

Cambridge IGCSE · Computer Science 0478 · Notes

Artificial intelligence

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What you need to know

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

1. **Say what artificial intelligence (AI) is.** AI is the branch of computer science that deals with computers **simulating intelligent behaviour**: doing things that would need intelligence if a person did them, such as making a decision, solving a problem or recognising a voice.
2. **Describe the main characteristics of AI.** An AI system has a **collection of data** and **rules for using that data**, and it has the **ability to reason** (use the data and rules to reach a decision or a prediction). It **can** also have the **ability to learn and adapt**.
3. **Explain how two kinds of AI system work, and what their parts are:**
 - **expert systems**, which have four components: a **knowledge base**, a **rule base**, an **inference engine** and an **interface**;
 - **machine learning**, where a program can **automatically adapt its own processes and/or its own data**.

Only these two kinds of AI system are in the syllabus. Robots that use AI come up in the same questions: what makes something a robot is in the robotics note.

Understand it

What AI is

An ordinary program does exactly what its programmer wrote, in the same way every time. An **AI** system is still a program, but it is built to **simulate intelligent behaviour**: it takes in data about a situation, uses rules to reason about it, and reaches a decision, a prediction or an answer that a thinking person might have given. Some AI systems also get better with experience.

AI is **simulated** intelligence. The computer does not understand or think like a person; it imitates the results of intelligent behaviour using data, rules and processing.

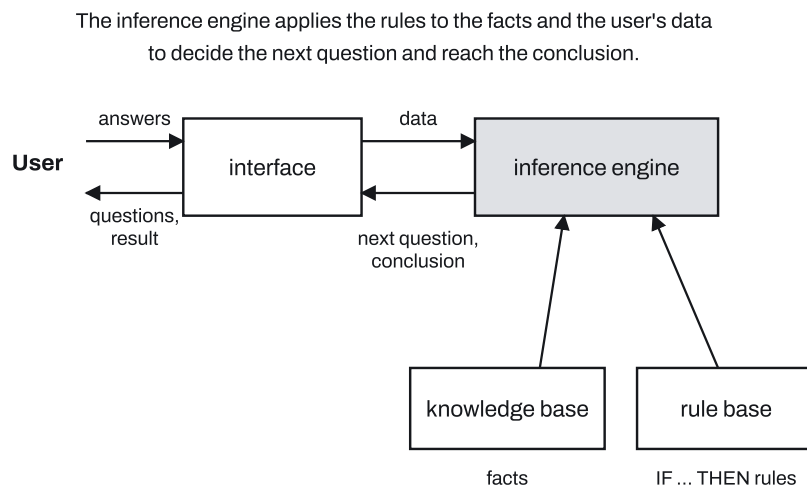
The characteristics of AI

Characteristic	What it means	Example
Collection of data	It holds or gathers facts about its task	A route planner stores road maps and live traffic reports
Rules for using the data	It has rules saying how the data leads to a decision	"IF a road is closed THEN do not use it"
Ability to reason	It applies the rules to the data to reach a conclusion, solve a problem or make a prediction	It works out the quickest route and predicts the arrival time
Ability to learn (can include)	It changes its own rules or data from experience	It notices that one junction is always jammed at 8 a.m.
Ability to adapt (can include)	It changes what it does as a result	It stops sending drivers through that junction at 8 a.m.

Every AI system has the first three. Learning and adapting are **possible** extras: an expert system that never changes is still AI.

Expert systems

An **expert system** does the job of a human expert in one narrow area, such as identifying a plant disease, finding a fault in a boiler or suggesting what illness a patient may have. It is built by collecting what experts know and storing it so that a computer can reason with it. It has four components.



