PrepWithTee

NOTES

Paper 1 Computer Systems

Cambridge O Level Computer Science (2210)

6 chapters, 29 notes. Every topic taught from the basics, then how it is examined: question types, marking points, keywords and real past-paper questions solved with the official mark scheme, with practice to finish.

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Each note has two parts. **Part 1** teaches the topic from the basics. **Part 2** shows how it is examined: the types of question, what the examiner gives marks for, the keywords to use, and real past-paper questions solved with the official mark scheme. The answers to every practice question are at the end of each note.

1

Data Representation

1 Number systems: binary, denary and hexadecimal

2 Hexadecimal uses, binary addition and overflow

3 Logical shifts and two's complement

4 Text, sound and images

5 Data storage units, file sizes and compression

NOTE 1.1

Number systems: binary, denary and hexadecimal

1 In this note

SYLLABUS 1.1 NUMBER SYSTEMS

- 1.1.1 Explain **how and why computers use binary** to represent all data.
- 1.1.2 Understand the **denary**, **binary** and **hexadecimal** number systems.
- 1.1.2 Convert positive whole numbers between denary, binary and hexadecimal, in every direction (up to 16 bits).
- 1.1.2 Work out the largest number a register can hold and the fewest bits a number needs.

Next: Hexadecimal uses and binary addition.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

Place value in denary

In 365 the 3 is worth 300, the 6 is worth 60 and the 5 is worth 5. Each column is worth **ten times** the column to its right: 1, 10, 100, 1000.

Quick check: what is the 4 worth in 4 072?

4000 (the thousands column).

Powers of 2

Keep doubling from 1: 1, 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024 … You will use these in every question on this page, so learn them up to 128 (and 2048, 4096 … for 12 and 16 bits).

Quick check: what comes after 128?

256.

3 Why computers use binary

Inside a computer, data is processed by millions of tiny electronic **switches** called transistors, wired together into **logic gates**. A switch can only be in one of **two states**: on or off. So a computer can only hold two values, which we write as **1 and 0**.

That is why **every** kind of data has to be turned into binary before a computer can process or store it: numbers, text, images, sound, and the program instructions themselves. Binary values are held in **registers** (small stores inside the processor) and in memory.

> **Binary** is a **base 2** number system: it uses only the two digits **0 and 1**. One binary digit is called a **bit**.

> Why binary, in one sentence: **computers are made of switches / logic gates that have only two states, so they can only process 1s and 0s.**

4 Denary, binary and hexadecimal

A number system's **base** is how many different digits it uses. Every system works with place value: each column is worth the base times the column to its right.

System	Base	Digits	Column values (right to left)	Who uses it
Denary	10	0 to 9	1, 10, 100, 1000 …	people, every day
Binary	2	0 and 1	1, 2, 4, 8, 16, 32, 64, 128 …	the computer itself
Hexadecimal (hex)	16	0 to 9, then A to F	1, 16, 256, 4096	programmers: a short way to write binary

In hex the letters stand for the numbers 10 to 15, because one column must hold a single digit:

Denary	0	1	2	3	4	5	6	7	8	9	10
Hex	0	1	2	3	4	5	6	7	8	9	A
Binary	0000	0001	0010	0011	0100	0101	0110	0111	1000	1001	1010

EXAM TIP

You do not need to memorise the binary row: in the exam, count up in four columns 8 4 2 1. Two worth knowing by heart:

ANSWER

A = 10 = 1010 and F = 15 = 1111.

5 Binary to denary

An 8-bit binary number has these column (place) values. A 1 means "include this column", a 0 means "leave it out":

	128	64	32	16	8	4	2	1
Binary	1	0	0	1	1	1	0	0

1001 1100 = 128 + 16 + 8 + 4 = 156

GENERAL METHOD **Binary to denary**

1. Write the place values over the bits: 1 under the **rightmost** bit, then 2, 4, 8 … going left.
2. Add the place values that have a 1 under them.
3. Check: the answer is odd only if the last bit is 1, and 8 bits can never give more than 255.

EXAMPLE **Convert 0010 1101 to denary.**

Add the place values of the 1s.

32 + 8 + 4 + 1

ANSWER **45**

TRY IT YOURSELF

1. Convert 0101 0101 to denary.
2. Convert 1111 1111 to denary.

3 Convert 1100 1000 to denary.

6 Denary to binary

Two methods give the same answer. Use whichever you find quicker; the mark scheme accepts both.

Method A: subtract place values

GENERAL METHOD **Take away the biggest place value that fits**

1. Write the place values 128 64 32 16 8 4 2 1.
2. Start at 128. Does it fit into what is left? Yes: write 1 and subtract it. No: write 0.
3. Move to the next place value and repeat until you reach 1.
4. Read the bits from left to right.

EXAMPLE **Convert 156 to 8-bit binary.**

Take away the biggest place value that fits, each time.

128 fits: 1, and 156 − 128 = 28 left

64? no: 0. 32? no: 0. 16 fits: 1, and 28 − 16 = 12 left

8 fits: 1, 4 left. 4 fits: 1, 0 left. 2? no: 0. 1? no: 0

ANSWER **1001 1100**

Method B: divide by 2

GENERAL METHOD **Keep dividing by 2 and read the remainders upwards**

1. Divide the number by 2. Write down the answer and the remainder (0 or 1).
2. Divide the answer by 2 again. Keep going until the answer is 0.
3. The **first** remainder is the **rightmost** bit: read the remainders from the bottom up.
4. Add 0s on the left to make 8 bits (or the number of bits asked for).

Divide	Answer	Remainder
156 ÷ 2	78	0
78 ÷ 2	39	0
39 ÷ 2	19	1
19 ÷ 2	9	1
9 ÷ 2	4	1
4 ÷ 2	2	0
2 ÷ 2	1	0
1 ÷ 2	0	1

Reading upwards: 1001 1100.

✗ COMMON MISTAKE

If the question says **8-bit**, the answer must have exactly 8 bits: 14 is **0000 1110**, not 1110. Leading zeros never change the value, but they show the size of the register.

TRY IT YOURSELF

1. Convert 50 to 8-bit binary.
2. Convert 102 to 8-bit binary.

3 Convert 221 to 8-bit binary.

7 How big a number can a register hold?

A **register** has a fixed number of bits. With all bits set to 1 you get the largest number it can hold.

Bits	Smallest	Largest	How many different values
4 (a nibble)	0	15 (1111)	16
8 (a byte)	0	255 (1111 1111)	256
12	0	4095 (FFF in hex)	4096
16	0	65 535 (FFFF in hex)	65 536

Largest value

n bits hold up to $2^n - 1$: 8 bits → $2^8 - 1 = 255$.

Fewest bits for a number

Keep doubling until the place value is **bigger** than the number, then count the place values you used. 301: 256 is not bigger, 512 is → 1, 2, 4 … 256 is **9 bits**.

Fewest bits for a hex number

Each hex digit is exactly 4 bits, so count the digits × 4: A4D has 3 digits → **12 bits**.

TRY IT YOURSELF

1 What is the largest denary number an 8-bit register can store?

2 What is the least number of bits needed to store the denary number 200?

3 What is the least number of bits needed to store the hexadecimal number 3F2?

8 Converting with hexadecimal

The key fact: **one hex digit is exactly 4 bits** (a nibble), because $16 = 2^4$. So binary and hex convert by **grouping in fours**; no adding up of big numbers is needed.

Binary to hex

GENERAL METHOD **Binary to hexadecimal**

1. Split the bits into groups of 4 **starting from the right**. If the left group is short, add 0s in front.
2. Work out each group with the place values 8 4 2 1 (10 to 15 become A to F).
3. Write the hex digits in the same order.

	8	4	2	1	8	4	2	1	8	4	2	1
Binary	1	0	1	1	0	0	1	1	1	0	1	0
Hex				B				3				A

1011 0011 1010 → B 3 A. Each group of four is worked out on its own.

Hex to binary

GENERAL METHOD **Hexadecimal to binary**

1. Turn **every** hex digit into exactly 4 bits, zeros included.
2. Write the groups side by side.

EXAMPLE **Convert A04 to binary.**

Four bits for every digit, even the 0.

A = 1010

0 = 0000

4 = 0100

ANSWER **1010 0000 0100**

✗ COMMON MISTAKE

Dropping a 0000 group is the classic mistake: A04 is 1010 **0000** 0100 (12 bits), not 1010 0100.

Hex to denary

Method A: hex place values

GENERAL METHOD **Multiply by 1, 16, 256**

1. Hex place values from the right are 1, 16, 256 (and 4096).
2. Multiply each digit (A = 10 … F = 15) by its place value.
3. Add them up.

EXAMPLE **Convert C0F to denary.**

Multiply each digit by its place value.

C = 12 in the 256s: 12 × 256 = 3072

0 in the 16s: 0

F = 15 in the 1s: 15

ANSWER **3072 + 0 + 15 = 3087**

Method B: through binary

GENERAL METHOD **Go through binary**

1. Turn each hex digit into 4 bits.
2. Convert the binary to denary by adding place values.

EXAMPLE **Convert F0 to denary.**

Through binary.

F0 = 1111 0000

128 + 64 + 32 + 16

ANSWER **240**

✗ COMMON MISTAKE

F0 is **not** "150" (writing 15 and 0 side by side). Every digit must be multiplied by its place value: 15 × 16 + 0 = 240.

Denary to hex

Method A: through binary (safest)

GENERAL METHOD **Go through binary**

1. Convert the denary number to binary.
2. Group the bits in fours from the right.
3. Turn each group into one hex digit.

EXAMPLE **Convert 251 to hex.**

Binary first, then group in fours.

251 = 1111 1011

1111 = F, 1011 = B

ANSWER **FB**

Method B: divide by 16

GENERAL METHOD **Divide by 16 and use the remainders**

1. Divide by 16. The remainder (0 to 15) is the **rightmost** hex digit.
2. Divide the answer by 16 again; the remainder is the next digit to the left.
3. Stop when the answer is 0. Read the remainders from the bottom up.

EXAMPLE **Convert 301 to hex.**

Divide by 16, keep the remainders.

301 ÷ 16 = 18 remainder 13 → D

18 ÷ 16 = 1 remainder 2 → 2

1 ÷ 16 = 0 remainder 1 → 1

ANSWER **12D**

TRY IT YOURSELF

1. Convert 1001 0011 to hex.
2. Convert 2D to binary.
3. Convert 236 to hex.
4. Convert 1A to denary.

9 Summary

- Computers use binary because they are made of switches / logic gates with only two states (1 and 0). All data is converted to binary.
- Denary is base 10, binary is base 2 (0, 1), hexadecimal is base 16 (0-9, A-F).
- 8-bit place values: 128 64 32 16 8 4 2 1. Binary to denary: add the place values of the 1s.
- Denary to binary: subtract the biggest place value that fits (or divide by 2, read remainders upwards). Give the number of bits asked for.
- One hex digit = 4 bits. Binary ↔ hex: group in fours from the right.
- Hex to denary: digit × 16 + digit (× 256 for a third digit). Denary to hex: go through binary, or divide by 16.
- n bits hold 0 to $2^n - 1$ (8 bits: 0-255). Fewest bits: first power of 2 bigger than the number; hex: digits × 4.

IF YOU SEE …

"Convert … to 8-bit binary"	→ exactly 8 bits, with leading zeros
"least number of bits"	→ first power of 2 bigger than the number (hex: 4 per digit)
a hex digit 0 in the middle	→ write it as 0000

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

10 Ways they test it

TYPE 1 Convert three numbers

> *"Convert these three denary numbers to 8-bit binary numbers: 50, 102, 221" [3]. Also binary → hex, hex → binary, denary → hex, often as a table to fill in.*

Spot it a list of numbers and a working space.

1. One mark per number, all or nothing, so check each one.
2. Binary answers: the number of bits asked for.
3. Hex answers: "one mark per correct character in the correct order" for longer conversions.

TYPE 2 Explain the system

> *"Explain what is meant by a binary number system" [2]*

Spot it "what is meant by" / "explain".

1. It is base 2.
2. It uses only two values, 1 and 0.

TYPE 3 Why binary

> *"Explain why data input into the machine needs to be converted to binary" [2]*

Spot it "why" + "binary".

1. The computer contains logic gates / switches ...
2. ... that only process two states / 1 and 0.

TYPE 4 Size of a register

> *"State the highest denary number in an 8-bit register" [1], "Calculate the least number of bits to store 301" [1]*

Spot it "highest", "least number of bits".

1. $2^n - 1$ for the highest.
2. First power of 2 bigger than the number for the bits.

TYPE 5 Similarities and differences

> *"Give one similarity and two differences between hexadecimal and binary" [3]*

Spot it two systems compared.

1. Similarity: both are number systems (both can represent the same values).
2. Differences: base 2 vs base 16; binary uses only 0 and 1, hex uses 0-9 and A-F; hex is shorter.

11 What the examiner looks for

"Explain why computers use binary" [2]

Marking points (one mark each, up to the marks shown)

- Computers contain logic gates / switches ...
- ... that only have two states // only process the values 1 and 0.

KEYWORDS **logic gates** **switches** **two states** **1 and 0**

TOO VAGUE "computers understand binary"; "binary is easier for computers"

"Explain what is meant by a binary number system" [2]

Marking points (one mark each, up to the marks shown)

- It has a base of 2.
- It only uses two values ...
- ... that are 1 and 0.

KEYWORDS **base 2** **1 and 0**

Wording trap · Writing an 8-bit binary answer

THE QUESTION **2210/13/O/N/23 Q2** ↗ Paper 1 · Computer systems **3 marks**

Convert the denary number 14 to binary.

✓ CREDITED

- 0000 1110
- 1110 (the scheme wrote (0000)1110: leading zeros optional when no number of bits is set)

✗ NOT CREDITED

- 111 (a bit missing)
- 0111 0000 (written backwards)

WHY

When the question says 8-bit, write all 8 bits; then a missing leading 0 can never cost you the mark.

From: 2210/13/O/N/23 Q2(b) mark scheme

12 Past-paper questions, solved

2210/13/O/N/23 Q2 ↗ Paper 1 · Computer systems **8 marks** ⤢ Full size

2 Humans use a denary number system and computers use a binary number system.

(a) Explain what is meant by a binary number system.

..... [2]

(b) Convert the denary numbers 14, 59 and 234 to binary.

234 .....
[3]

Working space

(c) Convert the denary numbers 9, 26 and 65 to hexadecimal.

[3]

Working space

Swipe sideways to read the whole question

How to start Part (a) is two facts about binary (base, two values). For (b) and (c) use the place-value table; go through binary for the hex.

▼ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

(a) A binary number system has a **base of 2**. It uses only **two values, 1 and 0**.

(b) 14 = 0000 1110 · 59 = 0011 1011 · 234 = 1110 1010

(c) 9 = 9 · 26 = 0001 1010 = 1A · 65 = 0100 0001 = 41

PART	ANSWER / WORKING	MARKS	GUIDANCE
2(a)	Any two from: it has a base of 2 · it only uses two values · … that are 1 and 0	B2	
2(b)	(0000)1110 · (00)111011 · 11101010	B3	one mark each
2(c)	9 · 1A · 41	B3	one mark each

Total: 8 marks

2 A car park has a payment machine that allows a customer to pay for their parking.

The cost of parking is displayed as a denary number on a screen on the payment machine.

The cost of parking is stored in two 8-bit binary registers.

For the parking cost of $10.50:
- register 1 stores the denary value 10 as binary
- register 2 stores the denary value 50 as binary.

