

Automated systems

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Read first: [Input and output devices](#)

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What you need to know

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

1. **Describe how sensors, microprocessors and actuators work together to make an automated system.** Sensors collect the data, the microprocessor decides what to do by comparing that data with stored values, and actuators carry out the physical action. You must be able to describe this for any system you are given, using its own values.
2. **Describe the advantages and disadvantages of an automated system in a given scenario,** from any of these areas: **industry, transport, agriculture, weather, gaming, lighting and science.**

What each type of sensor measures is in the input and output devices note. Exam questions about automated systems often have extra parts on other topics (binary numbers, embedded systems, data transmission, robots and artificial intelligence); those are covered in their own notes.

Understand it

What makes a system automated

An **automated system** carries out a task **by itself, without a person having to step in**. Once it is set up and switched on, it measures what is happening, decides what to do and does it, over and over, with no human decisions.

Every automated system in this course is built from three kinds of part:

Part	Its job	Examples
Sensor (input)	Measures something about its surroundings and sends the data on, all the time	Temperature, light, level, pressure, infra-red, proximity, magnetic field, pH, humidity
Microprocessor (process)	Receives the data, compares it with stored values , and decides whether anything must happen; if so, it sends a signal	The small processor built into the system, with memory holding the stored values

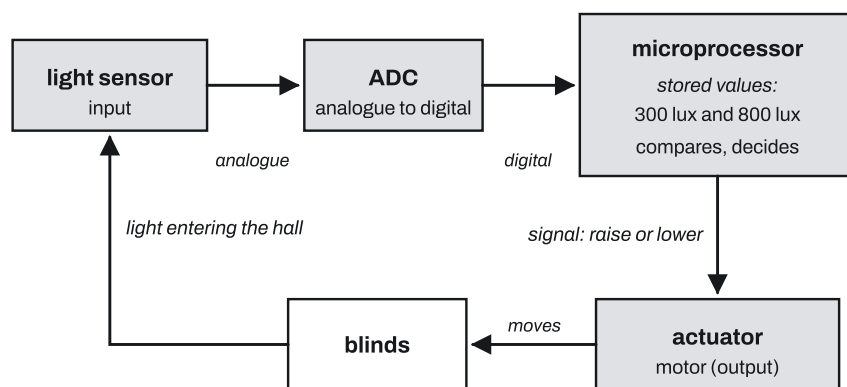
Part	Its job	Examples
Actuator (output)	Turns the microprocessor's signal into physical movement	A motor, a valve, a pump, a switch (relay), a bolt, a hydraulic arm

Most sensors give **analogue** readings, so an **analogue-to-digital converter (ADC)** turns them into digital data before the microprocessor can use them. The sensor itself **never decides** anything: it only measures and reports. The actuator never decides either: it only moves when told to.

Some outputs are **not** actuators. A screen showing a message, a speaker or an alert sent to someone's phone gets a signal from the microprocessor directly. An actuator is for things that **move**. Switching something on and off is the exception to watch for: a lamp or heater is not an actuator itself, but the **relay or switch** that turns it on or off **is**, and mark schemes give a mark for "an actuator is used to switch the light (or heater) on and off".