Component	What it holds or does
Knowledge base	Stores the facts about the area of expertise, collected from experts (for example, every known fault and the signs of each one)
Rule base	Stores the rules , usually written IF ... THEN ..., that link the facts in the knowledge base to conclusions. The inference engine uses these rules

Component	What it holds or does
Inference engine	The part that reasons and makes the decisions . It decides which question to ask next, based on the answers already given ; it applies the rules in the rule base to the facts in the knowledge base and the user's data; it reaches a conclusion (a diagnosis, identification or solution), and if more than one is possible, the most likely one
Interface	The screen (or connection) the user works with: it shows the questions , lets the user input data (answers, readings), and outputs the result . Many expert systems can also show how the result was reached

How it runs, step by step:

1. The user enters data about the problem through the **interface** (or plugs in the machine being tested).
2. The **inference engine** looks at the data so far and decides which **question** to ask next; the interface shows it and the user answers.
3. The inference engine **compares** the answers with the facts in the **knowledge base** and **applies the rules** in the **rule base** to them. Each answer rules some conclusions out, so the next question depends on the previous answers.
4. When the rules lead to one conclusion (or one most likely conclusion), the inference engine sends it to the **interface**, which **outputs** it, often with the reasoning or a probability.

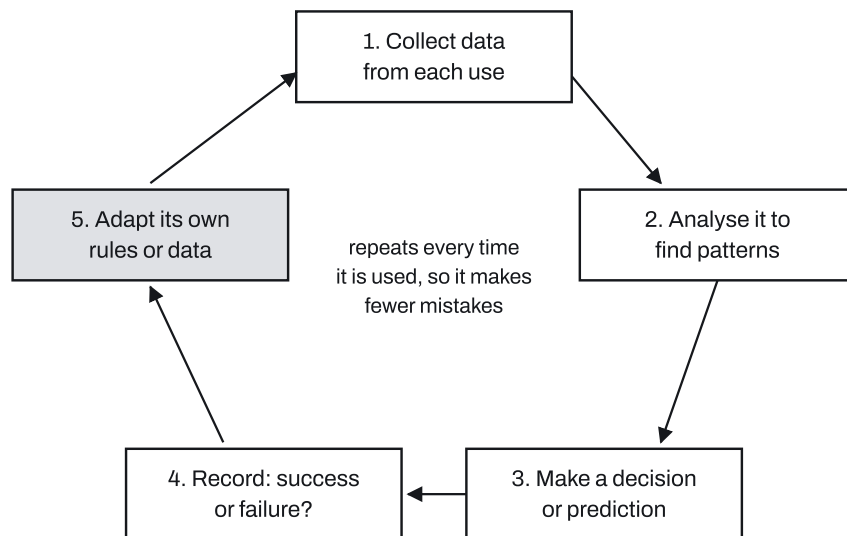
For example, a small rule base for a bike-repair helper could hold:

- IF the chain slips AND the chain is worn THEN replace the chain;
- IF the chain slips AND the chain is not worn THEN adjust the gears;
- IF the brakes squeal THEN clean the brake pads.

A user reports "chain slips". The inference engine now knows the brake rule can't apply, so it asks "Is the chain worn?" and never asks about the brakes. The answer "no" makes only the second rule true, so the output is "adjust the gears".

Machine learning

Machine learning is when a program can **automatically adapt its own processes and/or data**, without a programmer rewriting it. The program improves the more it is used.



1. **Collect data** every time it is used (what happened, what the user did, what the sensors read).
2. **Analyse the data to find patterns** (this user always skips slow songs; this corner of the room always has an obstacle).
3. **Make a decision or a prediction** based on those patterns.
4. **Record the result**: was it successful or not? This feedback can come from the user (a correction, a click, a "not this one") or from what happens next (it bumped into something).
5. **Adapt its own rules or data**, keeping what worked and changing what didn't, so it makes **fewer mistakes** and gives **more accurate** results next time.

A program can be **trained** in two ways, and mark schemes accept these words:

- **supervised learning**: it is given example inputs **with** the correct outputs (for example, thousands of photos labelled "cat" or "dog") and learns the link;
- **unsupervised learning**: it is given inputs **without** the answers and has to find the patterns itself (for example, grouping shoppers who buy similar things).

