Cambridge IGCSE · Computer Science 0478 · Notes

# Input and output devices

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Read first: **Computer architecture**



## What you need to know

By the end of this topic you should be able to:

1. **Say what an input device is and why a computer needs one.** Know each of these input devices, what data it captures and when you would use it: barcode scanner, digital camera, keyboard, microphone, optical mouse, QR code scanner, touch screens (resistive, capacitive and infra-red), and 2D and 3D scanners.
2. **Say what an output device is and why a computer needs one.** Know each of these output devices, what it produces and when you would use it: actuator, digital light processing (DLP) projector, inkjet printer, laser printer, LED screen, LCD projector, LCD screen, speaker and 3D printer.
3. **Say what a sensor is and what sensors are for**, for these fourteen: acoustic, accelerometer, flow, gas, humidity, infra-red, level, light, magnetic field, moisture, pH, pressure, proximity and temperature.
4. **For each sensor, say what data it captures and when it would be used**, and **choose the most suitable sensor** for a situation you are given.

The current syllabus asks what each device is, what it is for and when to use it. It no longer asks you to describe in detail how each device works; the short "how it works" lines below are there so the devices make sense and so you can answer the older (2021–2022) questions that asked about it.

## Understand it

### Why computers need input and output devices

A computer can only process **binary data**. Everything it works on has to come in from the outside world, and every result has to go back out in a form people (or machines) can use.

- An **input device** captures data from the outside world (key presses, sound, light, movement, a touch) and converts it into binary data the computer can process. Without one there would be nothing to process.
- An **output device** takes binary data from the computer and converts it into a form that is useful outside it: an image, sound, a printed page, a solid object or a movement. Without one the results would stay locked inside the computer.

A **storage device** (hard disk, SSD, DVD, USB flash drive) is neither: it keeps data for later. So is a **register** or **RAM**, which are memory inside the computer. Questions often mix all of these together to see whether you can sort them.

## Input devices

| Input device | What it captures, and how | Typical use |
|---|---|---|
| **Keyboard** | Each key sits over a grid of circuits (a key matrix). Pressing a key closes a switch and completes a circuit; the processor works out which key it was and stores that character's binary code. | Typing text and numbers |
| **Optical mouse** | An LED lights up the surface under the mouse; the reflected light passes through a lens onto a sensor that takes many pictures a second. Comparing them gives the **direction and speed** of movement. The buttons are small switches. | Moving a pointer, clicking and selecting |
| **Microphone** | Sound waves make a thin diaphragm vibrate, which gives an analogue electrical signal; this is sampled and converted to binary. | Voice commands, recording, video calls |
| **Digital camera** | A lens focuses light onto a sensor made of millions of tiny light-sensitive cells, one per pixel; each cell's light level and colour is stored as a binary value. | Photos, video calls, reading codes |
| **Barcode scanner** | Shines light (often a red laser) across the black and white bars. White bars reflect a lot of light and black bars very little; sensors detect the pattern, which is converted to the binary number the barcode stands for. | Shop checkouts, libraries, stock control |
| **QR code scanner** | Reads a two-dimensional pattern of black and white squares. Three large squares in the corners tell the scanner where the code is and which way up it is. A QR code holds much more data than a barcode, such as a web address. | Tickets, links to web pages or videos, payments |
| **2D scanner** | Moves a bar of light across a flat document; sensors capture the reflected light line by line and turn it into a digital image. | Copying documents and photos |
| **3D scanner** | Scans the **shape and appearance of a solid object** from many angles (with lasers or light) and builds a digital 3D model of it. | Making a 3D-printed copy, measuring body parts for medical fittings |
| **Touch screen** | A screen that is also an input device: it works out the coordinates of where it is touched. There are three types, below. | Phones, tablets, ticket machines, kiosks |

#### The three touch screens

- **Resistive**: two flexible layers with a small gap between them. Pressing the top layer pushes it onto the bottom layer, which **completes a circuit**, and the coordinates of the touch are calculated from where. It needs pressure, so it works with gloves or any stylus, and it is **cheap to manufacture**, hard to shatter and

copes with bad weather. But it is less clear in sunlight, is less sensitive, usually cannot do multi-touch, and the top layer can scratch and wear out.