Following one system through

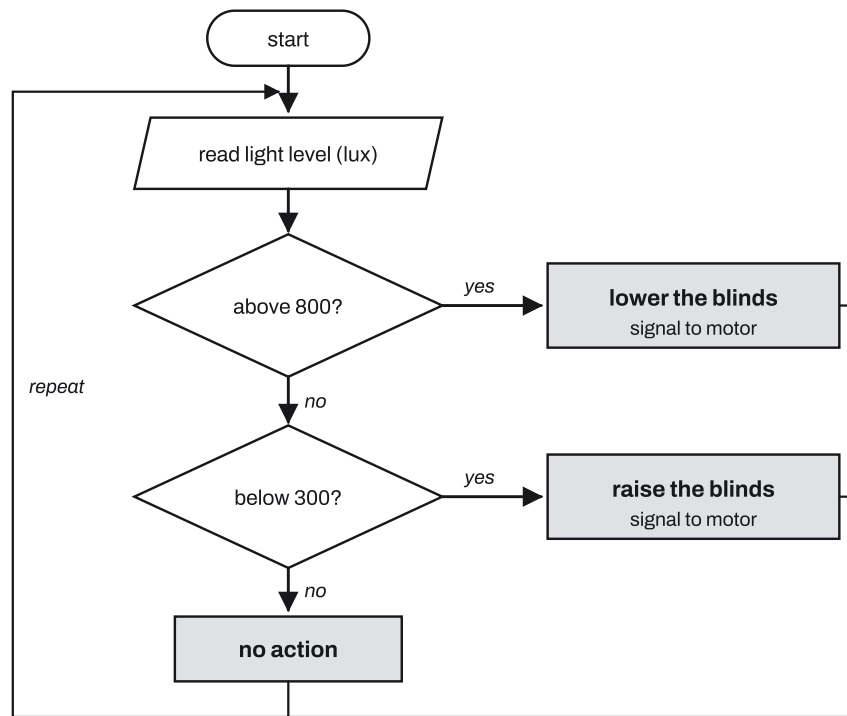
Take a school sports hall with **automatic blinds**. The aim is to stop the sun dazzling players but keep the hall bright enough. The hall has a **light sensor** near the windows. The stored values are **300 lux** and **800 lux** (lux is the unit of brightness).



the sensor keeps measuring, so the loop repeats continuously

1. The light sensor **continuously** measures the brightness and sends the readings to the microprocessor.
2. Each reading is converted from analogue to digital by the ADC.
3. The microprocessor **compares** each reading with the stored values 300 and 800.
4. If the reading is **above 800**, it sends a signal to the **motor (actuator)** to **lower** the blinds.
5. If the reading is **below 300**, it sends a signal to the motor to **raise** the blinds.
6. If the reading is **between 300 and 800**, **no action** is taken.
7. This repeats **continuously** until the system is switched off. Because moving the blinds changes the light, the next readings show whether it worked: this is a **feedback loop**.

The same decisions drawn as a flowchart:



Examiners suggest thinking of the steps as a flowchart like this: every comparison has a **yes** branch and a **no** branch, and you should say what happens on **each**.

Extra features you will meet

Real systems add a few standard features. Each has a standard way to describe it.

- **A range with two ends** (keep something between two values): say what happens above the top, below the bottom, and in between.
- **Two sensors that must both agree**, such as a porch light that should come on only when it is dark **and** someone is near: the microprocessor checks **both** readings, and acts only when both are outside their stored values. If only one is, nothing happens.
- **A timer**. "Stays on for 3 minutes" means: when the microprocessor switches something on, it **starts a timer**; if the trigger happens again, it **resets** the timer; when the timer reaches 3 minutes, it sends a signal to switch off. The sensor keeps sending data the whole time: it does not wait for the timer.
- **A counter**. To count cars into a car park, or points in a game, the microprocessor **adds 1 to a stored counter** each time the right data arrives, and can compare the counter with a limit (such as the number of spaces).
- **An alert**. When a reading passes a danger value, the microprocessor sends a message or sets off an alarm, as well as (or instead of) moving an actuator.
- **Something that must stop**. For safety, some systems stop a movement: a machine that must halt if a hand comes too close sends a signal to the actuator to **stop** the motor, and only restarts it when the readings are safe again.

Automated systems in different areas

Area	Example system	Sensors	What the actuator does
Industry	Filling and capping bottles on a production line; a chemical tank kept at the right temperature	Level, flow, temperature, pressure	Opens and closes valves; moves arms that push faulty items off the belt
Transport	Barriers at a railway level crossing; automatic train doors; traffic lights that change when cars wait	Magnetic field, infra-red, pressure	Lowers and raises barriers; opens and closes doors
Agriculture	Watering crops when the soil is dry; refilling animal drinking troughs; a self-steering plough	Moisture, level, pH, proximity	Opens water valves; switches pumps; steers the vehicle
Weather	A weather station that records conditions day and night and sends alerts	Temperature, humidity, light, pressure, rain (level)	Often none: it sends data and alerts rather than moving anything
Gaming	Dance mats, motion-controlled games, arcade machines	Pressure, accelerometer, infra-red	Vibration motors in controllers; moving parts on arcade machines
Lighting	Street lights that switch on at dusk; security lights; automatic blinds	Light, infra-red	Switches (relays) turning lights on and off; blind motors
Science	Incubators and fridges for samples; experiments that take readings every second for days	Temperature, pH, gas, humidity	Switches heaters and coolers; opens valves to add chemicals

Advantages and disadvantages

Whether an automated system is a good idea depends on the scenario and on **who** you are asking about: the owner, the workers, or the public. These points apply in most scenarios; always turn them into a sentence about the system in the question.