What it learns depends on the machine. Exam questions always give a context, so think about what data that machine can collect and what it could get better at:

Kind of machine	Data it can collect	What it can learn or adapt
Something that moves (robot, drone, self-driving vehicle, cleaner, mower)	Its routes, obstacles met, the shape and size of the area, which moves worked	A map of the area; where obstacles are and how to get round them; the quickest or most efficient route; not to repeat a wrong turn (going back to the last choice point after a dead end)
Something that listens (smart speaker, voice assistant)	Many recordings of each user's voice, and which commands it got right or wrong	Each user's voice, accent and pronunciation; different ways of asking for the same thing; to ignore background noise

Kind of machine	Data it can collect	What it can learn or adapt
Something that recommends or searches (shop, streaming service, search engine)	What each user searches for, clicks, buys, skips or rates	Which results or items this user wants; to rank results that users actually chose higher; to suggest the rest of a search as it is typed
An opponent in a game	The player's moves and choices	The player's patterns, so it can predict the next move and change its own tactics to match

Expert system or machine learning?

An expert system needs a **user who answers questions**. A machine working by itself (a robot in a maze, a vacuum cleaner, a game character) has no one to answer, so the AI there is **machine learning**, not an expert system. The two can be combined: an expert system with machine learning can update its own knowledge base and rules as new cases are confirmed.

An **automated system** is not automatically AI. A heater that switches on below a stored temperature always uses the same stored value; if it **changed that value itself** from what it learned, that would be machine learning.

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
AI: the branch of computer science dealing with the simulation of intelligent behaviour by computers	Learn it
Main characteristics: collection of data; rules for using that data; ability to reason; can include ability to learn and adapt	Learn it
Expert system components: knowledge base, rule base, inference engine, interface	Learn it
Knowledge base: the facts. Rule base: the rules that link the facts. Inference engine: decides the questions and applies the rules to reach the conclusion. Interface: input of data, output of questions and result	Learn it
Machine learning: a program automatically adapts its own processes and/or data	Learn it
Machine learning loop: collect data → find patterns → decide or predict → record success or failure → adapt rules or data → repeat	Learn it
Supervised: trained with inputs and correct outputs. Unsupervised: finds the patterns in inputs by itself	Learn it

How to do it

In the Paper 1 questions we have tagged for this topic (17 questions, 2023–2025), the AI parts came in these types. 8 of the 17 questions mix two types, so the counts add up to more than 17. Parts of the same questions on robots, automated systems, translators and data transmission are in their own notes.

Question type	Questions
How machine learning is used in a given context	8
How an expert system operates (including gap-fills)	5
What AI is and its characteristics	5
The components of an expert system and their roles	4
What machine learning is (name or describe it)	3

1. How machine learning is used in a given context (8 questions)

2–4 marks; "Explain how ... can use machine learning", "Explain how this will improve ...", "Give three ways ... could make use of AI".

1. **Say it uses machine learning** (often a mark by itself).
2. **Say what data this machine collects**, in the context: its routes, the player's moves, the users' voices, the searches.
3. **Say it analyses the data to find patterns and stores successful and unsuccessful** results.
4. **Say how it adapts**: it changes its own rules, data or processes.
5. **Say what gets better, in the context**: a quicker route, fewer collisions, recognising an accent, more relevant results, predicting the next move.

Use the table in "Understand it" for ideas. Every sentence should be one that only fits this machine.

Variations you will meet:

- **"Give three ways ... could make use of AI"** (1 mark each): three separate things it could learn, each in the context. For a robot lawn mower, for example: "learn the shape of the lawn and the edges of the flower beds"; "learn which parts of the lawn grow fastest and cut them more often"; "learn the order of strips that cuts the whole lawn on the least battery".
- **A machine that moves**: gather data as it goes → build a map → remember obstacles and dead ends → work out the most efficient route → avoid past mistakes. After a dead end it can go back to its last decision point and try a different way.
- **A search engine or recommendation system**: it records which results users choose or ignore (feedback), changes its rules so those results rank higher or lower, and so gives more relevant results next time. It can also learn one user's preferences.
- **A voice-controlled device**: it listens to many voices and many ways of saying the same command, stores which commands it got right, and learns accents, pronunciations and to ignore background noise.