- **Capacitive**: an **electrostatic field** covers the glass. A bare finger is **conductive**, so touching the screen causes a **change** in the field, and the change is used to calculate the **coordinates**. It is very responsive, supports multi-touch and gives a clear, bright picture, and it still works if the glass is cracked. It does **not** respond to an ordinary glove or plastic stylus, because they are not conductive.
- **Infra-red**: LEDs along two edges send beams of infra-red light across the screen to sensors on the opposite edges, making an invisible grid. A touch **breaks some beams**, and which ones were broken gives the coordinates. Anything can be used to touch it (glove, pen), it supports multi-touch, needs no pressure, and keeps working if the glass is cracked; it is more expensive and can be set off by dirt or insects near the edge.

## Output devices

| Output device | What it produces, and how | Typical use |
|---|---|---|
| **Actuator** | A motor, valve, pump or switch that turns an electrical signal into **physical movement**. | Opening a window, turning a valve, moving a robot arm, raising a barrier |
| **Speaker** | The digital sound is converted to an analogue electrical signal; this drives a coil next to a magnet, which moves a cone back and forth to make sound waves in the air. | Music, alarms, spoken instructions for blind users |
| **LCD screen** | A grid of **pixels** made of liquid crystals, lit from behind (usually by LEDs). Each crystal twists to let more or less light through red, green and blue filters, which mix to make each pixel's colour. The crystals do not give out light themselves. | Monitors, laptops, TVs |
| **LED screen** | A grid of **pixels** where light-emitting diodes give the light: tiny red, green and blue LEDs mixed to make each colour (some "LED" screens are LCD panels lit by LEDs, with a diffuser spreading the light evenly). Bright, thin, low power, long life, cool running. | Large outdoor displays, seat-back and small displays, TVs |
| **LCD projector** | A bright lamp's light is split into red, green and blue, passed through three small LCD panels, recombined and focused through a lens onto a wall or screen. | Classrooms, home cinema |
| **DLP projector** | Light passes through a spinning colour wheel onto a chip covered in **thousands of tiny mirrors**, one per pixel, which tilt very quickly towards or away from the lens to make each pixel light or dark. | Portable projectors, cinemas |

| Output device | What it produces, and how | Typical use |
|---|---|---|
| **Inkjet printer** | Data is held in a **buffer** in the printer. A print head moves across the page and **nozzles** spray tiny droplets of **liquid ink**, made by **thermal bubble** or **piezoelectric** technology. If the paper jams or the ink runs out, it sends an **interrupt** to the computer. | Photos and small numbers of prints at home |
| **Laser printer** | Prints a whole page at a time: a laser draws the page as a pattern of electric charge on a rotating drum, powdered **toner** sticks to the charged areas, is rolled onto the paper and fixed with heat. | Large volumes of pages quickly, in offices and schools |
| **3D printer** | Builds a solid object **layer by layer** from a digital design, for example by squeezing melted plastic through a moving nozzle, or hardening liquid resin with light. | Prototypes, spare parts, custom medical parts |

**Choosing between similar devices**

- **Inkjet or laser?** An inkjet is cheap to buy, small, and good for high-quality colour photos and a few pages. A laser printer is faster and cheaper per page for large volumes, and its toner doesn't smudge. Either is a correct answer when you are only asked for "a suitable printer" for text on paper.
- **LCD or DLP projector?** An LCD projector tends to give brighter, more accurate colours and a sharper picture, runs quieter and doesn't show the "rainbow" flicker some people see with DLP. A DLP projector is smaller and lighter, so it is easier to carry about, and gives deeper blacks.
- **LED screen**: brighter, thinner and uses less power than older screens, runs cool and lasts a long time.

## Sensors

A **sensor** is an **input device** that measures a physical property of its surroundings, such as temperature or light, and sends that data to a computer or microprocessor. Sensors let a system collect data **automatically and continuously**: no person needs to be there, readings are taken faster and more accurately than a person could, day and night, and in places that are dangerous or hard to reach.