(a) Give the parking cost that would be displayed on the payment machine when the registers store:
- register 1: 00010001
- register 2: 01000110

Parking cost displayed $ ..... [2]

Working space

(b) The parking cost of $14.98 is displayed on the payment machine.

Give the 8-bit binary numbers that are stored in the registers to display the parking cost.

Register 1 .....

Register 2 .....
[2]

Working space

(c) The payment machine gives the customer a ticket when they have paid their parking cost. Each ticket has a 4-digit hexadecimal ticket number that is stored as binary.

The binary number 1010000000111101 is stored for a customer's ticket number.

Give the hexadecimal ticket number that would be displayed on this customer's ticket.

Hexadecimal ticket number ..... [4]

Working space

Swipe sideways to read the whole question

How to start Each register is a separate 8-bit number: convert register 1 for the dollars and register 2 for the cents. For (c) group the 16 bits in fours.

▼ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

(a) 0001 0001 = 16 + 1 = 17 and 0100 0110 = 64 + 4 + 2 = 70, so **$17.70**.

(b) 14 = 0000 1110 and 98 = 64 + 32 + 2 = 0110 0010.

(c) 1010 | 0000 | 0011 | 1101 = A 0 3 D, so **A03D**.

PART	ANSWER / WORKING	MARKS	GUIDANCE
2(a)	17 · 70 (correct fee $17.70)	B2	one mark for each part, in the correct order
2(b)	Register 1: 00001110 · Register 2: 01100010	B2	
2(c)	A · 0 · 3 · D	B4	one mark per correct character in the correct order

Total: 8 marks

EXAMINER TIP A whole 16-bit number given at once? Split it into nibbles first and write the four groups down before converting.

0478/13/M/J/23 Q1 ↗ Paper 1 · Computer systems **5 marks** ⤢ Full size

1 Computers store data as binary. The binary number 10101110 is stored.

(a) Convert the binary number to denary.

..... [1]

Working space

(b) Convert the binary number to hexadecimal.

..... [2]

Working space

(e) The denary number 301 needs to be stored.

Calculate the least number of bits that can be used to store the denary number 301.

..... [1]

Working space

(f) The hexadecimal number A4D needs to be stored.

Calculate the least number of bits that can be used to store the hexadecimal number A4D.

..... [1]

Working space

Swipe sideways to read the whole question

How to start Same number twice: add the place values for denary, group in fours for hex. For the least number of bits, find the first power of 2 above the number.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a) 128 + 32 + 8 + 4 + 2 = **174**

(b) 1010 = A, 1110 = E → **AE**

(e) 256 < 301 < 512 = 2^9 → **9** bits

(f) 3 hex digits × 4 bits = **12** bits

PART	ANSWER / WORKING	MARKS	GUIDANCE
1(a)	174	B1	
1(b)	A · E	B2	one mark per character in the correct order
1(e)	9	B1	
1(f)	12	B1	
			Total: 5 marks

13 Common mistakes

✗ 14 → 1110 when 8 bits are asked for ✓ 0000 1110

Give the number of bits the question asks for.

✗ A04 → 1010 0100 ✓ 1010 0000 0100

Every hex digit is 4 bits, the 0 too.

✗ F0 → 150 ✓ F0 = 15 × 16 = 240

Multiply each hex digit by its place value.

✗ Grouping bits from the left: 101101 → 1011 01

✓ 0010 1101 → 2D

Always group from the right and pad the left group.

✗ "Computers use binary because it is easy"

✓ "made of switches / logic gates with two states, 1 and 0"

Name the hardware reason.

14 Practice

Practice: easy, medium, hard

1. Convert 0110 1001 to denary.
2. Convert 77 to 8-bit binary.
3. Convert 1100 0111 to hex.
4. What is the base of hexadecimal?
1. Convert B9 to denary.
2. Convert 175 to hex.
3. Convert 3C to 8-bit binary.
4. What is the least number of bits needed to store 1000?
1. Convert 5E3 to binary.
2. Convert 1000 0000 1111 to denary.
3. Convert 700 to hex.
4. A register is 12 bits. Give the largest number it can store in denary and in hex.

15 Can I do this?

0 / 6 ticked

- [ ] I can explain why computers use binary (switches / logic gates, two states).
- [ ] I know the base and the digits of denary, binary and hexadecimal.
- [ ] I can convert binary to denary and denary to 8-bit binary.
- [ ] I can convert between binary and hex by grouping in fours, keeping every 0000.
- [ ] I can convert between hex and denary both ways.
- [ ] I can give the largest value of a register and the fewest bits for a number.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

1. 64 + 16 + 4 + 1 = 85

ANSWER **85**

2.

1. 128 + 64 + 32 + 16 + 8 + 4 + 2 + 1 = 255 (the largest 8-bit number)

ANSWER **255**

3.

1. 128 + 64 + 8 = 200

ANSWER **200**

Try it yourself 2

1.

1. 32 + 16 + 2 = 50

ANSWER **0011 0010**

2.

1. 64 + 32 + 4 + 2 = 102

ANSWER **0110 0110**

3.

1. 128 + 64 + 16 + 8 + 4 + 1 = 221

ANSWER **1101 1101**

Try it yourself 3

1.

ANSWER **255**

2.

1. 128 ≤ 200 < 256, and 256 = 2^8, so 8 bits

ANSWER **8**

3.

1. 3 hex digits × 4 bits = 12

ANSWER **12**

Try it yourself 4

1.

1. 1001 = 9, 0011 = 3

ANSWER **93**

2.

1. 2 = 0010, D = 1101

ANSWER **0010 1101**

3.

1. 236 = 1110 1100
2. 1110 = E, 1100 = C

ANSWER **EC**

4.

1. 1 × 16 + 10 = 26

ANSWER **26**

Practice: easy, medium, hard

Easy 1.

1. 64 + 32 + 8 + 1

ANSWER **105**

Easy 2.

1. 64 + 8 + 4 + 1

ANSWER **0100 1101**

Easy 3.

ANSWER **C7**

Easy 4.

ANSWER **16**

Medium 1.

1. 11 × 16 + 9 = 176 + 9

ANSWER **185**

Medium 2.

1. 175 = 1010 1111
2. A F

ANSWER **AF**

Medium 3.

ANSWER **0011 1100**

Medium 4.

1. $512 < 1000 < 1024 = 2^{10}$

ANSWER **10**

Hard 1.

ANSWER **0101 1110 0011**

Hard 2.

1. 2048 + 8 + 4 + 2 + 1

ANSWER **2063**

Hard 3.

1. 700 ÷ 16 = 43 r 12 (C)
2. 43 ÷ 16 = 2 r 11 (B)
3. 2 ÷ 16 = 0 r 2

ANSWER **2BC**

PART	ANSWER / WORKING	MARKS	GUIDANCE
	2BC	B2	one mark for two correct characters, two marks for all three in order

Total: 2 marks

Hard 4.

1. 12 bits all 1 = 2^{12} − 1 = 4095
2. three groups of 1111 = FFF

ANSWER **4095 · FFF**

NOTE 1.2

Hexadecimal uses, binary addition and overflow

1 In this note

SYLLABUS 1.1 NUMBER SYSTEMS

- 1.1.3 Explain **how and why hexadecimal is used** as a beneficial way to represent data, and name where it is used.
- 1.1.4 **Add two positive 8-bit binary integers**, showing the carries.
- 1.1.4 Explain **overflow** and why it happens in binary addition.

Before this: Number systems (conversions). Next: Logical shifts and two's complement.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

Binary ↔ hex

One hex digit is exactly four bits: group binary in fours from the right.

Quick check: what is 1101 0010 in hex?

D2.

Adding in columns

In denary, 7 + 5 = 12: write 2 and carry 1 into the next column. Binary works the same way, but you carry as soon as a column reaches 2.

Quick check: in denary, what is carried in 8 + 6?

1 (8 + 6 = 14: write 4, carry 1).

3 Why hexadecimal is used

A computer never processes hexadecimal: inside, everything stays binary. Hex is used by **people** (programmers, technicians) as a short way of **writing** binary. Compare the same 16-bit value:

Binary	Hexadecimal
1010 0000 0011 1101	A03D

The hex is four characters instead of sixteen. That is the whole idea, and the benefits all come from it:

Shorter

A **shorter representation** of binary: one hex digit replaces four bits, so it **takes up less space on screen** or paper.

Easier for humans

Easier and quicker to read, write, understand and remember than a long string of 1s and 0s.

Fewer mistakes

Less likely to make a mistake copying or typing it, and **easier to spot errors / debug**.

Converts easily

Each hex digit is **exactly 4 bits**, so it converts straight to and from binary (no big sums, unlike denary).

✗ COMMON MISTAKE

Never say hex "uses less memory" or "is faster for the computer". The computer still stores the binary. Every benefit is **for humans**.

4 Where hexadecimal is used

Use	What it looks like	What it is
HTML colour codes	#FF8000	a colour on a web page: two hex digits each for the amount of red, green and blue (00 to FF = 0 to 255)
MAC addresses	00:1A:2B:3C:4D:5E	the unique address of a network interface card (12 hex digits = 48 bits)
IPv6 addresses	2001:0DB8:85A3::8A2E:0370:7334	the address of a device on the internet (128 bits, written in groups of 4 hex digits)
Memory addresses and **memory dumps**	A2F, 0x7FF3A2	locations in memory shown to a programmer when **debugging**
Error codes	0x80070057	codes shown when a program or device fails, so a technician can look them up
Assembly language / machine code	LDA &3F	instructions and values written in hex by low-level programmers
URLs	%20 for a space	characters that can't appear in a web address are written as hex codes
Character codes	ASCII 41 = 'A'	the ASCII / Unicode value of a character

TRY IT YOURSELF

1. An HTML colour code is #00FF00. What is the denary value of the green part (the middle two digits)?
2. How many bits does a MAC address of 12 hex digits use?

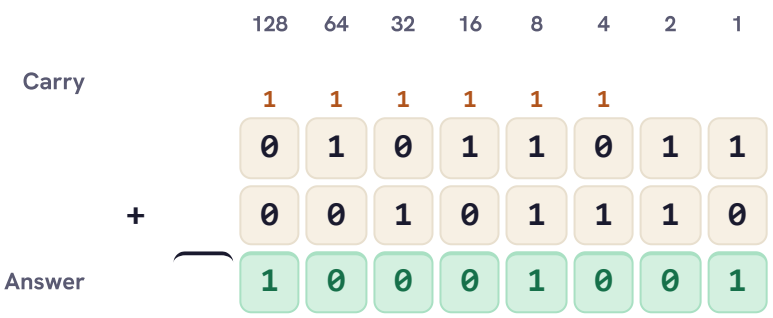
5 Adding two binary numbers

Binary addition works column by column from the right, exactly like denary, except that there are only two digits. There are only four sums to know:

Column adds up to	Write	Carry to the next column
0 + 0 = 0	0	0
0 + 1 = 1	1	0
1 + 1 = 2 (binary 10)	0	1
1 + 1 + 1 = 3 (binary 11), with a carry	1	1

GENERAL METHOD **Adding two 8-bit binary numbers**

1. Write the two numbers one under the other, lined up on the right. Leave a row above for the carries.
2. Start at the rightmost column. Add the two bits and any carry.
3. Write the result bit (0 or 1) underneath; write any carry above the next column to the left.
4. Repeat for every column, moving left.
5. If there is still a carry out of the leftmost (8th) column, it needs a 9th bit: that is **overflow**.
6. Check: convert both numbers and the answer to denary; the sums must match.



0101 1011 + 0010 1110 = 1000 1001. Check: 91 + 46 = 137.

EXAM TIP

Show the carries. Mark schemes give a mark for "correct working, e.g. showing carries" on top of one mark per correct nibble.

ANSWER

Write every carry above its column, even when you can do it in your head.

TRY IT YOURSELF

1. Add 0011 0011 and 0111 1000.
2. Add 1001 1011 and 0001 0011.

6 Overflow

A register has a **fixed number of bits**. An 8-bit register can hold 0 to **255**; a 16-bit register 0 to 65 535. Every computer and device has a predefined limit like this.

If the answer to a sum is **too large to fit in the number of bits available**, it would need an extra bit that the register does not have. This is an **overflow error**. The extra bit is lost and the value left in the register is wrong.

	OF	128	64	32	16	8	4	2	1
Carry	1	1							
		1	1	0	0	1	0	1	0
+		0	1	1	1	0	1	0	1
Answer	1	0	0	1	1	1	1	1	1

1100 1010 + 0111 0101: 202 + 117 = 319, more than 255. The 9th bit is the overflow; the register keeps only 0011 1111 = 63, which is wrong.

Overflow in two marks: **the result is greater than 255 (too large for the register) · it would need more than 8 bits / more bits than the register has.**

TRY IT YOURSELF

1. Add 1100 0011 and 0101 0000. Is there overflow?

2 What is the largest number a 16-bit register can hold?

7 Summary

- Hex is for humans: a shorter representation of binary, easier to read, write, remember and debug, fewer mistakes, less screen space. It converts easily because one hex digit = 4 bits.
- Uses of hex: HTML colour codes, MAC addresses, IPv6 addresses, memory addresses / dumps, error codes, assembly language, URLs, character codes.
- Binary addition: 1 + 1 = 0 carry 1; 1 + 1 + 1 = 1 carry 1. Work right to left and show every carry.
- Overflow: the result is too large for the number of bits in the register (over 255 for 8 bits), so an extra bit would be needed and the stored value is wrong.

IF YOU SEE …

"Give a reason hexadecimal is used"	→ a benefit FOR HUMANS: shorter / easier to read / fewer mistakes
"Show all your working" in an addition	→ write the carry row
a carry out of the 8th column	→ show the 9th bit and say overflow

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

8 Ways they test it

TYPE 1 Benefit of hex

> *"Give one reason why the addresses are displayed in hexadecimal instead of binary" [1-2]*

Spot it "instead of binary", "benefit", "reason a programmer may use hexadecimal".

1. Pick one benefit per mark: shorter / easier to read / fewer mistakes / easier to debug / less screen space.
2. Write it as a comparison: "it is shorter than binary".

TYPE 2 Uses of hex

> *"Identify two other ways hexadecimal is used in computer science" [2]*

Spot it "identify", "other ways".

1. Name two uses from the table, not the one already in the question.
2. A name is enough for "identify".

TYPE 3 Binary addition

> *"Add the two 8-bit binary numbers using binary addition. Show all of your working" [3-4]*

Spot it two 8-bit numbers one above the other.

1. Carry row, then the answer.
2. Marks: one per correct nibble, one for the carries, one more for showing the overflow bit when there is one.

TYPE 4 **Explain overflow**

> *"Explain why the overflow error occurred" [2]*

Spot it "overflow".

1. The result is greater than 255 / too large for the register.
2. It needs more than 8 bits / the register has a fixed number of bits.

TYPE 5 **Definition (multiple choice)**

> *"Tick one box to show the correct definition of overflow" [1]*

Spot it four statements.