- **Don't answer with an expert system** when nobody is there to answer questions.

2. How an expert system operates (5 questions)

3–6 marks; "Explain how an expert system operates", "Describe how the expert system decides the diagnosis", or a paragraph with gaps to fill from a list.

1. **The interface**: the user inputs data (answers, readings), and it shows questions and outputs the result.
2. **The inference engine decides which questions to ask**, based on the previous answers.
3. It **compares** the data entered with the **knowledge base**, and **applies the rule base** to the knowledge base (the rules link the facts).
4. The **inference engine** reaches the **diagnosis** (or decision or solution), choosing the most likely if there are several.
5. The **interface outputs** it, and can show how it was reached.

Variations you will meet:

- **"Describe how it decides"** wants what the inference engine does, in order, not just a list of what each component contains. Examiners in 2025 said most answers only named the parts.
- **In context**: use the question's user and problem ("the mechanic enters the fault code through the interface...").
- **Gap-fill paragraphs**: decide which component fits each gap by its job: facts → knowledge base; rules → rule base; decides, chooses questions, links facts to rules → inference engine; typing in data, showing the output → interface. Terms such as CPU, ROM or primary storage are distractors. A term can be needed twice.

3. What AI is and its characteristics (5 questions)

1–3 marks; "Describe what is meant by AI", "State one of the main characteristics", "Identify three other characteristics".

1. **What AI is**: the simulation of intelligent behaviour by computers.
2. **The characteristics**: a collection of data; rules for using that data; the ability to reason (make decisions or predictions); the ability to learn; the ability to adapt.

Variations you will meet:

- **"One characteristic is the ability to learn; identify three others"**: collection of data, rules for using the data, ability to reason, ability to adapt. Don't repeat "learn".
- **Describe the characteristics**, not examples of AI or types of AI system. Naming "expert system" or "a chatbot" earns nothing here.

4. The components of an expert system and their roles (4 questions)

1–3 marks for naming, 2 marks for a role.

1. **Name the four**: knowledge base, rule base, inference engine, interface. If one is given, name the **other** three.
2. **Role of the rule base**: stores the rules; the inference engine uses them; they link the facts in the knowledge base (to conclusions).
3. **Role of the inference engine**: makes the decisions, by applying the rules to the facts, to give a result or diagnosis; it also decides which question to ask next.

Variations you will meet:

- **"Circle three components"** from a list with distractors such as operating system, firewall, actuator or server.
- **Role of the knowledge base**: stores the facts about the area, collected from experts. **Role of the interface**: lets the user input data and see the questions and output.

5. What machine learning is (3 questions)

1–4 marks.

1. **"Give the name of the ability to automatically adapt its own processes (and data)"**: machine learning.
2. **"Describe what is meant by machine learning"**: start with the definition: a program that changes its own processes and data by itself, with no programmer editing it. Then say how it gets better: each use gives it more data, it spots patterns in that data, keeps a record of what went right and wrong, and uses that record to make its next decisions better. Then, for a longer answer, say how it can be taught: with labelled examples where the right answer is shown (supervised), or with no answers, finding the patterns itself (unsupervised). Machine learning is one kind of AI, which is worth a mark too.

Worked examples

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

- **M1** method mark: for a correct method, even if the numbers slip.
- **A1** accuracy mark: for a correct answer; it needs the M mark before it.
- **B1** mark for a correct result on its own, with no method needed.

Example 1

A student makes four statements about AI. For each one, state whether it is true or false. If it is false, correct it.
[4]

- A: "A system can only be called AI if it can learn."

