A-LEVEL COMPUTER SCIENCE • EXERCISE SHEET

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

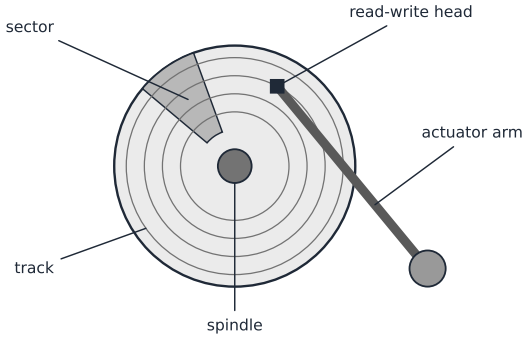
Study these first. Each one shows a **method** that a question later on this sheet needs.

■ 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.

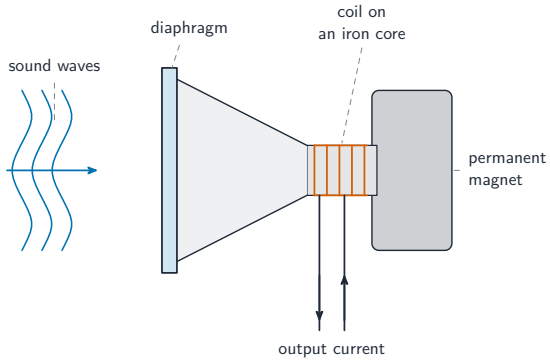
■ Solid state (flash) memory

- 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**.

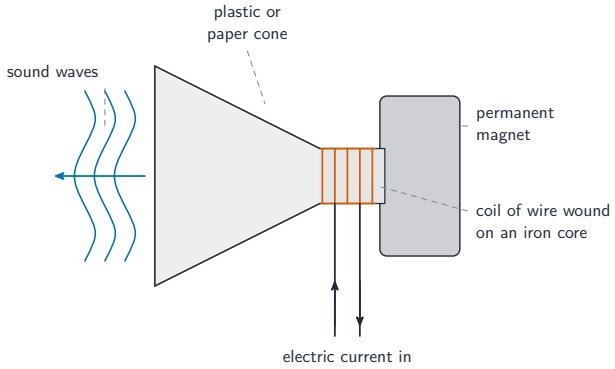
	magnetic hard disk	solid state drive
access speed	slower: the head must move and the platter must turn	faster: no moving parts
robustness	can be damaged if it is dropped while running	more robust
power and heat	more	less
cost per GB	lower	higher
typical use	video archives and backups on a server	laptops,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

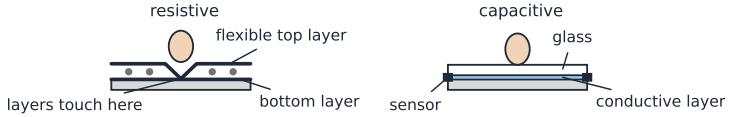


- **Microphone:** sound waves make the **diaphragm** 膜片 vibrate. The diaphragm moves a coil backwards and forwards near a permanent magnet, which produces a varying electric current. This is an **analogue** signal, and an **ADC** converts it to binary for the computer.



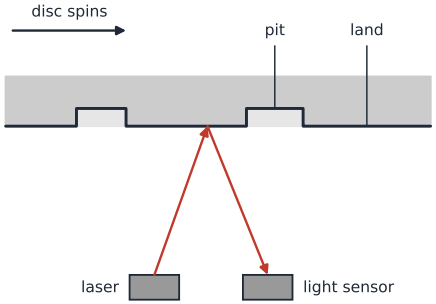
- **Speaker:** a **DAC** converts the digital sound into a varying current. The current flows through a coil, which becomes an **electromagnet**. As the current changes, the coil is attracted to and repelled by the permanent magnet, so the cone vibrates and makes sound waves.

Touchscreens



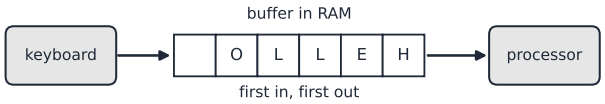
	resistive	capacitive
layers	two flexible conductive layers with a small gap	glass over a conductive layer that holds an electrostatic field
a touch	pressure pushes the layers together and completes a circuit at that point	the finger draws a little charge, so the current changes at that point
finding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