Advantages

- It works **without human intervention**, so people are free to do other, more skilled work.
- It can work **24 hours a day** without breaks, and doesn't get tired or bored of **repetitive** tasks.
- It is **faster**, and its readings and actions are **more accurate and consistent** than a person's.
- It is **safer**: nobody has to work in **dangerous** places (hot, toxic, high up, bad weather, near heavy machinery).
- It can **save money** over time, for example on wages, and cut waste of water, energy or materials.
- It reacts **immediately** to a change, day or night.

- It can **create jobs** installing and maintaining the equipment.

Disadvantages

- It is **expensive to buy and set up**.
- It needs **maintenance and repairs**, which cost money and need skilled technicians.
- It can **replace workers**, causing unemployment, and **deskill** the workers who remain.
- Staff may need **training** to use it.
- It can **malfunction**: a faulty sensor could cause damage or be dangerous (for example, failing to detect a person).
- It **can't cope with unexpected situations** it wasn't programmed for.
- If it breaks down, the work may have to be done **by hand** until it is fixed.
- **Changing** what it does can be difficult and expensive.

Key facts and formulas

There are no formulas in this topic and nothing is given in the exam. These are the facts to learn.

Fact	Status
Automated system: performs a task without human intervention	Learn it
Sensor = input (measures, sends data continuously); microprocessor = process (compares with stored values, sends signals); actuator = output (physical movement)	Learn it
Analogue sensor readings are converted to digital by an ADC before the microprocessor uses them	Learn it
Loop: sensor sends data → ADC → microprocessor compares with stored value(s) → outside range: signal to actuator; within range: no action → repeat continuously	Learn it
Timer: start when switched on, reset on each new trigger, switch off when it reaches the limit	Learn it
Two sensors: act only when both readings meet their conditions	Learn it
An actuator makes physical movement; screens, speakers and alerts are not actuators. A lamp or heater isn't one, but the relay or switch that turns it on and off is	Learn it
Advantages: no human intervention, 24/7, faster, more accurate, safer, saves labour costs	Learn it
Disadvantages: set-up cost, maintenance cost, job losses and deskilling, training, malfunctions, can't handle the unexpected	Learn it

How to do it

In the Paper 1 questions we have tagged for this topic (17 questions, 2021–2025), the automated-systems parts came in these types. 12 of the 17 questions mix more than one type, so the counts add up to more than 17. Parts of the same questions on other topics (binary, embedded systems, serial transmission, robots, artificial intelligence and machine learning) are in their own notes.

Question type	Questions
Describe how sensors, a microprocessor and actuators control the system	15
Identify a suitable sensor or other component	10
Advantages and disadvantages of the automated system	6
State what is meant by an automated system	2

1. Describe how sensors, a microprocessor and actuators control the system (15 questions)

Worth 3–8 marks, one mark per point. Examiners report every year that generic answers lose marks: use the **scenario's own sensor, values and actions**.

1. **Name the sensor** that fits (if the question hasn't), for example "an infra-red sensor".
2. The sensor **continuously sends data** (readings) to the microprocessor. Don't say it sends data "when it detects something": it sends all the time.
3. The data is **converted from analogue to digital** by an ADC.
4. The microprocessor **compares the data with the stored value(s)** from the question: "compares the reading with the stored value of 5 metres".
5. **If** the reading is above / below / outside the range, the microprocessor **sends a signal** to the **actuator** to do the specific action ("to a motor to close the gate").
6. **Otherwise no action is taken** (or say the opposite action for the other side of a range).
7. The process **repeats continuously** until the system is switched off.

Count the marks and write at least that many separate points. Don't just repeat the question ("if the car is too close the gate closes"); show the **comparison** that makes the decision.

Variations you will meet:

- **A range** (between 18 °C and 22 °C): three outcomes, above, below and within.
- **A distance** (stop if a person is within 2 metres): the sensor's reading is turned into a distance, which is compared with the stored 2 m; if it is less than or equal to 2 m, a signal goes to the actuator to stop (apply the brakes); if it is more, no action; if stopped and the path is clear again, a signal to start.
- **Two sensors** (dark and movement): act only when both readings are past their stored values.