- B: "In an expert system, the inference engine stores the facts."
- C: "Machine learning lets a program change its own processes and data without a programmer rewriting it."
- D: "A calculator app is AI because it solves problems."
- **A is false.** Learning is a characteristic an AI system **can** have. A system that has data, rules for using the data and the ability to reason is AI even if it never learns. **B1**
- **B is false.** The facts are stored in the **knowledge base**; the inference engine applies the rules to those facts to make the decisions. **B1**
- **C is true. B1**
- **D is false.** A calculator carries out fixed calculations exactly as programmed; it does not use a collection of data and rules to reason towards a decision, so it does not simulate intelligent behaviour. **B1**

Example 2

A wildlife charity's app uses an expert system to help people identify garden birds. Its rules are:

- R1: IF size is small AND breast is red THEN the bird is a robin
- R2: IF size is small AND breast is yellow THEN the bird is a blue tit
- R3: IF size is medium AND colour is all black AND beak is orange THEN the bird is a blackbird
- R4: IF size is medium AND colour is black and white AND tail is long THEN the bird is a magpie

(a) State which component of the expert system stores R1 to R4. **[1]**

(b) A user answers the first question, "What size is the bird?", with "medium". State the next question the app should ask, and explain why it does not ask about the colour of the breast. **[2]**

(c) The user then answers "black and white", and then "long". State the bird the app outputs. **[1]**

(d) Describe how the components of the expert system work together to reach this answer. **[4]**

(a) The rule base. B1

(b) "What colour is the bird?" B1 (Colour comes first because it is the only thing that both R3 and R4 test, so one answer settles which rule can still apply; asking about the beak or the tail first would also be accepted.) The breast colour only appears in R1 and R2, which need a small bird. "Medium" has already ruled them out, so the inference engine only asks questions that R3 and R4 still need. **B1**

(c) A magpie (only R4 has all three of its conditions met). B1

(d) Any four:

- the user inputs each answer through the interface **B1**;
- the inference engine decides which question to ask next, using the answers already given **B1**;

- it compares the answers with the facts in the knowledge base (what each bird looks like) **B1**;
- it applies the rules in the rule base to find the rule whose conditions are all met **B1**;
- it reaches the conclusion "magpie", and the interface outputs it to the user **B1**.

Example 3

A home has a smart thermostat that controls the heating. It has machine learning capabilities.

(a) Explain how the thermostat can use machine learning to decide when to switch the heating on in the evening. **[4]**

(b) The thermostat's first setting was to switch the heating on at 17:00 every weekday. It then records the family's arrival times for one week: 17:40, 17:50, 17:35, 17:55, 17:40. The room takes 25 minutes to warm up, and it now switches the heating on 25 minutes before the mean arrival time. State the new switch-on time. **[2]**

(c) An older thermostat switches the heating on whenever the room is below 19 °C. Explain why this older thermostat is not using machine learning. **[2]**

(a) Any four:

- it collects data every day: when the family gets home, when they turn the heating up or down by hand, and the room temperature **B1**;
- it analyses the data to find patterns, such as the usual arrival time on each weekday **B1**;
- it uses the pattern to predict when the family will arrive, and switches on early enough for the room to be warm then **B1**;
- it records whether the prediction worked (for example, someone turned it up by hand, so the room was too cold) **B1**;
- it adapts its own stored times and rules from that feedback, so the schedule becomes more accurate and wastes less energy **B1**.

(b) Mean arrival time: the five times are 40, 50, 35, 55, 40 minutes after 17:00, and $\frac{40+50+35+55+40}{5} = 44$, so 17:44. **M1** Switch-on time: 17:44 – 25 minutes = 17:19. **A1**

(c) It always compares the temperature with the same stored value of 19 °C, which only a person can change. **B1** It never changes its own rules or data from what happens, so it does not adapt its own processes: it is an automated system, not machine learning. **B1**

Common mistakes

- **Answering a context question with a general definition.** Examiners in 2025 said most students described what machine learning is instead of how the search engine, the robot or the speaker uses it. Every point should mention the machine's own data or task.
- **Describing an expert system where there is no user.** A robot in a maze or a game character has nobody to answer questions; use machine learning. Examiners flagged this in 2023.