1. Choose "too large to represent in the number of bits available"; not "too small", not "negative".

9 What the examiner looks for

"Give two reasons why a programmer may use hexadecimal to represent binary" [2]

Marking points (one mark each, up to the marks shown)

- Easier / quicker to understand, read or write
- Easier / quicker to debug
- Less likely to make a mistake
- Shorter representation // takes up less screen space

KEYWORDS **shorter** **easier to read** **fewer errors** **debug**

TOO VAGUE "takes less memory"; "the computer processes it faster"

"Explain why the overflow error occurred" [2]

Marking points (one mark each, up to the marks shown)

- The result of the calculation is greater than 255 // the value is larger than can be stored in the register
- The result would need more than 8 bits // a register has a predetermined number of bits and there are too many bits for it

KEYWORDS **greater than 255** **more than 8 bits** **fixed number of bits**

TOO VAGUE "the number is too big" with no mention of the bits or 255

Wording trap · A reason for using hexadecimal

THE QUESTION **0478/13/M/J/24 Q3** ↗ Paper 1 · Computer systems **1 mark**

Give one reason why the addresses are displayed in hexadecimal instead of binary.

✓ CREDITED

- It is easier / quicker to read, understand or debug
- It is a shorter representation of binary // takes up less screen space

✗ NOT CREDITED

- It uses less storage / memory
- The computer can process it faster

WHY

The computer stores binary whatever you display. Hex only helps the person reading it.

From: 0478/13/M/J/24 Q3(c) mark scheme

10 Past-paper questions, solved

0478/13/M/J/24 Q3 ↗ Paper 1 · Computer systems **8 marks** ⤢ Full size

3 A programmer is creating a computer game. One character is **not** moving correctly.

The programmer needs to debug the program. To do this they need to look at addresses that are locations in memory.

The addresses are displayed as hexadecimal numbers.

(a) One address is A2F.

(i) Convert the address to binary.

..... [3]

(ii) Convert the address to denary.

..... [1]

Working space

(b) The binary number stored for another address is 000110011011.

(i) Convert the binary number to hexadecimal.

..... [3]

(ii) Convert the binary number to denary.

..... [1]

Working space

(c) Give **one** reason why the addresses are displayed in hexadecimal instead of binary.

..... [1]

(d) Identify **two** other ways that hexadecimal is used in computer science.

[2]

Swipe sideways to read the whole question

How to start Hex to binary is four bits per digit (keep the 0010). For binary to hex group in fours from the right. Parts (c) and (d) are recall.

▼ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

(a)(i) A = 1010, 2 = 0010, F = 1111 → **1010 0010 1111** (ii) 10 × 256 + 2 × 16 + 15 = **2607**

(b)(i) 0001 | 1001 | 1011 → **19B** (ii) 256 + 128 + 16 + 8 + 2 + 1 = **411**

(c) It is shorter than binary, so it is easier to read and debug.

(d) HTML colour codes; MAC addresses.

PART	ANSWER / WORKING	MARKS	GUIDANCE
3(a)(i)	1010 0010 1111	**B3**	one mark for each correct nibble, in the correct order
3(a)(ii)	2607	**B1**	
3(b)(i)	1 · 9 · B	**B3**	one mark for each correct character, in order
3(b)(ii)	411	**B1**	
3(c)	Any one: easier / quicker to read / understand / debug · shorter representation of binary // less screen space	**B1**	
3(d)	Any two: HTML colour codes · URL · memory dump · IP address · MAC address · assembly language · error codes · ASCII / Unicode	**B2**	

Total: 11 marks

2210/12/M/J/25 Q1 ↗ Paper 1 · Computer systems **5 marks** ⤢ Full size

1 A computer stores data temporarily in random access memory (RAM).

(e) The 8-bit binary numbers 01100101 and 01110000 are stored in RAM.

The binary numbers are added together.

Add the **two** binary numbers using binary addition.

Give your answer in binary. You must show all your working.

```
  0 1 1 0 0 1 0 1
+ 0 1 1 1 0 0 0 0
```

[3]

(f) An overflow occurs when two other 8-bit binary numbers are added together.

Explain why the overflow error occurs.

..... [2]

Swipe sideways to read the whole question

How to start Set out the carry row first. For (f), give two separate facts: the size of the result and the size of the register.

▼ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

		128	64	32	16	8	4	2	1
Carry		1	1						
		0	1	1	0	0	1	0	1
	+	0	1	1	1	0	0	0	0
Answer		1	1	0	1	0	1	0	1

(e) **1101 0101** (101 + 112 = 213, so no overflow here).

(f) The result is greater than 255, so it is too large for the register. It would need more than 8 bits, but the register only has 8.

PART	ANSWER / WORKING	MARKS	GUIDANCE
1(e)	1101 0101	B2	one mark for each correct nibble
1(e)	correct method of working, e.g. showing carries	M1	
1(f)	Any two: the result is greater than 255 // too large · cannot be stored in 8 bits // in the bits available for the register	B2	

Total: 5 marks

2210/13/O/N/24 Q1 ↗ Paper 1 · Computer systems **4 marks** ⤢ Full size

1 Data can be measured using different units of storage.

(d) Binary integers can be added together.

Add the **two** binary integers using binary addition. Show all your working. Give your answer in binary.

```
  1 1 1 0 0 0 1 1
+ 1 1 0 0 1 1 0 0
```

[4]

Swipe sideways to read the whole question

How to start Two big numbers (both start with 11): expect a carry out of the last column. Show it as a 9th bit.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

	OF	128	64	32	16	8	4	2	1
Carry	1	1							
		1	1	1	0	0	0	1	1
+		1	1	0	0	1	1	0	0
Answer	1	1	1	0	1	0	1	1	1

1 1010 1111: the 9th bit is an overflow (227 + 204 = 431, more than 255).

PART	ANSWER / WORKING	MARKS	GUIDANCE
1(d)	1010 1111	**B2**	one mark for each correct nibble
1(d)	method of working, e.g. carries	**M1**	
1(d)	identification of overflow (the extra 1)	**B1**	

Total: 4 marks

EXAMINER TIP The overflow bit earns its own mark: write it, and label it.

11 Common mistakes

✗ "Hex takes up less memory"

The computer stores binary either way.

✓ "Hex is shorter / easier for humans to read"

✗ Leaving out the carries

The working mark is for the carries.

✓ A carry row above the sum

✗ Dropping the 9th bit silently

✓ Write the extra 1 and label it overflow

There is a mark for identifying the overflow.

✗ "Overflow is when the number is too small / negative"

✓ "Too large for the number of bits available"

12 Practice

Practice: easy, medium, hard

1. Add 0001 0101 and 0010 0110.
2. Give one use of hexadecimal.
3. What is the largest denary value an 8-bit register can store?
1. Add 0111 0110 and 0011 0000.
2. Give two reasons why hex is used instead of binary to display error codes.
3. An HTML colour is #8000FF. Give the denary amount of red (the first two digits).
1. Add 1011 1101 and 0110 0110. Explain what happens in an 8-bit register.
2. A memory dump shows the address 0FC8. Give it in binary and in denary.

13 Can I do this?

0 / 4 ticked

- [ ] I can give benefits of hexadecimal, all of them for humans.
- [ ] I can name at least four uses of hexadecimal.
- [ ] I can add two 8-bit binary numbers with a carry row.
- [ ] I can explain overflow in two marking points and show the overflow bit.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

1. FF = 15 × 16 + 15 = 255

ANSWER **255**

2.

1. 12 × 4 = 48

ANSWER **48**

Try it yourself 2

1.

1. 51 + 120 = 171 = 1010 1011

ANSWER **1010 1011**

2.

1. 155 + 19 = 174 = 1010 1110

ANSWER **1010 1110**

Try it yourself 3

1.

1. 195 + 80 = 275
2. 275 needs 9 bits: 1 0001 0011

ANSWER **1 0001 0011: yes, overflow (195 + 80 = 275 > 255)**

2.

ANSWER **65 535**

Practice: easy, medium, hard

Easy 1.

1. 21 + 38 = 59

ANSWER **0011 1011**

Easy 2.

ANSWER **e.g. HTML colour codes / MAC addresses / error codes**

Easy 3.

ANSWER **255**

Medium 1.

1. 118 + 48 = 166

ANSWER **1010 0110**

Medium 2.

ANSWER

Shorter / takes less screen space; easier to read and remember; fewer mistakes when copying

Medium 3.

1. 80 = 8 × 16 = 128

ANSWER **128**

Hard 1.

1. 189 + 102 = 291

2. 9 bits needed

ANSWER **1 0010 0011: overflow, because 189 + 102 = 291 > 255 and the 9th bit is lost**

PART	ANSWER / WORKING	MARKS	GUIDANCE
	1 0010 0011 (each nibble)	B2	
	carries shown	M1	
	overflow identified	B1	
			Total: 4 marks

Hard 2.

1. 0 = 0000, F = 1111, C = 1100, 8 = 1000

2. 15 × 256 + 12 × 16 + 8 = 3840 + 192 + 8 = 4040

ANSWER **0000 1111 1100 1000 · 4040**

NOTE 1.3

Logical shifts and two's complement

1 In this note

SYLLABUS 1.1 NUMBER SYSTEMS

- 1.1.5 Perform **logical left and right shifts** (one or several places) on a positive 8-bit binary integer.
- 1.1.5 Explain the **effect of a shift**: multiply or divide by 2, 4, 8 ..., and what happens to bits that fall off.
- 1.1.6 Use **two's complement** to represent positive and negative 8-bit integers, in both directions.

Before this: binary addition and overflow. Next: Text, sound and images.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

8-bit place values

128 64 32 16 8 4 2 1. The leftmost bit is the **most significant bit** (MSB, worth the most); the rightmost is the **least significant bit** (LSB, worth 1).

Quick check: what is the MSB of 0100 0001 worth if it is 1?

128.

Multiplying by 10 in denary

Moving every digit one place left multiplies a denary number by 10: 36 → 360. In binary, one place left multiplies by **2**.

Quick check: what does moving 2 places left do in denary?

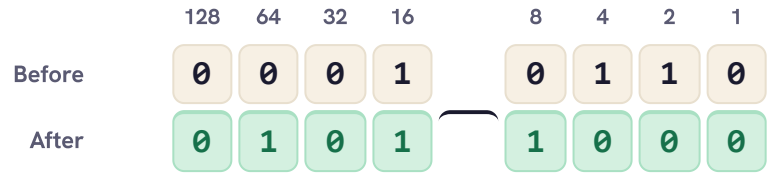
Multiplies by 100.

3 Logical shifts

A **logical shift** moves every bit in a register a set number of places to the left or to the right. The register stays 8 bits wide, so:

- bits that move off the end of the register are **lost**;
- the empty places at the other end are filled with **0s**.

Logical left shift

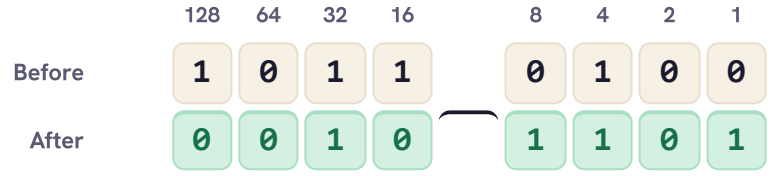


Logical left shift of 2 places: 0001 0110 (22) becomes 0101 1000 (88). Two 0s come in on the right.

GENERAL METHOD **Logical left shift by n places**

1. Move every bit n places to the left.
2. The n bits at the left end (the most significant bits) are lost.
3. Fill the n empty places on the right with 0s.
4. Effect: the number is **multiplied by 2^n** (1 place × 2, 2 places × 4, 3 places × 8), as long as no 1s were lost.

Logical right shift



Logical right shift of 2 places: 1011 0100 (180) becomes 0010 1101 (45). Two 0s come in on the left.

GENERAL METHOD **Logical right shift by n places**

1. Move every bit n places to the right.
2. The n bits at the right end (the least significant bits) are lost.
3. Fill the n empty places on the left with 0s.
4. Effect: the number is **divided by 2^n** (1 place ÷ 2, 2 places ÷ 4, 4 places ÷ 16).

When bits that are 1 fall off

If a **1** is pushed off the end, the answer is no longer exactly × or ÷ 2^n: the value becomes **incorrect / inaccurate**.

Shift	Before	After	What happened
right 1	0000 1101 (13)	0000 0110 (6)	13 ÷ 2 = 6.5, but the 1 on the right was lost: only the whole number 6 is left
left 1	1100 0011 (195)	1000 0110 (134)	195 × 2 = 390 needs 9 bits; the MSB 1 was lost, so the result is wrong

TRY IT YOURSELF

1. Perform a logical left shift of 3 places on 0000 1101.
2. Perform a logical right shift of 3 places on 0101 1000.
3. What is the effect of a logical right shift of 4 places on a positive binary integer?

4 Two's complement: negative numbers

Ordinary binary can only hold positive numbers. **Two's complement** lets one 8-bit register hold positive **and** negative numbers. The trick: the most significant bit is worth **−128** instead of +128.



1101 0011 = −128 + 64 + 16 + 2 + 1 = −45

The sign bit

MSB **0** → the number is positive (or 0). MSB **1** → the number is negative.

Positive numbers

Exactly the same as ordinary binary, with a 0 at the front: 45 = 0010 1101.

Range

8-bit two's complement holds **−128 to +127**: 1000 0000 = −128 and 0111 1111 = +127.

−1

1111 1111 = −128 + 127 = −1. All 1s is −1, not −255.

Denary to two's complement

Method A: flip and add 1

GENERAL METHOD **Flip and add 1**

1. Write the positive number in 8-bit binary.
2. If the number is positive, stop: that is the answer.
3. If negative, **flip** every bit (0 → 1, 1 → 0).
4. **Add 1** to the result.

EXAMPLE **Convert −45 to 8-bit two's complement.**

Write 45, flip every bit, add 1.

45 = 0010 1101

flip: 1101 0010

add 1: 1101 0011

ANSWER **1101 0011**

Method B: start from −128

GENERAL METHOD **Start from −128**

1. Put a 1 in the −128 column.
2. Work out what must be added to −128 to reach the number: −45 − (−128) = 83.
3. Write 83 in the other seven columns: 64 + 16 + 2 + 1.

EXAMPLE **Convert −45 to 8-bit two's complement.**

−128 + 83 = −45.

83 = 101 0011 in the 7 columns

ANSWER **1101 0011**

Two's complement to denary

GENERAL METHOD **Two's complement to denary**

1. Look at the MSB. If it is 0, convert as ordinary binary.
2. If it is 1, the number is negative: add the place values with the MSB worth −128.
3. (Or: flip every bit, add 1, convert, and put a minus sign in front.)

EXAMPLE **Convert the two's complement integer 1110 1100 to denary.**

MSB is 1, so the first column is −128.

−128 + 64 + 32 + 8 + 4

ANSWER **−20**

TRY IT YOURSELF

1. Convert −78 to an 8-bit two's complement integer.
2. Convert the two's complement integer 1011 0111 to denary.

3 Convert 45 to an 8-bit two's complement integer.

5 Summary

- Logical shift: every bit moves left or right; bits that fall off are lost; 0s fill the empty places.
- Left shift n places = × 2^n; right shift n places = ÷ 2^n. If 1s are lost, the result is inaccurate / wrong.
- Two's complement: the MSB is worth −128. MSB 1 = negative. Range −128 to +127.
- Negative denary → two's complement: write the positive in binary, flip every bit, add 1.
- Two's complement → denary: −128 + the other place values (when the MSB is 1).

IF YOU SEE …

"state the effect" of a shift	→ × or ÷ by 2^n, and bits lost → may be inaccurate
"describe the process" of a shift	→ bits move, MSB / LSB lost, 0s added at the other end
a negative number to store	→ two's complement: flip and add 1, and show it

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

6 Ways they test it

TYPE 1 **Do the shift**

> *"Give the 8-bit binary number stored after a logical left shift of three places" [1]*

Spot it a register and a number of places.