- **A timer** (on for 90 seconds; stop recording after 2 minutes with no movement): start the timer, reset it on each new trigger, switch off when it runs out. Examiners report that many students wrongly say the data is only checked every 2 minutes.
- **A counter** (count correct hits, count cars): the microprocessor checks which sensor sent the data and adds 1 to the counter.
- **Refilling** (a tank or trough): when the reading shows it is low, a signal opens a valve or starts a pump; when the reading reaches the stored "full" value (or after a set time), a signal closes it.
- **An alert** (warn staff above 40 °C): the microprocessor compares with 40 and, if above, sends a signal to trigger the alert. No actuator is needed for a message.
- **"Describe the role of the microprocessor"**: receives the data from the sensor, compares or analyses it (is it within the range?), and sends signals to trigger actions.

Try 0478/12/O/N/22 Q2 (a hands-free tap) and 0478/12/F/M/22 Q6 (a timer).

2. Identify a suitable sensor or other component (10 questions)

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

1. Ask **what physical quantity changes**: heat, brightness, closeness, weight, water in the air, water in soil, how full, how fast liquid flows, acidity, a large metal object passing.
2. Name the **sensor that measures exactly that**, with its proper name (temperature, light, proximity or infra-red, pressure, humidity, moisture, level, flow, pH, magnetic field).
3. **"One other component"** of an automated system (not a sensor): **microprocessor**, **actuator** or **memory/storage**.

Variations you will meet:

- **"Give a use for this sensor"**: a short situation that fits, such as "humidity: checking the air in a greenhouse isn't too dry".
- **"What does a flow sensor measure?"**: how much liquid or gas is moving through a pipe.
- **Detecting a person or object**: infra-red or proximity. "Motion sensor" is too vague in recent mark schemes.
- **Don't repeat** a sensor the question already gives when it asks for "one other".

3. Advantages and disadvantages of the automated system (6 questions)

1. **Check who** the question is about: the employees, the owner, the farmer, the public.
2. **Pick points that fit that person**. For employees: no repetitive or dangerous tasks, no night shifts outdoors; but possible job loss or deskilling. For the owner: works 24/7, fewer wages, more accurate; but high set-up and maintenance costs, training, breakdowns.
3. **Tie each to the scenario**: "the weather station keeps recording through the night, so staff don't have to go out in storms".
4. If asked to **explain**, give the point **and** why it matters (2 marks: point + consequence).

Variations you will meet:

- **"Benefits of using sensors"** in an automated system: data collected without a person; faster; more accurate; continuous (24/7); works in dangerous places.
- **"Explain the drawbacks"** (3 marks): three separate points, or a point and its consequence ("maintenance is expensive, because skilled technicians are needed").
- Two advantages must be **different**: "saves time" and "is faster" count once.

4. State what is meant by an automated system (2 questions)

1 mark: a system (or robot) that **performs actions without human intervention**. "Without humans" alone is weaker; say it carries out the task **by itself**.

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 small art gallery lets at most 40 visitors into one room at a time. Visitors enter through a turnstile at the entrance and leave through a separate exit door. Each doorway has an infra-red beam across it. When the room is full, the turnstile locks and a sign outside says "Full"; when someone leaves, the turnstile unlocks again.

(a) Explain why the system needs a sensor at the exit as well as at the entrance. **[1]**

(b) Identify the component that locks and unlocks the turnstile. **[1]**

(c) Describe how the sensors and the microprocessor control entry to the room. **[7]**

(a) The count must go down when visitors leave, or the room would be shown as full even after people had gone. **B1**

(b) An actuator (for example a motor or solenoid that moves the lock). **B1**

(c) Any seven:

- the infra-red sensors continuously send data to the microprocessor, converted to digital by an ADC **B1**;
- the microprocessor compares each sensor's data with the stored value for an unbroken beam **B1**;
- if the entrance beam is broken, it adds 1 to the stored counter **B1**;
- if the exit beam is broken, it takes 1 off the counter **B1**;

- after each change it compares the counter with the stored limit of 40 **B1**;
- if the counter equals 40, it sends a signal to the actuator to lock the turnstile, and a signal to the sign to show "Full" **B1**;
- if the counter is below 40, it sends a signal to unlock the turnstile (if it is locked) and to switch off "Full"; otherwise no action **B1**;
- the process repeats continuously while the gallery is open **B1**.