Most sensors produce **analogue** data (a value that changes smoothly). A computer can only process digital data, so an **analogue-to-digital converter (ADC)** turns each reading into binary before the microprocessor uses it.

| Sensor | Data it captures | When it would be used |
|---|---|---|
| **Acoustic** | Sound level (noise) | Burglar alarm listening for breaking glass; detecting a dripping leak from a pipe; noise monitoring |
| **Accelerometer** | Acceleration, movement and tilt | Turning a phone's screen when it is rotated; counting steps in a fitness tracker; detecting a crash to set off a car's airbag |

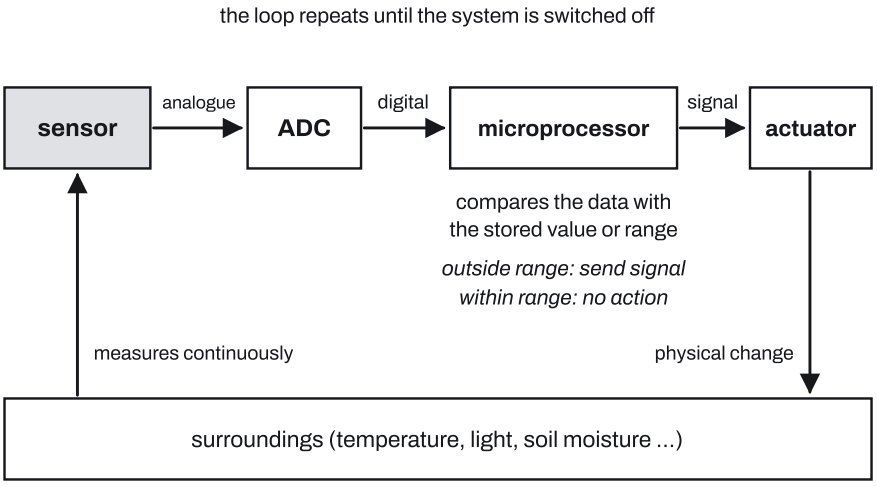
| Sensor | Data it captures | When it would be used |
|---|---|---|
| **Flow** | How fast a liquid or gas flows through a pipe | Measuring water or fuel flow; spotting a leak when flow doesn't stop |
| **Gas** | The amount of a particular gas (such as carbon monoxide, carbon dioxide or oxygen) | Carbon monoxide alarm; carbon dioxide in a greenhouse; checking a car's exhaust |
| **Humidity** | The amount of water vapour in the **air** | Keeping the air in a museum or art gallery from getting damp; switching on a bathroom extractor fan |
| **Infra-red** | Infra-red radiation, such as body heat, or a beam of infra-red light being broken | Detecting a person moving (security lights, automatic doors, alarms); checking a vehicle's height with a beam |
| **Level** | How full a container is (the height of a liquid) | Water tanks, fuel tanks, an animal's water bowl |
| **Light** | Light intensity (brightness) | Switching on street lights or car headlights when it is dark; screen brightness; inside a barcode scanner |
| **Magnetic field** | Changes in a magnetic field, such as when a large metal object passes | Detecting a car waiting at traffic lights; a phone's compass; door and window alarms |
| **Moisture** | The amount of water **in a substance**, such as soil | Deciding when to water plants |
| **pH** | How acidic or alkaline something is | Soil in a greenhouse; swimming pool water; water in a washing machine or fish tank |
| **Pressure** | Force pressing on it (so also weight) | Weighing clothes in a washing machine; pressure mats in games and alarms; detecting a car in a parking space |
| **Proximity** | How close an object is, without touching it | Car parking sensors; turning a phone screen off near the ear; a robot vacuum cleaner avoiding obstacles |
| **Temperature** | Temperature | Thermostats, kettles, ovens, greenhouses, air conditioning |

Easily confused pairs:

- **Humidity** measures water in the **air**; **moisture** measures water **in something** such as soil.
- **Level** tells you how full a tank is; **flow** tells you how fast liquid is moving through a pipe.
- **Infra-red** and **proximity** sensors both detect people. "Motion sensor" on its own is too vague for recent mark schemes: name the actual sensor, usually infra-red or proximity.
- **Light** sensors measure brightness; they don't detect a person unless a beam is broken.