1 Copy the 8 bits, move them, fill with 0s, count that you still have 8 bits.

TYPE 2 Effect of the shift

> *"State one effect this logical shift has on the binary number" [1] / "State the mathematical effect of a right shift of four places" [2]*

Spot it "effect".

1. Multiplied / divided by 2^n (give the number: by 8, by 16).
2. Bits are lost, so the value may become incorrect.

TYPE 3 Describe the process

> *"Describe the process of the logical left shift" [2]*

Spot it "describe" + "process".

1. Every bit is moved left (by the number of places).
2. The leftmost / most significant bit is lost.
3. A 0 is added as the rightmost / least significant bit.

TYPE 4 Convert to or from two's complement

> *"Complete the register for −78. Show all your working" [2]*

Spot it a negative denary number or a binary integer starting with 1.

1. 1 mark for a working method (flip and add 1, or −128 + ...).
2. 1 mark for the correct answer.

TYPE 5 Name it

> *"Give the name of the number system used to represent negative binary integers" [1]*

Spot it "negative".

1. Two's complement.

7 What the examiner looks for

"Describe the process of a logical left shift" [2] + "State the effect" [1]

Marking points (one mark each, up to the marks shown)

- Each / every bit in the binary number is shifted / moved to the left
- The leftmost / most significant bit is lost
- A 0 is added as the rightmost / least significant bit
- Effect: the binary integer is multiplied by 2 (per place)

KEYWORDS **moved left** **most significant bit lost** **0 added** **multiplied by 2**

Two's complement conversion [2]

Marking points (one mark each, up to the marks shown)

- One mark for a full method of working, e.g. conversion to binary then flipping and adding 1
- One mark for the correct 8-bit answer

KEYWORDS **flip** **add 1** **−128**

TOO VAGUE an answer with no working (loses the method mark); fewer than 8 bits

Wording trap · The effect of a right shift

THE QUESTION **2210/12/M/J/23 Q2** ↗ Paper 1 · Computer systems — **1 mark**

State one effect this logical right shift (of three places) has on the binary number.

✓ CREDITED

- It is divided by 8
- The value becomes incorrect / inaccurate because the rightmost bits are lost

✗ NOT CREDITED

- It gets smaller
- It is divided by 3

WHY

Give the exact operation: 3 places = ÷ 2^3 = ÷ 8. "Smaller" is not specific enough.

From: 2210/12/M/J/23 Q2(b)(ii) mark scheme

8 Past-paper questions, solved

2210/12/O/N/23 Q2 ↗ Paper 1 · Computer systems **3 marks** ⤢ Full size

2 A register stores the binary number:

1	1	1	0	0	0	1	1

(c) A logical left shift of **two** places is performed on the binary number stored in the register.

Complete the binary register to show its contents after this logical left shift.

[1]

(d) The negative denary number −99 needs to be stored in the register.

Complete the register to show the binary number that would be stored, using two's complement. Show all your working.

Working space .....

Register:

[2]

Swipe sideways to read the whole question

How to start For (c) move every bit two places left and add two 0s. For (d) write 99 in binary first, then flip and add 1.

▼ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

(c) 1110 0011 → **1000 1100** (the two 1s on the left are lost).

(d) 99 = 0110 0011 → flip: 1001 1100 → add 1: **1001 1101**. Check: −128 + 16 + 8 + 4 + 1 = −99.

PART	ANSWER / WORKING	MARKS	GUIDANCE
2(c)	1 0 0 0 1 1 0 0	B1	
2(d)	suitable working method, e.g. flip and add 1	M1	
2(d)	1001 1101	A1	

Total: 3 marks

0478/12/F/M/24 Q8 ↗ Paper 1 · Computer systems **5 marks** ⤢ Full size

(b) Two's complement can be used to represent positive and negative binary integers.

(i) Convert the two's complement integer 10110111 into denary.

Show all your working.

..... [2]

(ii) Convert the denary number 45 into an 8-bit two's complement integer.

..... [1]

Working space

(c) Logical shifts are performed on binary integers.

State the mathematical effect of a right shift of **four** places on a positive binary integer.

..... [2]

Swipe sideways to read the whole question

How to start The MSB of 10110111 is 1, so it is negative: start from −128. 45 is positive, so it is plain binary. Four places right = ÷ 2^4.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(b)(i) −128 + 32 + 16 + 4 + 2 + 1 = **−73** (or flip 1011 0111 → 0100 1000, add 1 → 0100 1001 = 73, so −73).

(b)(ii) **0010 1101**

(c) The integer is **divided by 16**.

PART	ANSWER / WORKING	MARKS	GUIDANCE
8(b)(i)	working, e.g. flip and add 1: 10110111 = 01001001	M1	
8(b)(i)	−73	A1	
8(b)(ii)	00101101	B1	
8(c)	divide · … by 16 // 2^4	B2	one mark each

Total: 5 marks

2210/12/O/N/24 Q3 ↗ Paper 1 · Computer systems **3 marks** ⤢ Full size

3 A user enters data that is hexadecimal into a computer system. The data is converted to binary to be processed by the computer.

(d) A binary integer that is stored in a register in the computer has a logical left shift performed on it.

(i) Describe the process of the logical left shift that is performed on the binary integer.

..... [2]

(ii) State what effect this will have on the binary integer.

..... [1]

Swipe sideways to read the whole question

How to start "Describe the process" wants the three things that physically happen to the bits; "effect" wants the maths.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(d)(i) Every bit in the integer is moved one place to the left. The leftmost (most significant) bit is lost and a 0 is added as the rightmost (least significant) bit.

(d)(ii) The integer is multiplied by 2.

PART	ANSWER / WORKING	MARKS	GUIDANCE
3(d)(i)	Any two: every bit is shifted left · the leftmost / MSB is lost · a 0 is added as the rightmost / LSB	**B2**	
3(d)(ii)	The binary integer is multiplied by 2	**B1**	
			Total: 3 marks

9 Common mistakes

✗ Shifting and ending up with 9 or 7 bits ✓ Always exactly 8 bits after the shift

Lost bits are gone; new places are 0s.

✗ "Right shift of 3 divides by 3" ✓ Divides by $2^3 = 8$

Each place is a factor of 2.

✗ Flipping the bits and forgetting to add 1 ✓ Flip, THEN add 1

Flip alone gives one's complement, which is not on the syllabus.

✗ Writing –73 as 1100 1001 (73 with a 1 in front) ✓ 1011 0111

Two's complement is not "sign and size".

✗ No working for two's complement

✓ Show the flip and the +1

One of the two marks is for the method.

10 Practice

Practice: easy, medium, hard

1. Logical left shift of 1 place on 0010 0101.
2. Logical right shift of 1 place on 0110 0100.
3. Is the two's complement integer 1000 0101 positive or negative?
1. Convert −25 to an 8-bit two's complement integer.
2. Convert the two's complement integer 1000 1110 to denary.
3. A logical right shift of 2 places is done on 1100 1011. Give the result and say why it is not exactly ÷ 4.
1. Convert −22 to an 8-bit two's complement integer. Show your working.
2. What are the smallest and largest numbers in 8-bit two's complement? Give each in binary.
3. A value 0001 0110 is shifted left 3 places. Give the result and its denary value. Has any data been lost?

11 Can I do this?

0 / 4 ticked

- [ ] I can do left and right logical shifts of any number of places.
- [ ] I can state the effect of a shift (× or ÷ 2^n, bits lost).
- [ ] I can convert a negative denary number to 8-bit two's complement, with working.
- [ ] I can convert a two's complement integer to denary.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

1. $13 \times 8 = 104 = 0110\ 1000$

ANSWER **0110 1000**

2.

1. $88 \div 8 = 11$

ANSWER **0000 1011**

3.

ANSWER **It is divided by 16 (2^4)**

Try it yourself 2

1.

1. $78 = 0100\ 1110$
2. flip: 1011 0001
3. +1: 1011 0010

ANSWER **1011 0010**

2.

1. $-128 + 32 + 16 + 4 + 2 + 1 = -73$

ANSWER **−73**

3.

1. positive: ordinary binary with 0 at the front

ANSWER **0010 1101**

Practice: easy, medium, hard

Easy 1.

ANSWER **0100 1010**

Easy 2.

ANSWER **0011 0010**

Easy 3.

ANSWER **negative (MSB is 1)**

Medium 1.

1. 25 = 0001 1001
2. flip 1110 0110
3. +1 1110 0111

ANSWER **1110 0111**

Medium 2.

1. −128 + 8 + 4 + 2

ANSWER **−114**

Medium 3.

1. 203 ÷ 4 = 50.75, the register holds 50

ANSWER **0011 0010: the two 1s on the right were lost**

Hard 1.

1. 22 = 0001 0110
2. flip 1110 1001
3. +1 1110 1010

ANSWER **1110 1010**

PART	ANSWER / WORKING	MARKS	GUIDANCE
	flip and add 1 shown	M1	
	1110 1010	A1	

Total: 2 marks

Hard 2.

ANSWER **−128 = 1000 0000; +127 = 0111 1111**

Hard 3.

ANSWER **1011 0000 = 176; no 1s were lost (22 × 8 = 176)**

NOTE 1.4

Text, sound and images

1 In this note

SYLLABUS 1.2 TEXT, SOUND AND IMAGES

- 1.2.1 Explain how and why a computer represents **text**, using a **character set** such as **ASCII** or **Unicode**.
- 1.2.2 Explain how **sound** is sampled and stored, and the effects of the **sample rate** and **sample resolution**.
- 1.2.3 Explain how an **image** is stored as pixels, and the effects of the **resolution** and **colour depth**.

Before this: Number systems. Next: Data storage and compression (file-size calculations use these ideas).

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

Everything becomes binary

A computer is made of switches with two states, so text, sound and pictures must all be turned into 1s and 0s before it can process or store them.

Quick check: why can't a computer store the letter A directly?

It can only store binary (1s and 0s), so A must be given a binary code.

n bits give 2^n values

1 bit: 2 values; 2 bits: 4; 8 bits: 256; 16 bits: 65 536.

Quick check: how many values do 3 bits give?

8.

3 Text and character sets

When you press a key, the computer has to turn the character into binary. It does this with a **character set**: a list of all the characters the computer can use, with a **unique binary code** (number) for each one.

Each character typed is looked up in the character set and its code is stored. A word is stored as the codes of its characters, one after another, **in sequence**. Upper and lower case letters have different codes.

Character	Denary code	Binary (ASCII)
A	65	0100 0001
B	66	0100 0010
C	67	0100 0011
a	97	0110 0001
space	32	0010 0000

Codes follow the alphabet: if A is 65, then C is 67. So "CAB" is stored as 67, 65, 66.

ASCII and Unicode

	ASCII	Unicode
Bits per character	**7 bits** (8 bits in extended ASCII)	**up to 16 or 32 bits**
Number of characters	**128** (256 extended)	**over a million possible** (about 65 000 with 16 bits; about 4 billion with 32)
Languages	English only (letters, digits, punctuation, control codes)	**almost every language** in the world
Emojis and symbols	no	**yes**
Storage	less: 1 byte per character	**more storage per character**, so files are bigger

Unicode allows a **greater range of characters and symbols** (different languages, emojis), but it needs **more bits per character**, so text takes more storage space.

TRY IT YOURSELF

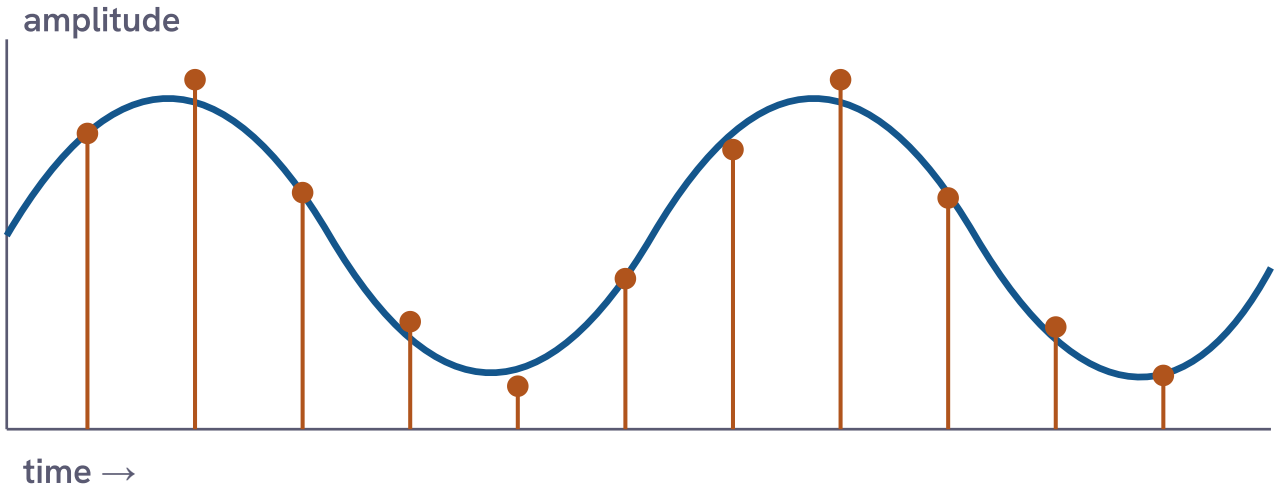
1. In ASCII, D is 68. What is the denary code for G?
2. A text message uses Arabic letters and emojis. Which character set must be used?

4 Sound

Sound is an **analogue** wave: it changes smoothly all the time. A computer can only store separate binary numbers, so the wave must be turned into **digital** data. A microphone picks up the sound, then the wave is **sampled**:

GENERAL METHOD **How sound is recorded and converted to binary**

1. The sound is recorded by a **microphone**, which turns it into an electrical (analogue) signal.
2. The sound wave is **sampled** at regular time intervals: the **amplitude** (height) of the wave is measured.
3. Each amplitude measured is given a **binary value**.
4. The **sample rate** sets how many samples are taken **per second**.
5. The **sample resolution** sets how many **bits are used for each sample**.
6. The binary values of all the samples are stored, in order.



Each orange line is one sample: the height of the wave at that moment, stored as a binary number.

Change	Effect on the recording	Effect on the file
Higher **sample rate** (more samples per second)	**more accurate**, closer to the original sound	**larger file size**
Higher **sample resolution** (more bits per sample)	more amplitudes can be recorded, so **more accurate** / better quality	**larger file size**
Lower rate or resolution	less accurate, poorer quality	smaller file

Sample rate: the number of samples taken per second (measured in hertz, Hz). **Sample resolution**: the number of bits used to store each sample (e.g. 16-bit).

TRY IT YOURSELF

1. A song is recorded with a sample resolution of 8 bits. How many different amplitudes can be stored for each sample?
2. Give one drawback of increasing the sample rate.

5 Images

A digital (bitmap) image is a grid of tiny squares called **pixels**. Each pixel is one colour, and that colour is stored as a binary number. The whole image is stored as the binary codes of all its pixels, plus some extra data about the image.

Term	Meaning
Pixel	the smallest component of an image: one square of one colour
Resolution	the number of pixels in the image: pixels wide × pixels high, e.g. 1920 × 1080
Colour depth (bit depth)	the number of bits used to represent each colour (each pixel)
Metadata	extra data stored with the image, e.g. its width and height, colour depth, date and time taken

Colour depth	Number of colours	Example
1 bit	2	black and white
8 bits	256	simple graphics
24 bits	about 16.7 million	photographs (8 bits each for red, green, blue)

Change	Effect on the image	Effect on the file
Higher **resolution** (more pixels)	more detail, better quality	**larger file size** (more pixels to store)
Higher **colour depth** (more bits per pixel)	**a greater range of colours**, closer to real life	**larger file size** (more bits per pixel)
Lower resolution or colour depth	less detail / fewer colours	smaller file

TRY IT YOURSELF

1. An image has a colour depth of 4 bits. How many colours can it use?
2. An image is 600 pixels wide and 400 pixels high. How many pixels does it have?