Example 2

A level crossing has barriers that stop road traffic when a train is coming. A magnetic field sensor A is in the track 2 km before the crossing, and a second magnetic field sensor B is just after it. When sensor A detects a train, warning lights flash for 8 seconds and then the barriers come down.

(a) The crossing used to be worked by a keeper who lowered the barriers by hand. Give two advantages to the railway company of the automated system. **[2]**

(b) The barriers go up 5 seconds after sensor B shows the train has passed, as long as sensor A has not detected another train. Describe how the sensors and the microprocessor control the barriers. **[7]**

(a) Any two: it works day and night without breaks, so no keeper has to be paid for every shift **B1**; the barriers always come down the same time before each train, with no risk of a keeper forgetting or being late **B1**; nobody has to work beside a busy railway line.

(b) Any seven:

- both sensors continuously send data to the microprocessor, converted to digital by an ADC **B1**;
- the microprocessor compares the data from sensor A with the stored value for a train (a large metal object) **B1**;
- if it matches, the microprocessor sends a signal to flash the warning lights **B1**;
- it starts an 8-second timer; when this ends it sends a signal to the actuators (motors) to lower the barriers **B1**;
- if the data from A does not match, no action is taken **B1**;
- the microprocessor compares the data from sensor B with the stored value to find when the train has passed **B1**;
- it then starts a 5-second timer **B1**;
- when the timer ends, it checks the data from sensor A : if no other train has been detected, it sends a signal to the motors to raise the barriers and to stop the lights **B1**;
- if another train has been detected, the barriers stay down **B1**;
- the process repeats continuously **B1**.

Example 3

A drinks factory used to fill bottles by hand, with six workers. It now uses an automated line: a level sensor checks each bottle, a valve fills it to the 500 ml mark, and an arm pushes any under-filled bottle off the conveyor belt. The line runs for 20 hours a day.

- (a) Identify the two actuators in the line, and what each one does. **[2]**
- (b) The owner expects the line to pay for itself. Give two reasons why the line may be better for the business than filling by hand. **[2]**
- (c) The six workers are moved to other jobs in the factory. Explain one way this could be good for them and one way it could be bad for them. **[2]**
- (d) Explain two risks to the business of relying on the automated line. **[4]**
- (a)** The valve, which opens to let drink into the bottle and closes when the level sensor's reading reaches the 500 ml mark. **B1** The arm, which moves to push an under-filled bottle off the belt. **B1**
- (b)** Any two: every bottle is filled to exactly 500 ml, so less drink is wasted and fewer customers complain **B1**; under-filled bottles are removed automatically, with no one checking by hand **B1**; fewer wages are needed for filling; it runs 20 hours a day without breaks, so more bottles are filled.
- (c)** Good: they no longer do the same boring, repetitive task all day and can learn more skilled work, such as checking and maintaining the line. **B1** Bad: the filling skills they had are no longer needed (deskilling), and they may need training, or some jobs may later be cut. **B1**
- (d)** Any two, each with its explanation: the line needs regular maintenance **B1**, so skilled technicians must be employed or paid **B1**; if the level sensor fails **B1**, bottles could be over-filled or good ones rejected until someone notices, wasting stock **B1**; if the line breaks down, production stops or bottles must be filled by hand again; a change such as a new bottle size may need expensive reprogramming or new parts.

Common mistakes

- **Generic answers.** The examiner reports for almost every session say this. "The sensor sends data to the microprocessor, which compares it" is only a start: name the sensor, use the question's values (40 °C, 1 metre, 2 minutes) and say the exact action.
- **Saying the sensor only sends data when something happens.** The sensor sends data **continuously**; it is the microprocessor that decides whether the data means anything.
- **Letting the sensor decide.** "The sensor detects that it is too hot and turns the heater off" gives the microprocessor's job to the sensor.
- **Repeating the question instead of describing the comparison.** "If the person is within 1 metre the message is shown" is in the question already. Say the microprocessor **compares the reading with the stored value of 1 metre**, and **if** it is less, sends a signal to show the message.

