style questions

3.1 A video call app uses a microphone and a speaker.

(a) **Describe** the principal operation of a microphone. [3]

(b) **Describe** the principal operation of a speaker. [3]

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

(a) **Describe** how data is read from an optical disc. [3]

(b) 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. [2]

3.3 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. [4]

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

(a) **Explain** how a keyboard buffer makes sure that no key presses are lost. [3]

(b) State **one** reason why DRAM, not SRAM, is used for the computer's main memory. [1]

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

(a) **Explain** why the controller is an embedded system. [2]

(b) Give **one** benefit and **one** drawback of using an embedded system in the thermostat. [2]

(c) The thermostat's program is stored in EEPROM, not in PROM. **Explain** why. [2]

(d) 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. [3]

(e) State **one** item of data the thermostat stores in RAM. [1]

Solutions

Each answer shows the steps, then the **result**.

2.1

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

2.2 any **three** of:

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

2.3 any **two** of:

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

2.4

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

2.5

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

2.6

- (a) an **infra-red** (motion) sensor
- (b) a **pressure** sensor
- (c) a **sound** sensor

3.1

(a) any **three** of:

- sound waves make the diaphragm vibrate
- the diaphragm moves a coil backwards and forwards near a permanent magnet

- this produces a varying electric current
- the analogue signal is converted to digital by an ADC

(b) any **three** of:

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

3.2

(a) any **three** of:

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

(b) any **two** of:

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

3.3 any **four** of:

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

3.4

(a) each key press is stored in the buffer, in RAM, in the order it was typed

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

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

3.5

(a) it is a microprocessor-based system inside a larger device

- it has one dedicated task: controlling the heating

(b) benefit, e.g. small, cheap, low power or reliable

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

(c) PROM can be written only once, so the program could never be changed

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

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

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

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