### How a sensor and a microprocessor control something

Many questions describe a system (a greenhouse, a water tap, a car park barrier, a door) and ask how the sensor and the microprocessor work together. Every one follows the same loop.




1. The **sensor continuously** measures its surroundings and sends the data to the microprocessor. It doesn't wait until something happens, and it never makes a decision itself.
2. Analogue data is converted to digital by an **ADC**.
3. The **microprocessor compares** the data with a **stored value or range** (such as 30 °C, or between 25 °C and 30 °C).
4. If the reading is outside the range (or matches the trigger), the microprocessor **sends a signal** to an output: usually an **actuator** to make something move (open a window, switch a heater, turn a tap, raise a barrier, close a door), or a screen, light or alarm.
5. If the reading is within the range, **no action is taken**.
6. The process **repeats continuously** until the system is switched off.

An actuator only makes **physical movement**. Changing a message on a screen or switching on a light is a signal from the microprocessor to the screen or light, not an actuator's job.

## Key facts and formulas

There is no formula list for this subject, so you must learn all of these.

| Formula | Status |
|---|---|
| Input device: captures data from outside and converts it to binary for the computer to process | Learn it |
| Output device: converts the computer's binary data into a form useful outside it (image, sound, print, object, movement) | Learn it |

| Formula | Status |
|---|---|
| Storage devices (HDD, SSD, DVD, USB flash drive) and memory (RAM, ROM, registers) are neither input nor output | Learn it |
| Sensor = input device; actuator = output device; headphones and speakers = output; microphone = input | Learn it |
| Sensor: an input device that measures a physical property of its surroundings and sends the data to a computer or microprocessor | Learn it |
| Analogue sensor data goes through an ADC before a microprocessor can use it | Learn it |
| Control loop: sensor sends data continuously → ADC → microprocessor compares with stored value → outside range: signal to actuator/output; within range: no action → repeat | Learn it |
| Resistive: layers pushed together complete a circuit · capacitive: conductive finger changes an electrostatic field · infra-red: touch breaks a grid of beams | Learn it |
| The 14 sensors and what each measures (table above) | Learn it |

## How to do it

In the Paper 1 questions we have tagged for this topic (46 questions, 2021–2025), the types came up this often. 18 of the 46 questions mix more than one type, so the counts add up to more than 46.

| Question type | Questions |
|---|---|
| Name suitable input or output devices for a device or situation | 18 |
| Describe how a sensor and a microprocessor control a system | 14 |
| Choose the right sensor for a task (or give a sensor's use) | 11 |
| Explain how a device works | 11 |
| Classify a device as input, output or storage | 9 |
| Justify a choice of device technology | 4 |

### 1. Name suitable input or output devices for a device or situation (18 questions)

Usually 1 mark per device: "Identify two input devices that could be built into a smartphone."

1. **Picture the device** and what a person does with it. Only name devices that could really be **built into** it (a smartwatch has no room for a keyboard or printer).
2. **Give the device's name**, not what it does ("microphone", not "something to speak into").
3. **Give different devices** for each answer line, and **don't repeat a device the question already mentions** ("the machine has a touch screen; identify one **other** input device").

Answers that score for a phone, tablet or smartwatch:

- **Input**: touch screen, microphone, digital camera, button, a named sensor (accelerometer, light, proximity), fingerprint scanner (a biometric device).
- **Output**: screen, speaker, LED (light), actuator (the vibration motor).

"Screen" on its own is an **output**; for an input, write **touch screen**.

**Variations you will meet:**

- **Users who are blind**: output a **speaker** or **headphones**; input a **microphone** (voice commands) or a **Braille keypad**.
- **Reading tickets automatically**: **barcode scanner**, **QR code scanner** or **digital camera**.
- **No keyboard or mouse allowed** (they might be stolen or get dirty): **touch screen**, **microphone**, touchpad, barcode or QR code reader.
- **A paper ticket or receipt**: a **printer**. "A suitable printer" for a list of text: **inkjet** or **laser**.
- **Device plus how it's used**: give the device, then one sentence tied to the situation ("touch screen, to select a shop on the map").
- **"Give three examples of output devices"** with no situation: any from the syllabus lists, such as speaker, actuator, 3D printer, LCD projector.