- **Using an actuator for a screen.** An actuator makes physical movement (a motor, a valve). It does not change what a screen displays or send an alert.
- **Missing the "otherwise" branch.** Say what happens when the reading is within range (no action) and on the other side of a range.
- **Misunderstanding timers.** The data isn't checked "every 2 minutes"; the data is checked all the time, and the timer is reset whenever the trigger happens again.
- **Answering for the wrong person.** "Workers can have more free time" isn't an advantage to the owner; "it saves money on wages" isn't an advantage to the workers.
- **Vague advantages.** "It is easier" or "it is better" earns nothing. Say faster, more accurate, 24/7, safer, cheaper over time, and why.
- **Confusing purpose, characteristics and advantages.** Read the key word in the question: what it is **for**, what it **has**, and why it is **better** need different answers.

How to get the marks

- **"Identify" / "Give" / "State"** (1 mark each): a single precise term, such as "level sensor" or "microprocessor". For "one other", don't repeat what's in the stem.
- **"Describe how the sensor and microprocessor..."**: one mark per step, in order: sensor sends data continuously → ADC → compare with the **stored value from the question** → **if** ... signal to the actuator to **do the specific thing** → **else** no action → repeats. Six marks need six separate steps.
- **"Describe the role of the microprocessor"**: receive, compare (analyse), send signals. Don't describe the sensor's job.
- **"Explain" an advantage or disadvantage** (2 marks): the point, then a reason or consequence in the scenario, joined with "so" or "because".
- **Use the context.** Examiners reward answers that could only be about **this** system. Reusing the wording of a different past question gets few marks.
- **Different points must be different.** "Works 24/7" and "doesn't need breaks" are usually the same mark.

Quick check

1. State what is meant by an automated system, and give the job of each of its three main kinds of component.
2. A smart front door shows "Welcome home" on a screen and slides a bolt across to unlock when its owner's phone comes near. Which of these two actions uses an actuator? Explain why the other does not.
3. A bathroom extractor fan is switched on by a microprocessor when the humidity reading goes above 70%. It keeps running until 4 minutes after the last reading above 70%. After a shower, the readings are above 70% from minute 0 to minute 6, then below, then above again from minute 8 to minute 9, then below for the rest of the hour. When does the fan stop, and how many times is it switched on?

4. The microprocessor of a pitch sprinkler follows this rule: "If the moisture reading is below 20, open the valve. If it is 35 or more, close the valve. Otherwise take no action." The valve starts closed. The readings arrive in this order: 28, 19, 24, 36, 30. For each reading, say what the microprocessor does and whether the valve is then open or closed.
5. A town replaces the people who read its river gauges with an automated river-level monitor that alerts residents if the river rises above a danger level. Explain why residents might welcome this change, and why the gauge readers might not.

Answers

1. A system that carries out a task by itself, without human intervention. Sensors measure the surroundings and send data continuously; the microprocessor compares the data with stored values and decides whether to act, sending signals; actuators carry out the physical movement.
2. Sliding the bolt uses an actuator, because it is a physical movement (a motor moves the bolt). Showing the message does not: the microprocessor sends the signal straight to the screen, and nothing moves.
3. The fan starts at minute 0. After minute 6 the 4-minute timer would end at minute 10, but the humidity is above 70% again at minute 8, so the fan is still running and the timer is reset. The last high reading is at minute 9, so the fan stops at $9 + 4 = 13$ minutes. It is switched on only **once**.
4. 28: no action, valve stays closed. 19: below 20, so a signal is sent to the actuator to open the valve; open. 24: between the stored values, no action, so it stays **open**. 36: 35 or more, so a signal is sent to close the valve; closed. 30: no action, stays closed. Readings between the two stored values leave the valve as it was, which is why 24 and 28 give different valve states.
5. Residents: the river is watched continuously, day and night, and the alert goes out the moment the level passes the danger value, so they have more time to protect their homes. Gauge readers: the monitor does their job, so they may lose their jobs or have to retrain for different work.

Past questions to try

- 0478/11/M/J/21 Q5: keeping a greenhouse within a temperature range.
- 0478/12/M/J/21 Q5: a security light with two sensors and a timer.
- 0478/12/O/N/21 Q8: a game with sensors, a timer and a counter.
- 0478/12/O/N/23 Q11: a flow sensor and advantages and disadvantages in manufacturing.