- **Naming the parts instead of explaining how it works.** "It has a knowledge base, a rule base..." earns little on an "explain how it operates" question. Say what the inference engine **does** with them, in order.
- **Muddling the roles.** The knowledge base holds facts, the rule base holds rules, and the **inference engine** makes the decision. Few students could describe the roles of the inference engine and rule base in 2023.
- **Giving examples or types instead of characteristics.** "Robots" or "an expert system" is not a characteristic of AI. Give data, rules, reason, learn, adapt.
- **Repeating the characteristic in the stem.** If the question already says "the ability to learn", don't give it again.
- **Calling AI a characteristic of a robot.** Many robots have no AI (examiners, 2025). AI is something a robot **may** also have.
- **Writing "it gets smarter" or "it learns" on its own.** Say what data it collects and what it changes.

How to get the marks

- **"State" / "Give" / "Identify" / "Name"** (1 mark each): the exact term, such as "inference engine" or "machine learning". Answers in one list must be different.
- **"Describe what is meant by AI"**: simulation of intelligent behaviour, plus characteristics (data, rules, reason, learn, adapt), one mark each.
- **"Explain how an expert system operates"**: a chain of steps, one mark each: interface input → inference engine chooses questions from previous answers → compares with the knowledge base → applies the rule base → reaches the diagnosis → interface output.
- **"Explain how ... uses machine learning"**: one mark per step or example, **in the context**: collect data about ... → find patterns in ... → store successes and failures → adapt its own rules or data → so that it ... (the improvement).
- **Gap-fills**: one mark per gap, in order. Read the whole paragraph first, and check each gap against a component's job.
- **Read the context.** Examiners reward answers that could only be about this system: its user, its data and its task.

Quick check

1. Name the component of an expert system that each of these describes: (a) holds the facts about the area of expertise; (b) shows the user the questions and the result; (c) chooses the next question from the answers so far.
2. A language-learning app marks spoken answers. At first it often rejects correct answers from students with strong accents, but it makes fewer of these mistakes each month without any update from the developers. Name the ability the app has, and explain how it is improving.
3. A plant-care app uses an expert system with these rules:
 - P1: IF leaves are yellow AND soil is wet THEN the plant is overwatered

- P2: IF leaves are yellow AND soil is dry THEN the plant needs more water
- P3: IF leaf tips are brown AND the plant is near a radiator THEN the air is too dry
- P4: IF leaves are pale AND the plant is in a dark corner THEN it needs more light

A user answers "yellow" for the leaves and "dry" for the soil. What does the app output, and which of the conditions in P3 and P4 does it never ask about?

4. A spam filter moves emails it decides are junk into a separate folder. Using the characteristics of AI, explain why it is an AI system.
5. A student writes: "The rule base makes the decision in an expert system." Correct this statement.

Answers

1. (a) Knowledge base. (b) Interface. (c) Inference engine.
2. Machine learning. It collects the answers it rejected that turned out to be correct (feedback from teachers or students), finds patterns in how students with different accents say the same words, and adapts its own data and rules so that it accepts those pronunciations next time.
3. "The plant needs more water" (only P2 has both conditions met). It never asks whether the plant is near a radiator or in a dark corner: the answer "yellow" has already ruled out P3 and P4, so those questions are not needed.
4. It has a collection of data (many emails already known to be junk or not); it has rules for using that data (for example, words and senders that often appear in junk); it reasons with them to decide whether each new email is junk. If it learns from users marking emails "not junk", it also learns and adapts.
5. The rule base only **stores** the rules. The **inference engine** makes the decision, by applying those rules to the facts in the knowledge base and the user's answers.

Past questions to try

- [0478/11/O/N/24 Q9](#): completing a paragraph on how an expert system diagnoses an illness, then naming machine learning.
- [0478/12/M/J/24 Q10](#): what AI is, and how an expert system helps find a car's fault.
- [0478/12/F/M/23 Q6](#): the characteristics of AI, and how a robot in a maze uses it.
- [0478/12/O/N/25 Q7](#): how a smart speaker uses machine learning on voice commands.