6 Summary

- Text: a character set gives every character a unique binary code; the codes are stored in sequence.
- ASCII: 7 (or 8) bits, 128 (256) characters, English. Unicode: up to 16/32 bits, many languages and emojis, more storage per character.
- Sound: microphone → wave sampled → amplitude measured → each sample given a binary value.
- Sample rate = samples per second; sample resolution = bits per sample. Higher → more accurate, bigger file.
- Image: grid of pixels, each colour a binary code. Resolution = number of pixels; colour depth = bits per colour. Higher → better quality, bigger file.

IF YOU SEE …

"describe how text is converted to binary"	→ character set · unique binary value per character · e.g. ASCII / Unicode
"explain how sound is converted"	→ sampled · amplitude · binary value · sample rate · resolution
"what is meant by colour depth"	→ number of bits used for each colour

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

7 Ways they test it

TYPE 1 Text to binary

> *"Describe how the text is converted to binary" [2-3]*

Spot it keyboard / text / characters.

1. A character set is used (name one: ASCII or Unicode).
2. Each character has a unique binary value.
3. The codes are stored in sequence.

TYPE 2 ASCII vs Unicode

> *"Explain the differences between ASCII and Unicode" [4]*

Spot it both names in the question.

1. Write each point as a comparison: "ASCII has fewer characters, whereas Unicode has more".
2. Max 3 marks if you only describe one of them: always cover both.

TYPE 3 Sound conversion

> *"Explain how the analogue sound is recorded and converted to digital" [5]*

Spot it "analogue", "recorded", "converted".

1. Follow the six steps of the method: microphone, sampled, amplitude, binary value, sample rate (defined), resolution (defined).

TYPE 4 **Effects**

> *"State two ways the accuracy of the recording could be increased" [2] / "Explain the effect of changing the colour depth" [2]*

Spot it "effect", "increase", "accuracy", "quality".

1. Say what happens to quality AND to file size.
2. Give the reason: more bits per sample / per colour.

TYPE 5 **Define a term**

> *"State what is meant by the image resolution" [1]; a table of terms to complete [4]*

Spot it "what is meant by".

1. Use the exact definitions from the table above.

8 What the examiner looks for

"Explain the differences between the ASCII and Unicode character sets" [4] (MAX 3 for one set only)

Marking points (one mark each, up to the marks shown)

- ASCII has fewer / a limited number of characters // Unicode has more characters
- ASCII covers a limited set of / fewer languages
- Unicode includes many more languages and emojis
- ASCII uses 7 / 8 bits per character; Unicode uses up to 16 / 32 bits per character
- ASCII has 128 / 256 characters; Unicode about 65 536 / over 4 billion

KEYWORDS **character set** **bits per character** **languages** **emojis**

"Explain how the analogue sound is recorded and converted to digital" [5]

Marking points (one mark each, up to the marks shown)

- The sound is recorded using a microphone
- The sound wave is sampled ...
- ... measuring the height / amplitude
- Each amplitude has a unique binary value
- The sample rate is set ... that is the number of samples taken per second
- The sample resolution is set ... that is the number of bits used for each sample
- Each sample taken is converted to binary

KEYWORDS **sampled** **amplitude** **sample rate** **sample resolution** **binary value**

Wording trap · Colour depth

THE QUESTION **0478/13/M/J/24 Q2** ↗ Paper 1 · Computer systems **1 mark**

State what is meant by a 16-bit colour depth.

✓ CREDITED

- 16 bits are used to represent each colour in the image
- the number of bits used for each colour / pixel (with the 16)

✗ NOT CREDITED

- the number of colours in the image
- how bright the colours are
- 16 colours

WHY

Colour depth is a number of BITS. 16 bits give 2^{16} = 65 536 colours, not 16.

From: 0478/13/M/J/24 Q2(a) mark scheme

9 Past-paper questions, solved

0478/11/O/N/23 Q5 ↗ Paper 1 · Computer systems **11 marks** ⤢ Full size

5 A musician is recording herself playing the music for a song on the piano.

(a) Explain how the analogue sound is recorded and converted to digital.

..... [5]

(b) State **two** ways that the accuracy of the recording could be increased.

[2]

(d) The musician types the words for the song into a document.

Two character sets that can be used when converting text to digital are the American standard code for information interchange (ASCII) and Unicode.

Explain the differences between the ASCII character set and the Unicode character set.

..... [4]

Swipe sideways to read the whole question

How to start (a) is the six-step sound method. (b) names the two settings. (d) needs points about BOTH character sets, written as comparisons.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a) The piano is recorded with a microphone. The sound wave is sampled at regular intervals and the amplitude (height) of the wave is measured. Each amplitude is given a binary value. The sample rate is the number of samples taken per second and the sample resolution is the number of bits used for each sample.

(b) Increase the sample rate. Increase the sample resolution.

(d) ASCII has fewer characters (128, or 256 extended) whereas Unicode has many more. ASCII covers mainly English, whereas Unicode covers many languages and emojis. ASCII uses 7 or 8 bits per character, whereas Unicode uses up to 16 or 32 bits per character.

PART	ANSWER / WORKING	MARKS	GUIDANCE
5(a)	Any five: microphone · wave is sampled · … measuring the amplitude · each amplitude has a unique binary value · sample rate set · … number of samples per second · sample resolution set · … bits per sample · each sample converted to binary	B5	
5(b)	Increase the sample rate · increase the sample resolution	B2	
5(d)	Any four (MAX 3 for ASCII or Unicode alone): fewer / more characters · fewer / more languages, emojis · 7/8 vs 16/32 bits per character · 128/256 vs 65 536 / 4 billion characters	B4	

Total: 11 marks

2210/11/M/J/25 Q3 ↗ Paper 1 · Computer systems **4 marks** ⤢ Full size

3 An image is converted to binary to be represented by a computer.

Complete the table with the missing terms and definition about representing an image.

Term	Definition
	This is the smallest component of an image.
resolution	
	This is the number of bits used to create each colour in an image.
	This is additional data that is stored with an image that can provide information such as the time and date the image was taken.

[4

Swipe sideways to read the whole question

How to start Two rows give the term, two give the definition. Match each to the four key image words: pixel, resolution, colour depth, metadata.

▼ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

pixel: the smallest component of an image.

resolution: the number of pixels high by the number of pixels wide.

colour depth: the number of bits used to create each colour.

metadata: additional data stored with the image, such as the date and time it was taken.

PART	ANSWER / WORKING	MARKS	GUIDANCE
3	pixel / resolution / colour depth (bit depth) / metadata (header), one mark for each correct term or definition	B4	

Total: 4 marks

2210/12/M/J/25 Q2 ↗ Paper 1 · Computer systems **3 marks** ⤢ Full size

2 A student has an image file stored on their computer.

(c) The image file has a colour depth of 32 bits.

(i) State what is meant by a colour depth of 32 bits.

..... [1]

(ii) The colour depth of the image file is changed to 64 bits.

Explain what effect this change has on the image file.

[2]

Swipe sideways to read the whole question

How to start (i) is the definition with the number in it. (ii) asks for the effect on the FILE, with a reason.

▼ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

(c)(i) 32 bits are used to represent each colour in the image.

(c)(ii) The file size increases, because the number of bits used to store each colour has doubled.

PART	ANSWER / WORKING	MARKS	GUIDANCE
2(c)(i)	32 bits are used to represent each colour // 2^{32} different colours available	B1	
2(c)(ii)	the size of the image file increases · ... as the number of bits per colour has increased	B2	

Total: 3 marks

10 Common mistakes

✗	✓
"Colour depth is the number of colours"	"The number of bits used for each colour"
"Resolution is how clear the image is"	"The number of pixels (wide × high)"
"Sample rate is how fast the sound is played"	"Number of samples taken per second"
Describing only Unicode in a compare question Max 3 marks for one side only.	A point about each, as a comparison
"Higher sample rate makes the sound louder"	"More accurate / closer to the original; bigger file"

11 Practice

Practice: easy, medium, hard

1. State what is meant by a pixel.
2. How many characters can 7-bit ASCII represent?
3. Define sample resolution.
1. In ASCII, 'm' is 109. Give its 8-bit binary code and its hex.
2. Explain one benefit and one drawback of increasing the colour depth of an image.
3. Describe how the word 'Hi' is stored using a character set.
1. A music app lowers the sample rate and resolution of songs. Explain the effect on the songs and on the files. [4]
2. Give two reasons why Unicode files are larger than ASCII files of the same text.

12 Can I do this?

0 / 5 ticked

- [ ] I can describe how text is converted to binary using a character set.
- [ ] I can compare ASCII and Unicode in four points.
- [ ] I can explain how sound is sampled and define sample rate and resolution.
- [ ] I can define pixel, resolution, colour depth and metadata.
- [ ] I can give the effects of changing resolution, colour depth, sample rate and resolution.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

1. D, E, F, G: 68 + 3

ANSWER **71**

2.

ANSWER **Unicode**

Try it yourself 2

1.

1. $2^8 = 256$

ANSWER **256**

2.

ANSWER **The file size increases / it needs more storage space**

Try it yourself 3

1.

ANSWER **16**

2.

ANSWER **240 000**

Practice: easy, medium, hard

Easy 1.

ANSWER **The smallest component of an image: one square of one colour**

Easy 2.

ANSWER **128**

Easy 3.

ANSWER **The number of bits used for each sample**

Medium 1.

1. 64 + 32 + 8 + 4 + 1
2. 0110 = 6, 1101 = D

ANSWER **0110 1101 · 6D**

Medium 2.

ANSWER **Benefit: a greater range of colours, closer to real life. Drawback: larger file size**

Medium 3.

ANSWER

Each character is looked up in the character set (e.g. ASCII); its unique binary code is stored; H then i in sequence

Hard 1.

ANSWER

Fewer samples per second and fewer bits per sample: less accurate / lower quality, further from the original; smaller files, less storage, quicker to download

PART	ANSWER / WORKING	MARKS	GUIDANCE
	fewer samples per second / bits per sample	B1	
	less accurate / lower quality	B1	
	smaller file size	B1	
	less storage / quicker transmission	B1	
			Total: 4 marks

Hard 2.

ANSWER

Unicode uses more bits per character (16/32 vs 7/8), so each character needs more storage

NOTE 1.5

Data storage units, file sizes and compression

1 In this note

SYLLABUS 1.3 DATA STORAGE AND COMPRESSION

- 1.3.1 Know the units of data storage, from **bit** to **exbibyte (EiB)**, and convert between them (always **1024**).
- 1.3.2 **Calculate the file size** of an image file and of a sound file, in the unit asked for.
- 1.3.3 Explain the **purpose of and need for compression**.
- 1.3.4 Explain **lossy** and **lossless** compression, including **run-length encoding (RLE)**, and choose one for a situation.

Before this: Text, sound and images (resolution, colour depth, sample rate and resolution). This is the last page of the chapter.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

Image and sound settings

Resolution = pixels wide × high; colour depth = bits per pixel; sample rate = samples per second; sample resolution = bits per sample.

Quick check: a sound has 8-bit sample resolution: how many bits does one sample use?

8.

Dividing by 1024

1024 = 2^{10}. Halving ten times divides by 1024: 2048 ÷ 1024 = 2, 512 ÷ 1024 = 0.5.

Quick check: what is 3072 ÷ 1024?

3.

3 Units of data storage

Unit	Equal to	Notes
bit (b)	one binary digit, 0 or 1	the smallest unit
nibble	4 bits	one hex digit
byte (B)	8 bits (2 nibbles)	one ASCII character
kibibyte (KiB)	1024 bytes	
mebibyte (MiB)	1024 KiB	
gibibyte (GiB)	1024 MiB	
tebibyte (TiB)	1024 GiB	
pebibyte (PiB)	1024 TiB	
exbibyte (EiB)	1024 PiB	the largest unit on the syllabus

From byte upwards, every step is **× 1024** going up and **÷ 1024** going down. Never use 1000 in these questions.

EXAM TIP

A way to remember the order: **K**ind **M**onkeys **G**et **T**en **P**eanuts **E**ach.

ANSWER

KiB, MiB, GiB, TiB, PiB, EiB

GENERAL METHOD **Converting between units**

1. Going to a **bigger** unit: divide (÷ 1024 per step; ÷ 8 from bits to bytes).
2. Going to a **smaller** unit: multiply (× 1024 per step; × 8 from bytes to bits).
3. Count the steps between the two units and do one × or ÷ per step.

EXAMPLE How many bits are there in 1 KiB?

KiB → bytes → bits: two steps down, so multiply.

1 × 1024 = 1024 bytes

1024 × 8 = 8192 bits

ANSWER **8192 bits**

TRY IT YOURSELF

1. How many nibbles are in 8 bytes?
2. Convert 512 KiB to MiB.
3. Convert 4 GiB to MiB.
4. How many tebibytes are in 2 PiB?

4 Calculating file sizes

Image file size (bits)

LEARN IT

width × height × colour depth

resolution in pixels, colour depth in bits

Use it when an image with a resolution and a colour depth

Sound file size (bits)

LEARN IT

sample rate × sample resolution × length in seconds

rate in Hz (samples per second), resolution in bits

Use it when a recording with a rate, resolution and length

Bits → bytes → KiB → MiB

LEARN IT

÷ 8, then ÷ 1024, then ÷ 1024

Use it when an answer asked in KiB or MiB

GENERAL METHOD **Any file-size question**

1. Multiply the values given to get the size in **bits** (watch out: a colour depth given in bytes is already bytes).
2. Divide by 8 to get **bytes**.
3. Divide by 1024 for each step up to the unit the question asks for (KiB, then MiB …).
4. Write the answer **in the unit asked**, and show each stage: there are marks for the working.

EXAMPLE **An image is 1024 × 768 pixels with a colour depth of 16 bits. Calculate its size in MiB.**

Bits first, then ÷ 8, then ÷ 1024 twice.

1024 × 768 × 16 = 12 582 912 bits

÷ 8 = 1 572 864 bytes

÷ 1024 = 1536 KiB

÷ 1024 = 1.5 MiB

ANSWER **1.5 MiB**

EXAMPLE **A sound is recorded for 60 seconds at a sample rate of 16 384 Hz with a sample resolution of 16 bits. Calculate the size in KiB.**

Rate × resolution × seconds gives bits.

16 384 × 16 × 60 = 15 728 640 bits

÷ 8 = 1 966 080 bytes

÷ 1024 = 1920 KiB

ANSWER **1920 KiB**

TRY IT YOURSELF

1. An image is 640 × 480 pixels with a colour depth of 8 bits. Calculate the file size in KiB.

2. An image is 1000 × 1000 pixels with a colour depth of 2 bytes. Calculate the file size in bytes.

3. A 5-second sound has a sample rate of 8000 Hz and a sample resolution of 8 bits. Give the size in KiB.

5 Why files are compressed

Compression reduces the **size of a file**. A smaller file:

- needs **less storage space**;
- is **quicker to transmit** (upload, download, send by email);
- needs **less bandwidth** to transmit;
- uses less of a mobile **data allowance**;
- is more likely to fit **file size limits**, such as email attachment limits.