## 2. Describe how a sensor and a microprocessor control a system (14 questions)

Worth 3–8 marks, one mark per step of the loop. The marks go to answers that use the **situation**, not a general description.

1. **Name the sensor** (if not given) that fits the situation.
2. The **sensor continuously sends data** to the microprocessor, **converted from analogue to digital by an ADC**.
3. The **microprocessor compares** the data with the **stored value from the question** (40 °C, 1 metre, between 25 °C and 30 °C).
4. **If** it is above/below/outside the range, the microprocessor **sends a signal** to do the specific thing in the question ("to an actuator to open the window and to switch the heater off").
5. **Otherwise** no action is taken (or the opposite action, for example "close the window and switch the heater on" if it's too cold).
6. The process **repeats continuously**.

For a 6-mark question, write six separate points like these, each one a new step.

**Variations you will meet:**

- **A range with two ends** (keep a greenhouse between 25 °C and 30 °C): say what happens above the top, below the bottom, and in between.
- **Two sensors** (a security light that comes on only when it is dark **and** there is movement): the light comes on only if **both** readings are outside their stored values; if only one is, no action.

- **A timer** (the light stays on for 1 minute; CCTV stops 2 minutes after the last movement): the microprocessor **starts a timer** when it switches something on, **resets it** each time the trigger happens again, and sends a signal to switch off when the timer reaches the limit. The sensor still sends data all the time.
- **Refilling when something is empty** (a tank or bowl): when the reading shows it is empty, the microprocessor sends a signal to an actuator to start filling (open a valve, switch a pump on). It keeps comparing the readings, and when the reading reaches the stored "full" value (or after a set time), it sends a signal to stop the filling.
- **A counter** (a game that counts correct hits): the microprocessor checks which sensor the data came from and adds 1 to a counter if it is the right one.
- **Something that must not happen** (a door that must not close on a passenger): if a passenger is detected, the signal is **not** sent (or the driver is alerted), and the check repeats until the doorway is clear.
- **A microprocessor with no sensor** (a car park barrier reading a ticket, a library updating stock): the microprocessor **receives the data** (ticket number, book code), **searches for it in stored data** (a database), and **if it is found** acts (raises the barrier, takes 1 off the stock); **if not**, it doesn't (the barrier stays down, an error message is shown).

## 3. Choose the right sensor for a task, or give a sensor's use (11 questions)

1 mark each, often in a table where **each sensor must be different**.

1. **Ask what physical quantity changes** in the situation: heat, light, sound, closeness, weight, acidity, water in air, water in soil, liquid height, flow, a gas, movement or tilt, a magnetic field.
2. **Pick the sensor that measures exactly that**, from the table in "Understand it".

Clues and the sensor they point to:

- air "dry enough", "damp" → **humidity**; soil "dry", "needs watering" → **moisture**;
- "when it is dark" → **light**;
- "acidity", "alkaline" → **pH**;
- "a person nearby", "someone approaches", "detects movement" → **infra-red** or **proximity**;
- "how full", "a bowl is empty" → **level** (pressure is also accepted for a bowl);
- "weight", "someone standing on" → **pressure**;
- "count the cars" → **magnetic field** (or pressure);
- "hot", "°C" → **temperature**; "noise", "breaking glass" → **acoustic**;
- "carbon monoxide", "smoke", "air quality" → **gas**; "tilt", "shake", "fall" → **accelerometer**; "water through a pipe" → **flow**.

**Variations you will meet:**

- **The reverse**: a sensor is given; write a real use in a few words, tied to what it measures ("humidity: stopping the air in a bathroom getting damp enough for mould to grow").
- **Multiple choice**: pick the one that measures the quantity (a robot vacuum avoiding obstacles: **proximity**).

- **The sensor inside a device**: a barcode scanner contains a **light** sensor.
- **Benefits of using sensors**: data is collected **without a person** being there; readings are **continuous** (24/7), **faster** and **more accurate** than a person's; they can be used in **dangerous** places.