6 Lossy and lossless compression

	Lossy	Lossless
What it does	**permanently removes** some data	**no data is permanently removed**: the **original file can be restored exactly**
File size	much smaller	smaller, but usually less reduction than lossy
Quality	reduced (often not noticed by people)	unchanged
How (examples)	reduce the resolution or colour depth of an image; reduce the sample rate or sample resolution of a sound; remove sounds people cannot hear; JPEG, MP3	**run-length encoding (RLE)**; indexing repeated words or patterns
Use it for	photos, music and video for sharing or streaming	**text** and documents, program files, images or sound that will be edited or printed at full quality

✗ COMMON MISTAKE

Lossy is **never** suitable for text or program files: removing data would change the words or corrupt the program.

7 Run-length encoding (RLE)

Run-length encoding is a lossless method. It finds **runs of repeated data** (characters, or pixels of the same colour) and stores each run **once, with the number of times it repeats**, instead of storing every item.

Original data	RLE	Items stored
AAAAABBBCC (10 characters)	5A 3B 2C	6 instead of 10
a row of pixels: W W W W W W B B W W W W	6W 2B 4W	6 instead of 12

For text, a lossless algorithm can also find **repeated words or phrases**, store each one once in an index, and record the **positions** where it appears.

✗ COMMON MISTAKE

RLE only helps when the data has long runs (simple graphics, large areas of one colour). A photo with every pixel different could even get bigger.

TRY IT YOURSELF

1. Write GGGGGGRRRRB using RLE (number then letter).
2. A file must be emailed and the original must be restored exactly. Which type of compression should be used?

8 Summary

- bit → nibble (4 bits) → byte (8 bits) → KiB → MiB → GiB → TiB → PiB → EiB, × 1024 each step from byte up.
- Image size (bits) = width × height × colour depth. Sound size (bits) = sample rate × resolution × seconds.
- Bits ÷ 8 = bytes; ÷ 1024 = KiB; ÷ 1024 = MiB. Answer in the unit asked, show every stage.
- Compression reduces file size: less storage, quicker transmission, less bandwidth, fits email limits.
- Lossy permanently removes data (smaller, lower quality). Lossless removes nothing permanently (original restored).
- RLE (lossless): runs of repeated characters / pixels stored once with the number of repeats.

IF YOU SEE …

"calculate the file size … in KiB"	→ multiply → ÷ 8 → ÷ 1024, show each stage
text, documents, programs, editing, printing	→ lossless
"describe how lossless compression works"	→ RLE: repeated patterns identified, stored once with the count

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

9 Ways they test it

TYPE 1 Units

> *"State how many kibibytes equal a mebibyte" [1]; "Complete each conversion" [4]; "Tick the largest unit" [1]*

Spot it unit names.

1. Know the ladder and 1024.
2. Show working for conversions with more than one step.

TYPE 2 File size

> *"Calculate the file size of the image in kibibytes. Show all your working" [2-3]*

Spot it resolution + colour depth, or rate + resolution + length.

1. Marks: one for each correct stage of working, one for the answer.
2. Answer in the unit asked.

TYPE 3 Why compress

> *"Give two reasons why the file may have been compressed" [2-3]*

Spot it "compressed", "reason", "benefit".

1. Pick from: less storage · quicker to transmit · less bandwidth · email size limit · less data allowance.

TYPE 4 **Choose and justify**

> *"Explain why the musician would choose lossless compression instead of lossy" [3]*

Spot it both types named.

1. Lossless keeps all the data / original quality.
2. Lossy would permanently remove data and reduce quality.
3. Link to the scenario: editing, printing, text.

TYPE 5 **Describe a method**

> *"Describe how lossless compression compresses the text file" [3-4]*

Spot it "describe how" + lossless.

1. Name RLE.
2. Repeating characters / pixels / patterns are identified ...
3. ... stored once with the number of repeats (and the colour / position).

10 What the examiner looks for

"Explain how the image file is compressed using lossless compression" [3]

Marking points (one mark each, up to the marks shown)

- The size of the file is reduced without permanently removing any data
- A compression algorithm is used ... such as run-length encoding / RLE
- Repeating pixels are identified / grouped // patterns are identified ...
- ... and stored with the number of times they are repeated // indexed

KEYWORDS **RLE** **repeating** **number of times** **no data permanently removed**

"Explain why lossless was chosen instead of lossy" [3]

Marking points (one mark each, up to the marks shown)

- Lossless will keep all the data / the image is not changed
- Lossy would permanently remove data ...
- ... and reduce the quality (of the print / recording)
- Link to the scenario: they want to edit it / print it in detail / it is text

KEYWORDS **permanently** **original** **quality**

Wording trap · Working for a file size

THE QUESTION **2210/12/M/J/24 Q1** ↗ Paper 1 · Computer systems **3 marks**

A 16-bit colour image has a resolution of 512 × 512 pixels. Calculate the file size in KiB. Show all your working.

✓ CREDITED

- 512 × 512 × 16 = 4 194 304 bits, ÷ 8 = 524 288 bytes, ÷ 1024 = 512 KiB
- 512 × 512 = 262 144; × 2 bytes = 524 288 bytes; ÷ 1024 = 512 KiB

✗ NOT CREDITED

- dividing by 1000 (524.288)
- only the final answer, with a slip in it

WHY

Each stage of working earns a mark even if the last number goes wrong. The syllabus always uses 1024.

From: 2210/12/M/J/24 Q1(d) mark scheme

11 Past-paper questions, solved

0478/12/F/M/23 Q3 ↗ Paper 1 · Computer systems **4 marks** ⤢ Full size

3 A new computer comes with primary and secondary storage.

(a) Data storage is measured using binary denominations.

Complete each conversion.

8 bytes = ... nibbles

512 kibibytes (KiB) = ... mebibytes (MiB)

4 gibibytes (GiB) = ... mebibytes (MiB)

1 exbibyte (EiB) = ... pebibytes (PiB)

[4]

Working space

Swipe sideways to read the whole question

How to start For each, count the steps on the unit ladder: going up divide, going down multiply.

▼ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

8 bytes = **16** nibbles · 512 KiB = **0.5** MiB · 4 GiB = **4096** MiB · 1 EiB = **1024** PiB

PART	ANSWER / WORKING	MARKS	GUIDANCE
3(a)	16 · 0.5 · 4096 · 1024	B4	one mark each
			Total: 4 marks

2210/12/M/J/24 Q1 ↗ Paper 1 · Computer systems **3 marks** ⤢ Full size

1 Data can be measured in bits.

(d) A 16-bit colour image has a resolution of 512 pixels wide by 512 pixels high.

Calculate the file size of the image in kibibytes (KiB). Show all your working.

Answer ..... KiB

[3]

Swipe sideways to read the whole question

How to start Pixels × colour depth gives bits; then ÷ 8 and ÷ 1024.

▼ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

512 × 512 = 262 144 pixels · × 16 = 4 194 304 bits · ÷ 8 = 524 288 bytes · ÷ 1024 = **512 KiB**

PART	ANSWER / WORKING	MARKS	GUIDANCE
1(d)	512 × 512 (= 262 144)	M1	
1(d)	× 16 ÷ 8 // × 2 bytes, then 524 288 / 1024	M1	max 2 for working
1(d)	512 (KiB)	A1	

Total: 3 marks

2 Data storage can be measured using different units of measurement.

(c) A 10 second sound effect is recorded for a movie.

It is recorded with a sample rate of 22,016 Hz and a sample resolution of 8 bits.

Calculate the file size of the sound effect in kibibytes (KiB). Show all your working.

Answer ..... KiB

[3]

(d) The sound effect file is compressed for storage.

(i) State what is meant by file compression.

..... [1]

(ii) Give **one** benefit of compressing the file for storage.

..... [1]

Swipe sideways to read the whole question

How to start Rate × resolution × seconds gives bits; then ÷ 8 and ÷ 1024. (d) is recall.

▼ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

(c) 22 016 × 8 × 10 = 1 761 280 bits · ÷ 8 = 220 160 bytes · ÷ 1024 = **215 KiB**

(d)(i) Reducing the size of a file. (ii) It takes up less storage space.

PART	ANSWER / WORKING	MARKS	GUIDANCE
2(c)	Any two stages: 22 016 × 8 then ÷ 8 · × 10 · 220 160 / 1024	M2	
2(c)	215 KiB	A1	
2(d)(i)	reducing the size of a file	B1	
2(d)(ii)	it will take up / use less storage space	B1	

Total: 5 marks

2 An artist creates an image on a computer.

(c) The artist compresses the image file before uploading it to their website. Users can download the image file from the website to print as a poster.

The image file is compressed using lossless compression.

(i) Explain the reasons why the artist chose lossless compression instead of lossy compression to compress this image file.

..... [3]

(ii) Identify **one** lossless method of compressing an image.

Describe your chosen method.

Method .....

Description .....

[3]

Swipe sideways to read the whole question

How to start (i) contrast the two types and link to the scenario (people print the image as a poster). (ii) name RLE, then describe it.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(c)(i) Lossless keeps all of the image data, so the downloaded image is exactly the original. Lossy would permanently remove data and reduce the quality, and the artist wants users to print a detailed poster.

(c)(ii) Run-length encoding. Runs of repeating pixels of one colour are identified and each run is stored once, as the number of repetitions and the colour code.

PART	ANSWER / WORKING	MARKS	GUIDANCE
2(c)(i)	Any three: lossless retains all parts of the image // does not delete data · lossy reduces quality · artist wants a detailed image · image may be small anyway / server has space / download time OK	B3	
2(c)(ii)	Run-length encoding (name)	B1	
2(c)(ii)	repeating pixels of one colour / patterns identified · … indexed / put into a table · … as the number of repetitions and the colour code	B2	max 2 for describing
			Total: 6 marks

12 Common mistakes

✗ Dividing by 1000

✓ Divide by 1024

The syllabus says calculations must use 1024.

✗ Forgetting ÷ 8

✓ Bits ÷ 8 = bytes, then ÷ 1024

Image and sound formulas give BITS.

✗ Answer in the wrong unit

✓ Give exactly the unit in the question

✗ "Lossless removes some data"

That is lossy.

✓ Lossless removes no data permanently

✗ "Compression makes the file faster"

Be specific.

✓ "Quicker to transmit / less storage"

13 Practice

Practice: easy, medium, hard

1. How many bits are in a byte?
2. How many MiB are in 3 GiB?
3. Give two benefits of compressing a file.
1. A file is 3072 bytes. Give its size in KiB.
2. An image is 800 × 600 pixels with 24-bit colour depth. Calculate the size in bytes.
3. Explain why lossy compression should not be used for a text document.
1. A 2-minute song is recorded at 32 768 Hz with 16-bit resolution. Calculate the file size in MiB. Show your working.
2. A photographer needs to send 40 photos by email but they are too big. Explain which compression they should use and how it reduces the size. [4]

14 Can I do this?

0 / 5 ticked

- [ ] I know the units from bit to EiB in order and convert with 1024.
- [ ] I can calculate an image file size and a sound file size in the unit asked.
- [ ] I can give reasons for compressing a file.
- [ ] I can compare lossy and lossless and choose one for a situation.
- [ ] I can describe run-length encoding and apply it.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

1. 2 nibbles per byte

ANSWER **16**

2.

ANSWER **0.5**

3.

ANSWER **4096**

4.

ANSWER **2048**

Try it yourself 2

1.

1. 640 × 480 × 8 = 2 457 600 bits
2. ÷ 8 = 307 200 bytes
3. ÷ 1024 = 300 KiB

ANSWER **300**

2.

1. 1000 × 1000 = 1 000 000 pixels
2. × 2 bytes = 2 000 000 bytes (already bytes: no ÷ 8)

ANSWER **2 000 000**

3.

1. 8000 × 8 × 5 = 320 000 bits
2. ÷ 8 = 40 000 bytes
3. ÷ 1024 = 39.0625 KiB

ANSWER **39.0625**

Try it yourself 3

1.

ANSWER **6G 4R 1B**

2.

ANSWER **Lossless**

Practice: easy, medium, hard

Easy 1.

ANSWER **8**

Easy 2.

ANSWER **3072**

Easy 3.

ANSWER **Less storage space; quicker to transmit (or less bandwidth / fits email limits)**

Medium 1.

ANSWER **3**

Medium 2.

1. 800 × 600 × 24 = 11 520 000 bits
2. ÷ 8 = 1 440 000 bytes

ANSWER **1 440 000**

Medium 3.

ANSWER

It permanently removes data, so words / characters would be lost and the document corrupted

Hard 1.

1. 120 s × 32 768 × 16 = 62 914 560 bits
2. ÷ 8 = 7 864 320 bytes
3. ÷ 1024 = 7680 KiB
4. ÷ 1024 = 7.5 MiB

ANSWER **7.5 MiB**

PART	ANSWER / WORKING	MARKS	GUIDANCE
	32 768 × 16 × 120	M1	
	÷ 8 and ÷ 1024 (twice)	M1	
	7.5 MiB	A1	
			Total: 3 marks

Hard 2.

ANSWER

Lossy: permanently removes data, e.g. reduces resolution / colour depth / removes detail people won't notice; much smaller files, quicker to send; quality loss acceptable for viewing

2

Data Transmission

1. Data packets and packet switching
2. Serial, parallel, duplex and USB
3. Error detection: parity, checksum, echo check, ARQ, check digit
4. Encryption: symmetric and asymmetric

NOTE 2.1

Data packets and packet switching

1 In this note

SYLLABUS 2.1 TYPES AND METHODS OF DATA TRANSMISSION

- 2.1.1a Understand that data is broken down into **packets** to be transmitted.
- 2.1.1b Describe the **structure of a packet**: packet **header** (destination address, packet number, originator's address), **payload**, **trailer**.
- 2.1.1c Describe the process of **packet switching**, including the role of the **router**.

Next: Serial, parallel and duplex.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

Everything is binary

A file, an email or a web page is just a long string of bits when it is sent.

Quick check: what is a file made of when it is sent?

A long string of bits (binary).

Networks

A network is devices connected so they can share data. The internet is a huge network of networks.

Quick check: what do we call a network of networks?

The internet.

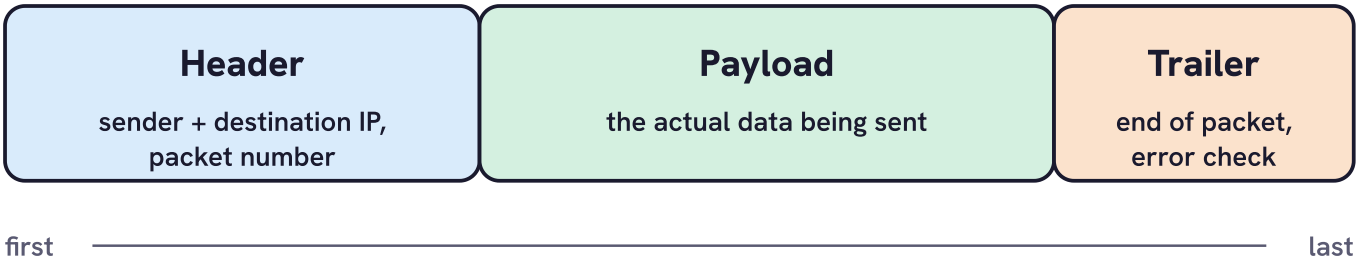
3 Why data is split into packets

When a file is sent across a network it is not sent in one go. It is **broken down into small units** called **packets**. Each packet is sent **independently** and the file is put back together at the other end.

Why? A small packet is quick to send. If one packet is lost or damaged, only that packet has to be sent again, not the whole file. And many people can share the same network, because packets from different users take turns on the cables.

4 The structure of a packet

Every packet has **three sections**: a **header**, a **payload** and a **trailer**.



A packet: the header goes first, then the data (payload), then the trailer.

Section	What it holds
Header	the **destination address** (IP address of the receiver), the **originator's address** (IP address of the sender) and the **packet number** (so the packets can be put back in order). It can also give the size of the packet and the total number of packets.
Payload	the **actual data** being sent: one small piece of the file
Trailer	data that shows the **end of the packet**, and **error checking** data (e.g. a checksum value)

> Memory hook: the **header** is like the address and number written on an envelope, the **payload** is the letter inside, the **trailer** says "end of letter" and how to check it arrived complete.

TRY IT YOURSELF

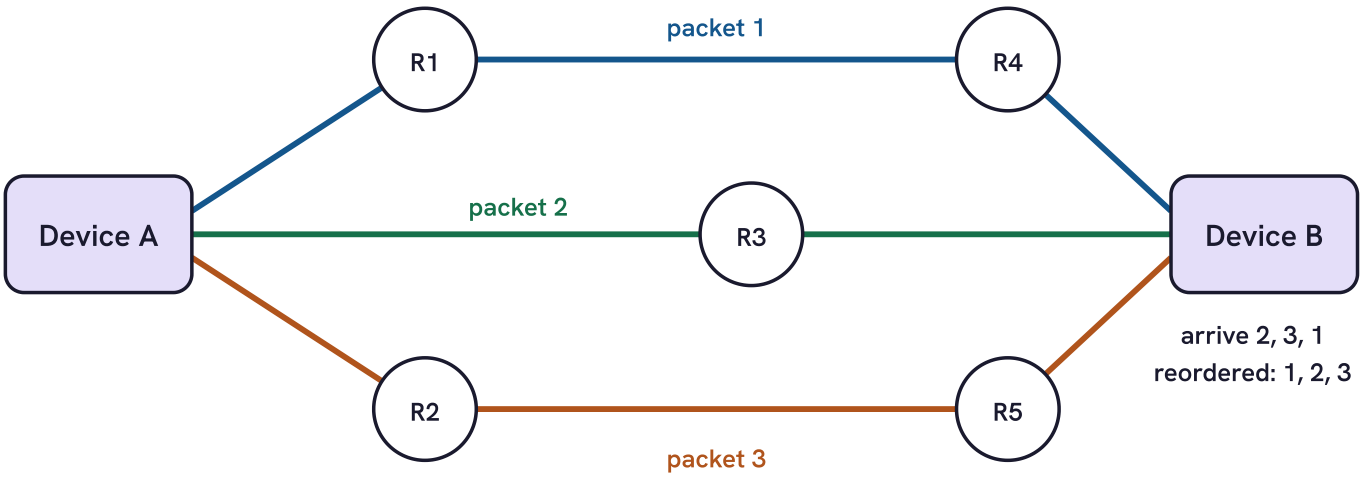
1. Which section of a packet holds the packet number?
2. Which section holds the actual data being sent?
3. Give one item of data stored in the trailer.

5 Packet switching

Packet switching is the method used to send the packets across a network such as the internet. A device called a **router** sits at each junction of the network and decides where each packet goes next.

GENERAL METHOD **How packet switching works**

1. The data is **broken down into packets**.
2. Each packet is given a header with the destination address and its **packet number**.
3. Each packet is sent **independently**: it **could take a different route** across the network.
4. At each **router**, the router reads the **destination address** in the header and sends the packet on towards its destination, choosing the **shortest / fastest available route** at that moment.
5. Packets may **arrive out of order** (some routes are slower or busier).
6. When the **last packet** has arrived, the packets are **reordered** using their packet numbers.
7. If a packet is **missing or corrupted**, it is **requested again**.



Three packets of one file take three different routes through the routers, arrive in the order 2, 3, 1 and are put back in order at B.

Advantages of packet switching	Disadvantages
packets can **avoid busy or broken routes**, so data still gets through	packets can **arrive out of order** and must be reordered
only a **lost / damaged packet is resent**, not the whole file	packets can be **lost** and need resending, which causes delay
many users can **share the network** at the same time	the receiver must wait for every packet before the file is complete

TRY IT YOURSELF

1. Name the device that controls the route each packet takes.
2. Why might packets arrive in a different order from the order they were sent?

6 Summary

- Data is broken down into packets; each packet is sent independently.
- Header: destination address, originator's address, packet number. Payload: the data. Trailer: end of packet + error checking.
- Packet switching: each packet may take a different route; routers read the destination address and send it on by the best route.
- Packets can arrive out of order; they are reordered (packet numbers) once the last one arrives; missing ones are requested again.

IF YOU SEE …

"describe the structure of a packet"	→ three sections · header (with 2 examples) · payload (the data) · trailer (end + error check)
"explain how packet switching works"	→ split into packets · different routes · router · out of order · reordered · resent
"purpose of a router"	→ reads destination address · sends packet towards destination · chooses the route

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

7 Ways they test it

TYPE 1 **Header items**

> *"Identify two items of data contained in a packet header" [2]*

Spot it "header".

1. Destination IP address · originator's (sender's) IP address · packet number. Not "the data" (that is the payload).

TYPE 2 **Structure**

> *"Describe the structure of a data packet" [3-6]; a labelled diagram to complete*

Spot it "structure", "sections".

1. Name all three sections in order AND say what each holds: one mark per name, one per example.

TYPE 3 **Process**

> *"Explain how the file is transmitted using packet switching" [5]; "complete and annotate the diagram" [4]*

Spot it "packet switching", "routers".

1. Write the method steps in order: split, different routes, router, out of order, reordered, resent.

TYPE 4 **Router**

> *"Give the purpose of a router in packet switching" [1]; "identify the component that ..." [1]*

Spot it "controls the route".

1. Router: reads the destination address and sends the packet towards its destination by the best route.

TYPE 5 **Cloze**

> *"Complete the statements ... use the terms from the list" [4]*

Spot it a word list.

1. Each gap uses a keyword from the notes: header, destination address, routers, last.

8 What the examiner looks for

"Describe the structure of a packet of data" [4]

Marking points (one mark each, up to the marks shown)

- The data packet has three sections
- It has a packet header ...
- ... that contains data such as the destination address
- It has a payload ...
- ... that contains the main data
- It has a trailer ...
- ... that contains data such as the error detection method used

KEYWORDS **header** **payload** **trailer** **destination address** **packet number**

"Explain how the file is transmitted using packet switching" [5]

Marking points (one mark each, up to the marks shown)

- Data is broken / split / divided into packets
- Each packet (could) take a different route
- A router controls the route / path a packet takes ...
- ... selecting the shortest / fastest available route
- Packets may arrive out of order
- Once the last packet has arrived, packets are reordered
- If a packet is missing / corrupted, it is requested again

KEYWORDS **packets** **different route** **router** **out of order** **reordered**

Wording trap · Packet header

THE QUESTION **2210/11/M/J/25 Q4** ↗ Paper 1 · Computer systems **1 mark**

Which item would NOT be included in a packet's header? A destination address · B originator's address · C packet number · D payload

✓ CREDITED

- D, payload: the payload is a separate section, the data itself

✗ NOT CREDITED

- A, B or C: these three are exactly what the header holds

WHY

The header describes the packet; the payload IS the data.

From: 2210/11/M/J/25 Q4(c)(i) mark scheme

9 Past-paper questions, solved

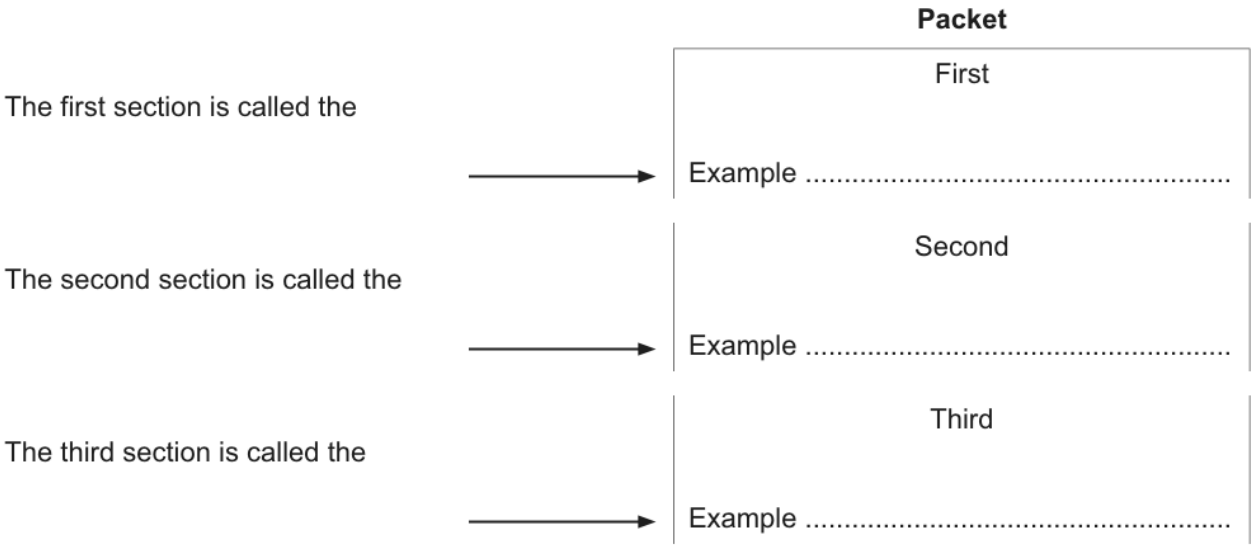
2210/13/O/N/25 Q3 ↗ Paper 1 · Computer systems **6 marks** ⤢ Full size

3 Data is split into packets before it is transmitted across a network.

(a) The diagram shows a packet with **three** sections.

Complete the diagram by writing the name of each section of the packet.

Write an example in each section of what would be stored in that part of the packet.



[6]

Swipe sideways to read the whole question

How to start Three sections, three examples: one mark each. Write them in order: first, second, third.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

First section: the **header**. Example: the destination IP address (or packet number, or sender's IP address).

Second section: the **payload**. Example: the data itself.

Third section: the **trailer**. Example: error checking data (or end of packet notification).

PART	ANSWER / WORKING	MARKS	GUIDANCE
3(a)	Header · e.g. originator's / destination (IP) address, packet number	B2	
	Payload · the data itself	B2	
	Trailer · e.g. end of packet notification, error checking data	B2	

Total: 6 marks

2 A student has a sound file that is too large to be stored on their external secondary storage device. The student compresses the sound file to make the file size smaller.

The compression method used reduces the sample rate and the sample resolution of the sound file.

(c) The student sends the sound file to a friend. The file is transmitted across a network that uses packet switching.

(i) Identify **two** pieces of data that would be included in the header of each packet.

[2]

(ii) Explain how the file is transmitted using packet switching.

..... [5]

Swipe sideways to read the whole question

How to start (i) is two of the three header items. (ii) is the seven-step method: aim for five clear points.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(c)(i) The destination IP address. The packet number.

(c)(ii) The file is broken down into packets. Each packet can take a different route across the network. Routers control the route each packet takes, choosing the fastest available route. The packets may arrive out of order, so once the last packet has arrived they are reordered using the packet numbers. If a packet is missing or corrupted it is requested again.

PART	ANSWER / WORKING	MARKS	GUIDANCE
2(c)(i)	Any two: destination (IP) address · packet number · originator's (IP) address	B2	
2(c)(ii)	Any five: split into packets · different routes · router controls the route · … shortest / fastest route · may arrive out of order · reordered once the last arrives · missing / corrupted packet requested again	B5	

Total: 7 marks

7 Complete the statements about data packets and packet switching.

Use the terms from the list.

Some of the terms in the list will **not** be used. You should only use a term once.

destination address first footer header

last main data packets payload

routers servers trailer

Data is broken down into packets. A data packet has a packet ..... that contains the packet number and the ..... .

Each packet could take a different path from the sender to the receiver; this is controlled by ..... .

Packets may arrive out of order. Once the ..... packet has arrived, the packets are reordered.

[4]

Swipe sideways to read the whole question

How to start Read the whole paragraph first. Each gap matches one keyword from the notes; not every word in the list is used.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

header · destination address · routers · last

(A packet has a packet **header** that contains the packet number and the **destination address**. The path is controlled by **routers**. When the **last** packet arrives, the packets are reordered.)

PART	ANSWER / WORKING	MARKS	GUIDANCE
7	header · destination address · routers · last, one mark each in the correct order	B4	

Total: 4 marks

10 Common mistakes

✗ "The header contains the data"

The header only describes the packet.

✓ "The payload contains the data"

✗ "All packets take the same route"

✓ "Each packet can take a different route"

✗ "The router puts the packets back in order"

The router only sends each packet on.

✓ "The receiving device reorders the packets"

✗ "Address" on its own

Say which address.

✓ "Destination IP address" or "sender's IP address"

11 Practice

Practice: easy, medium, hard

1. What is the name given to the small units that data is broken into for transmission?
2. Name the three sections of a packet, in order.
3. Give the purpose of the packet number.
1. Give two items of data stored in a packet header.
2. Explain why packets may need to be reordered when they arrive. [2]
3. Describe the role of a router in packet switching.
1. A video is sent across the internet using packet switching. Explain how the video is transmitted. [5]
2. Give one benefit and one drawback of packet switching.

12 Can I do this?

0 / 3 ticked

- [ ] I can explain why data is split into packets.
- [ ] I can name the three sections of a packet and say what each holds.
- [ ] I can explain packet switching in order, including the router.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

ANSWER The header

2.

ANSWER The payload

3.

ANSWER End of packet notification / error checking data such as a checksum

Try it yourself 2

1.

ANSWER Router

2.

ANSWER

Each packet can take a different route; some routes are longer or busier, so some packets take longer

Practice: easy, medium, hard

Easy 1.

ANSWER Packets

Easy 2.

ANSWER Header, payload, trailer

Easy 3.

ANSWER So the packets can be put back in the correct order when they arrive

Medium 1.

ANSWER Two of: destination IP address, originator's IP address, packet number

Medium 2.

ANSWER

Each packet can take a different route; some take longer, so they arrive in the wrong order

Medium 3.

ANSWER

Reads the destination address in the header and sends the packet towards its destination by the best available route

Hard 1.

ANSWER

Split into packets with header (destination address, packet number); each packet sent independently, may take a different route; routers read the destination address and choose the fastest route; packets arrive out of order; reordered when the last arrives; missing / corrupted packets requested again

PART	ANSWER / WORKING	MARKS	GUIDANCE
	split into packets	B1	
	different routes	B1	
	router chooses route	B1	
	out of order → reordered when last arrives	B1	
	missing packets requested again	B1	
			Total: 5 marks

Hard 2.

ANSWER

Benefit: packets avoid busy / broken routes, only lost packets resent. Drawback: packets arrive out of order / can be lost, causing delay

NOTE 2.2

Serial, parallel, duplex and USB

1 In this note

SYLLABUS 2.1 TYPES AND METHODS OF DATA TRANSMISSION

- 2.1.2a Describe **serial** and **parallel** transmission, and **simplex**, **half-duplex** and **full-duplex** transmission.
- 2.1.2b Explain the **suitability** of each method for a given situation, with **advantages and disadvantages**.
- 2.1.3 Understand the **universal serial bus (USB)** interface and how it is used to transmit data.