## 4. Explain how a device works (11 questions)

All of these are from 2021–2022, when the syllabus included how devices work; the examiners have since said that describing the operation of devices is no longer part of it. They are still good practice for knowing what each device is. Most were **gap-fill paragraphs** with a word list (1 mark per gap), using the key words in the "Understand it" tables:

- **Keyboard**: key matrix, **switch**, completes a **circuit**, **current** flows, processor **calculates** which **character**, stored as **binary**.
- **Optical mouse**: **LED** shines onto the surface, light **reflects** back through a **lens** (which **magnifies** it) onto a **photoelectric** cell; the computer works out **direction** and **speed**; buttons are **microswitches**; data goes by **USB**.
- **Inkjet printer**: data held in a **buffer**, **nozzles** spray **liquid** ink, **thermal bubble** or piezoelectric, paper jam causes an **interrupt**.
- **Touch screens**: capacitive: electrostatic field, **conductive** properties cause a **change**, **coordinates** calculated. Resistive: top layer pushed onto the bottom layer completes a **circuit**; cheaper to **manufacture**.

Other forms:

- **Name or describe the device** in a table: "uses thousands of tiny mirrors" is a **DLP projector**; an **actuator** "turns a signal into physical movement"; an inkjet "uses thermal bubble or piezoelectric technology".
- **Tick which device a statement fits**: position and alignment markers → **QR code reader**; shape and appearance of an object → **3D scanner**; laser reflected off a black-and-white pattern → barcode **and** QR code reader; all three are input devices.
- **Describe reading a barcode and finding the price**: light shone on the bars, reflected light detected by sensors and turned into binary, **then** the number is looked up in the shop's **database** and the price returned.
- **Describe reading a QR code**: light onto the code, corner squares give its position, black and white squares reflect differently, the reflections are turned into binary, which contains the link (URL) to the content.

## 5. Classify a device as input, output or storage (9 questions)

1 mark per device: tick a box, fill a tick table, or circle three from a list.

1. Ask: **does it bring data into the computer** (input), **send data out** into the world (output), or **keep data** for later (storage)?
2. Tick **one** box per row, unless the question says more than one may apply.

The traps: **sensor** and **keypad** and **barcode scanner** are input; **actuator**, **headphones** and **printer** are output; **register**, **RAM**, **HDD**, **SSD**, **DVD** and **USB flash drive** are storage (or memory), not input. A **microphone is input**, not output (a common mistake), and a **touch screen** is an input device (it is also an output, but it is on the input list in every mark scheme).

A fingerprint scanner can also be asked about with security terms: it is an **input device**, it is **biometric**, and it is used for **authentication**.

### 6. Justify a choice of device technology (4 questions)

2–4 marks: "Recommend a type of touch screen and justify your choice", "Give two benefits and two drawbacks", "Explain why an LCD projector would suit him".

1. **Name one type** clearly.
2. **Give reasons tied to the situation**, each a separate point ("it works when the customer wears gloves, because it responds to pressure").
3. For **benefits and drawbacks**, don't give the same idea twice as a benefit and its opposite.

Points you can use:

- **Resistive**: cheap to manufacture, works with gloves or any stylus, waterproof, hard to shatter, low power. Drawbacks: less responsive, poor in sunlight, usually no multi-touch, scratches and wears.
- **Capacitive**: very responsive, multi-touch, clear and bright, needs no pressure, works if cracked. Drawback: needs a bare finger or special stylus.
- **Infra-red**: anything can touch it, multi-touch, clear, works if cracked, no pressure needed.
- **LED screen**: bright, low power, cool, long life, thin and compact, works in the cold.
- **LCD projector for a fixed home setup**: brighter and more accurate colours, sharper picture, quieter, no rainbow effect; its bigger size doesn't matter because it won't be moved.

## Worked examples

The bold codes show where marks are earned, as in Cambridge mark schemes. The number is how many marks.

- **B1** mark for a correct result on its own, with no method needed.

### Example 1

A cinema has a self-service ticket kiosk. Customers choose a film and pay, and the kiosk gives them a paper ticket. The kiosk has a touch screen.

(a) Identify **one other** input device that could be built into the kiosk. **[1]**

(b) Identify **two** output devices that could be built into the kiosk, other than the screen. **[2]**

(c) Tick one box in each row to show whether each device is an input, output or storage device. **[4]**

| Device | Input | Output | Storage |
|---|---|---|---|
| 3D scanner | | | |
| headphones | | | |
| solid-state drive (SSD) | | | |
| accelerometer | | | |

**(a)** Any one, not the touch screen: microphone, barcode or QR code scanner (to read a voucher), keypad for a card PIN, digital camera. **B1**

**(b)** Printer (for the paper ticket) **B1**; speaker (to read out instructions) **B1**. An LED light or an actuator (to push out the ticket) would also score.

**(c)** 3D scanner: input **B1**. Headphones: output **B1**. SSD: storage **B1**. Accelerometer: input, because it is a sensor **B1**.

## Example 2

(a) Complete the table by identifying the most suitable sensor for each task. Each sensor must be different. **[4]**

| Task | Sensor |
|---|---|
| checking the air in a museum is not too damp | |
| switching on a garden's lights when it gets dark | |
| checking the water in a fish tank is not too acidic | |
| detecting when a smartwatch wearer falls over | |

(b) Give one use for each of these sensors: gas, magnetic field. **[2]**

**(a)** Humidity (water vapour in the air) **B1**. Light **B1**. pH **B1**. Accelerometer (sudden change in movement) **B1**.

**(b)** Gas: a carbon monoxide alarm in a house **B1**. Magnetic field: counting the cars that enter a car park **B1**.

## Example 3

A greenhouse has an automatic watering system. The soil must be kept between 40% and 60% moisture. A pump waters the soil. The system uses a sensor and a microprocessor.

(a) Identify the most suitable sensor for this system. **[1]**

(b) Describe how the sensor and the microprocessor keep the soil moisture in this range. **[6]**

**(a)** Moisture sensor. **B1** (Not humidity, which measures the air.)

**(b)** Any six:

- The moisture sensor **continuously** sends data to the microprocessor. **B1**
- The analogue data is converted to digital by an ADC. **B1**
- The microprocessor compares the reading, $m$, with the stored range, $40 \leq m \leq 60$ (per cent). **B1**
- If the reading is below 40%, the microprocessor sends a signal to switch the pump on. **B1**
- If the reading is above 60%, it sends a signal to switch the pump off. **B1**
- If the reading is between 40% and 60%, no action is taken. **B1**
- An actuator switches the pump on and off. **B1**
- The process repeats continuously. **B1**

So readings of 35%, 50% and 65% give "pump on", "no action" and "pump off".

### Example 4

A car park wants a payment machine with a touch screen, at the barrier, outdoors. Drivers often wear gloves in winter.

(a) Recommend a type of touch screen technology for the machine and justify your choice. **[3]**

(b) Give **one** drawback of the type you chose. **[1]**

**(a)** Resistive **B1**. Any two, tied to the car park: it responds to pressure, so drivers can use it with gloves on **B1**; it is waterproof, so rain won't stop it working outdoors **B1**; it is cheap to manufacture, so the car park can afford one at every barrier **B1**; it is hard to shatter, so it is less likely to be damaged **B1**.

(Infra-red is just as good an answer: anything can touch it, including a gloved finger **B1**, and it still works if the glass is cracked **B1**.)

**(b)** For resistive, any one: it is harder to see in bright sunlight; it is less responsive than a capacitive screen; the top layer scratches and wears over time. **B1**

## Common mistakes

- **Calling a microphone an output device**, or a sensor anything but an input. Check the direction the data goes.
- **Giving a storage device when asked for an input device** (HDD, USB drive). Read the question's word: input, output or storage.
- **Repeating a device that is already in the question** ("the kiosk has a touch screen; give one other input device": not touch screen). Examiner reports point this out again and again.
- **"Motion sensor"** when a specific sensor is needed. Recent mark schemes want the real sensor: **infra-red** or **proximity**.
- **Picking a sensor that doesn't fit the situation**: pressure to detect someone standing near an ATM, or infra-red to check a water bowl. Ask what physical quantity is changing.

- **Saying the sensor only sends data when something happens**, or that the sensor decides. The sensor sends data **continuously**; the **microprocessor** compares and decides.
- **Writing a general sensor answer**. Answers that don't use the situation's values and actions ("compares with 1 metre", "opens the window") lose most of the marks, and so do answers that just repeat the question ("if the person is within 1 m, the message is shown") without the comparison.
- **Using an actuator to change a screen or message.** An actuator only makes physical movement; the microprocessor sends signals straight to a screen.
- **Mixing up resistive and capacitive.** Conductive + electrostatic field = **capacitive**; layers + pressure + circuit = **resistive**.
- **Mixing up humidity and moisture**: air vs soil.
- **Describing the barcode instead of how it is read**, or describing stock being updated when the question asks how the price is found.
- **Giving generic features in "justify" questions** ("it's better") instead of a reason from the situation.

## How to get the marks

- **"Identify" and "give"** (1 mark each): just the name of the device or sensor. Don't add extra answers; a wrong second answer can cancel a right first one.
- **Use the proper names**: "infra-red sensor", "barcode scanner", "LCD projector", "Braille keypad". Brand names and vague words ("a scanner thing") score nothing.
- **"Describe" a control system**: one step per mark, in order: sensor sends data continuously → ADC → microprocessor compares with **the stored value from the question** → sends a signal to **a named output** to do **the named action** → otherwise no action → repeats. Say what happens on **both** sides of the value.
- **Use every number in the question**: 40 °C, 1 metre, 2 minutes, between 25 °C and 30 °C. A timer or counter in the question needs a timer or counter in your answer.
- **"Explain" or "justify"**: each point needs its reason, tied to the situation ("works with gloves, **so** drivers can use it in winter").
- **Tables where each sensor must be different**: don't repeat a sensor, even if it would fit two rows.
- **Tick or circle exactly the number asked for.** Circling four when three are asked for loses marks.
- **Give a use as a real situation** ("to check a baby's bath water is not too hot"), not a definition ("to measure temperature").

## Quick check

1. Circle the **three** output devices: DLP projector, QR code scanner, actuator, microphone, solid-state drive, 3D printer, accelerometer.
2. Identify the most suitable sensor for each task: (a) setting off a car's airbag in a crash; (b) warning of carbon monoxide in a kitchen; (c) stopping a water tank from overflowing; (d) checking the acidity of a swimming pool.
3. Explain why a capacitive touch screen does not respond when you touch it with a woollen glove on.

4. A freezer must stay between −20 °C and −16 °C. It has a temperature sensor, a microprocessor and a cooling unit that can be switched on and off. Describe how the system keeps the freezer in this range, and say what happens for readings of −14 °C, −18 °C and −21 °C.
5. Give **two** reasons why an office that prints hundreds of pages a day would choose a laser printer rather than an inkjet printer.

## Answers

1. DLP projector, actuator, 3D printer. (The QR code scanner, microphone and accelerometer are input devices; the SSD is storage.)
2. (a) Accelerometer. (b) Gas sensor. (c) Level sensor. (d) pH sensor.
3. A capacitive screen works because a bare finger is conductive and changes the electrostatic field on the screen. Wool is not conductive, so the field doesn't change and no touch is detected.
4. The temperature sensor continuously sends data to the microprocessor, converted to digital by an ADC. The microprocessor compares each reading $t$ with the stored range, $-20 \leq t \leq -16$ (in °C). Above –16 °C it sends a signal to switch the cooling unit on; below –20 °C it sends a signal to switch it off; in the range, no action is taken. This repeats continuously. So –14 °C: cooling on; –18 °C: no action; –21 °C: cooling off.
5. Any two: it prints pages faster; it is cheaper per page for large volumes; the toner cartridge lasts for many more pages; the printed toner doesn't smudge.

## Past questions to try

- **0478/11/O/N/21 Q9**: choosing three different sensors for a washing machine, then keeping the water at 30 °C.
- **0478/13/M/J/21 Q9**: sensors for a car park, and the red and green lights above each space.
- **0478/12/O/N/22 Q1**: input and output devices for a ticket machine, and how a resistive touch screen works.
- **0478/13/O/N/22 Q1**: tick input, output or storage for five components.