Before this: Packets and packet switching. Next: Error detection.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

Bits

All data is sent as bits (1s and 0s). Eight bits make a byte.

Quick check: how many bits in a byte?

8.

Interference

Electrical signals in wires can be disturbed by other signals nearby. This can change a 1 into a 0, or a 0 into a 1.

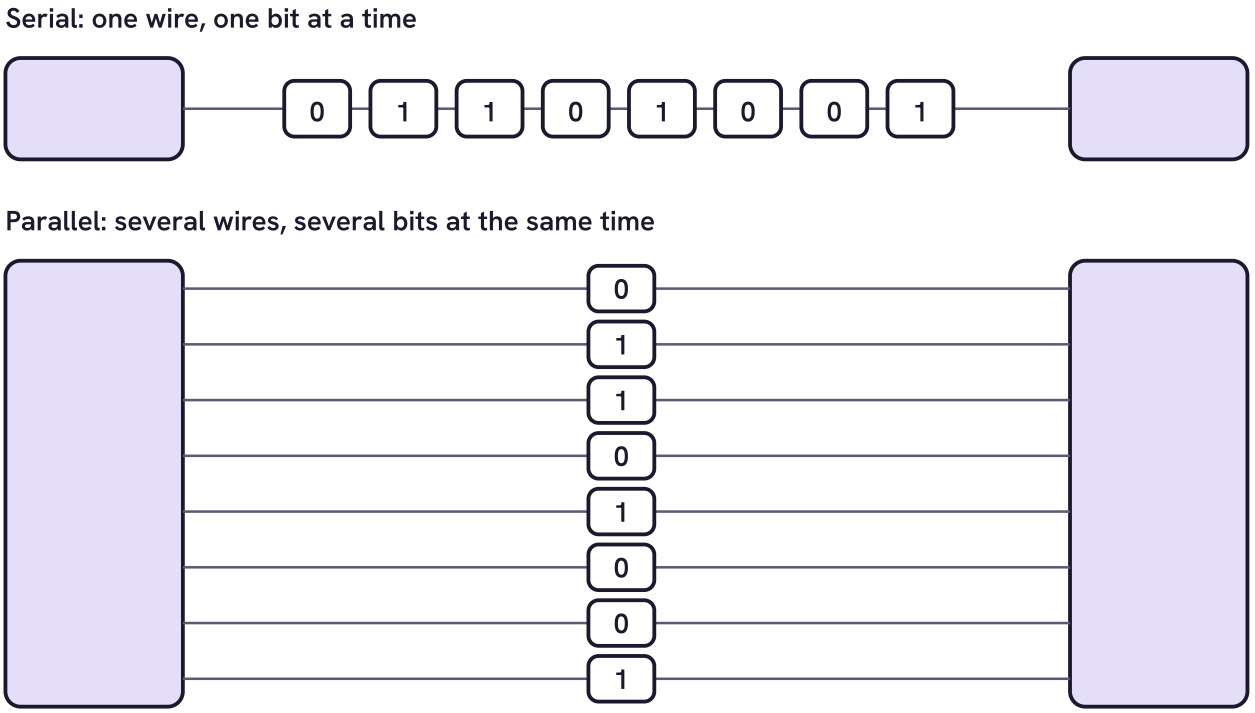
Quick check: what can interference do to a bit?

Change it (flip a 1 to a 0 or a 0 to a 1).

3 Serial and parallel

Every method is described in two ways: **how many wires** are used (serial or parallel) and **which directions** the data can go (simplex, half-duplex or full-duplex). An answer always needs both,

e.g. "serial half-duplex".

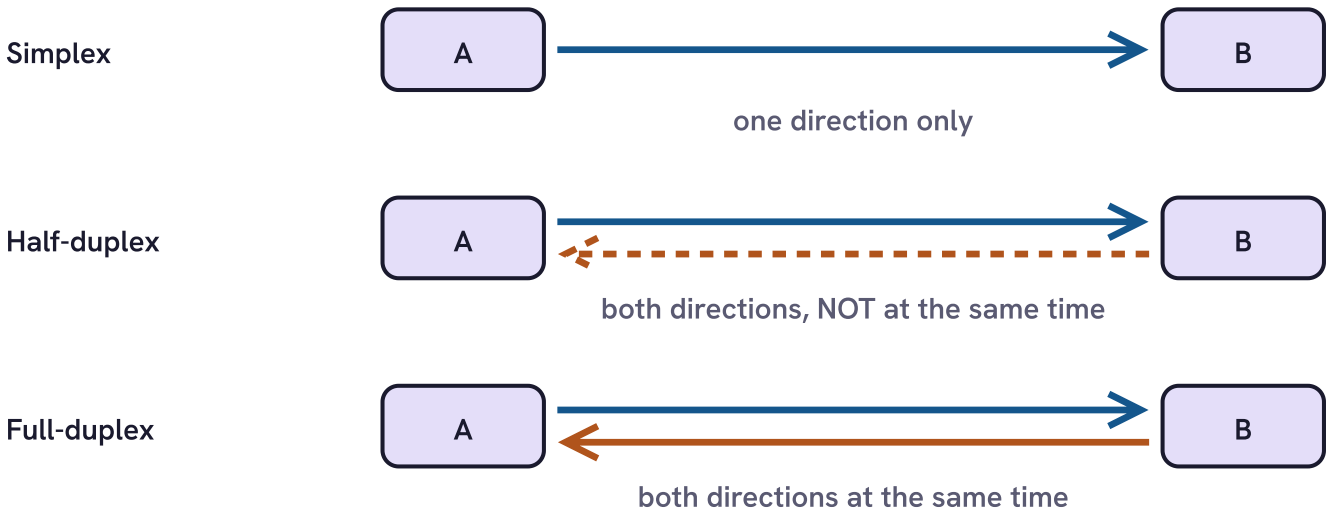


Serial sends the 8 bits one after another down one wire. Parallel sends 8 bits at once, one on each wire.

	Serial	Parallel
How	data is sent **one bit at a time** down a **single wire**	**several bits at the same time** down **several wires**
Speed	slower	**faster** (several bits at once)
Order of bits	bits **arrive in order**: they **cannot be skewed**	bits can arrive at slightly different times: **skewing**
Errors	**less interference / crosstalk**, so fewer errors	wires next to each other cause **crosstalk**, so more errors
Distance	reliable over **long distances**	only reliable over **short distances** (skewing gets worse with length)
Cost	cheaper: one wire	more expensive: many wires
Typical use	USB, networks, long cables	inside a computer (e.g. buses), very short cables

Skewing: the bits sent at the same time down parallel wires arrive at slightly different times, so they can be read out of order. **Crosstalk**: interference between wires that are next to each other.

4 Simplex, half-duplex and full-duplex



The three directions of transmission.

Method	What happens	Example
Simplex	data is sent in **one direction only**	computer to monitor; microphone to speakers
Half-duplex	data is sent in **both directions**, but **only one direction at a time**	walkie-talkie; a printer cable that also sends back "out of paper"
Full-duplex	data is sent in **both directions** **at the same time**	phone call; a network connection with upload and download together

TRY IT YOURSELF

1. Data is sent down one wire, one bit at a time, in both directions but not at the same time. Name the method.
2. Which method is fastest over a 30 cm cable: serial simplex or parallel simplex?
3. Give one reason serial is used for long distances.

5 Choosing a method for a situation

GENERAL METHOD **Choose and justify a method**

1. **Distance**: more than a few metres → **serial** (no skewing, less interference). Very short and speed matters → **parallel**.
2. **Speed / amount of data**: small amounts of data → serial is **fast enough**. Lots of data quickly over a short distance → parallel.
3. **Direction**: does data only go one way? → **simplex**. Does a reply come back but not at the same time? → **half-duplex**. Do both sides send at once? → **full-duplex**.
4. Write each reason as **point + because**: "serial, because the data travels a long distance and the bits will not be skewed".

EXAMPLE **A school's printer is in the next room. The computer sends documents; the printer sends back "paper jam" messages, but never while it is receiving. Choose a method.**

Two decisions: wires, then directions.

Distance: the next room, several metres → serial (bits not skewed, less interference).

Directions: both ways, but not at the same time → half-duplex.

ANSWER **Serial half-duplex**

6 The universal serial bus (USB)

USB is a standard way to connect devices (mouse, keyboard, printer, memory stick, phone) to a computer. It uses **serial** transmission: data is sent **one bit at a time** down a **single wire**. Newer versions can send in both directions.

Benefits of USB	Drawbacks of USB
it is a **universal standard**, so most devices and computers have it	**maximum cable length** is short (about 5 m)
the cable **can only be inserted one way** / cannot be plugged in wrongly	slower than some other connections (e.g. a parallel connection)
the device is **automatically detected** and the **driver installed automatically**	older versions may be slow for big transfers
it can **power the device** (and charge it)	
backwards compatible with older USB versions; supports different speeds	
serial, so **less chance of skewing / errors**	

TRY IT YOURSELF

1. Is USB serial or parallel?
2. Give two benefits of connecting a mouse by USB.

7 Summary

- Serial: one bit at a time, one wire; in order, less interference, long distances, slower.
- Parallel: several bits at the same time, several wires; faster, but skewing and crosstalk, short distances only.
- Simplex: one direction. Half-duplex: both directions, one at a time. Full-duplex: both directions at the same time.
- Choose by distance, speed needed and direction; justify each choice with a reason.
- USB = universal serial bus: serial, universal, auto-detected, powers the device, one-way plug; short cable.

IF YOU SEE …

"describe serial half-duplex"	→ one bit at a time · single wire · both directions · not at the same time
"explain why serial is suitable"	→ long distance · bits not skewed · less interference · speed adequate
"benefits of USB"	→ universal · auto-detected / driver · powers device · cannot insert wrongly · backwards compatible

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

8 Ways they test it

TYPE 1 Describe a method

> *"Explain how data is transmitted using serial full-duplex" [4]*

Spot it a method name with two words.

1. Two marks for the wire part (one bit at a time / single wire) and two for the direction part (both directions / at the same time).

TYPE 2 Name from a description

> *a table of descriptions to complete [4]; "circle the two methods" [2]*

Spot it "identify", "circle".

1. Read each description twice: once for the wires, once for the directions.

TYPE 3 Choose and justify

> *"Identify the most appropriate method. Explain your choice" [5]*

Spot it a scenario: distance, who sends what.

1. One mark per word of the method; then reasons tied to the scenario (distance, direction, speed).

TYPE 4 Benefits / drawbacks

> *"Give two drawbacks of using parallel full-duplex" [2]*

Spot it "benefit", "drawback".

1. Use the comparison table: skewing, crosstalk, collisions, distance, speed.

TYPE 5 **USB**

> *"Explain how data is sent using USB" [2]; "give two benefits" [2]*

Spot it "USB".

1. How: one bit at a time, single wire. Benefits from the USB table.

9 What the examiner looks for

"Explain how data is transmitted using serial full-duplex / parallel half-duplex" [4]

Marking points (one mark each, up to the marks shown)

- Serial: data is sent one bit at a time … down a single wire
- Parallel: data is sent multiple bits at the same time … down multiple wires
- Full-duplex: data can be sent in both directions … at the same time
- Half-duplex: data can be sent in both directions … but not at the same time
- Simplex: data is sent in one direction only

KEYWORDS **one bit at a time** **single wire** **multiple wires** **both directions** **at the same time**

"Explain why serial is the most appropriate method" [3]

Marking points (one mark each, up to the marks shown)

- The data may travel a long distance … serial is more reliable over long distances
- Bits are sent / arrive in order … so the data will not be skewed
- Less interference / crosstalk (single wire) … so fewer errors
- The data does not need to be sent quickly … only small amounts of data, so serial speed is adequate

KEYWORDS **long distance** **skewed** **interference** **crosstalk** **adequate speed**

TOO VAGUE "it is faster" (serial is not faster); "it is safer" (say why: fewer errors)

Wording trap · Choosing a method

THE QUESTION **2210/11/M/J/25 Q4** ↗ Paper 1 · Computer systems — **1 mark**

Give one improvement that would be made to the data transmission if parallel transmission is used instead of serial transmission.

✓ CREDITED

- The data may be transmitted faster

✗ NOT CREDITED

- it is more secure
- fewer errors
- it can go further

WHY

Parallel's only advantage is speed. It has MORE errors and works over SHORTER distances.

From: 2210/11/M/J/25 Q4(a)(ii) mark scheme

10 Past-paper questions, solved

2210/12/O/N/23 Q6 ↗ Paper 1 · Computer systems **4 marks** ⤢ Full size

6 The table contains descriptions about data transmission methods.

Complete the table by identifying which data transmission methods are described.

Data transmission method	Description
.....	Data is transmitted down a single wire, one bit at a time, in one direction only.
.....	Data is transmitted down multiple wires, multiple bits at a time, in both directions, but only one direction at a time.
.....	Data is transmitted down a single wire, one bit at a time, in both directions at the same time.
.....	Data is transmitted down multiple wires, multiple bits at a time, in one direction only.

Swipe sideways to read the whole question

How to start Each description has two parts. Single wire, one bit = serial; multiple wires = parallel. Then the direction words.

▼ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

serial simplex · parallel half-duplex · serial full-duplex · parallel simplex

PART	ANSWER / WORKING	MARKS	GUIDANCE
6	serial simplex · parallel half-duplex · serial full-duplex · parallel simplex (one mark each)	B4	

Total: 4 marks

0478/11/O/N/25 Q7 ↗ Paper 1 · Computer systems — **5 marks** — ⤢ Full size

7 A theatre has a microphone on stage that is connected by cables to several speakers around the theatre. A person speaks into the microphone and their voice is output from the speakers.

Identify the most appropriate data transmission method for this purpose. Explain your choice.

Data transmission method .....

Explanation .....

[5]

Swipe sideways to read the whole question

How to start Two marks for the method (one for each word), three for reasons. Look for distance (around the theatre) and direction (sound only goes from microphone to speakers).

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

Method: serial simplex.

Explanation: Serial, because the cables run a long distance around the theatre, and the bits are sent one at a time down one wire, so they will not be skewed and there is less chance of error. Simplex, because the data only needs to go in one direction, from the microphone to the speakers; nothing is sent back.

PART	ANSWER / WORKING	MARKS	GUIDANCE
7	Serial · Simplex	B2	
	Any three: long distance · one wire / bits in order · less chance of skewing / error · speed adequate · only one direction needed · nothing sent back from speakers to microphone	B3	

Total: 5 marks

4 A company decides to create a network for its devices.

All the company devices are within a single room.

The employees will need to use their devices to send data to each other and share files.

The company decides to send data across the network using packet switching.

(b) The company decides to use parallel full-duplex data transmission to send the data across the network.

(i) Explain the reasons why the company have chosen this method of data transmission.

..... [4]

(ii) Give **two** drawbacks of the company using this method of data transmission.

[2]

(iii) Give **one** other method of data transmission the company could have chosen.

..... [1]

Swipe sideways to read the whole question

How to start (i) Give a point AND its link to the scenario (single room, sending to each other). (ii) is the parallel and full-duplex drawbacks. (iii) any other method.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(b)(i) Parallel sends multiple bits at the same time down multiple wires, so the data is transmitted quickly. The data does not need to travel a long distance, as the devices are all in a single room. Full-duplex sends data in both directions at the same time, so employees can send data to each other with no delay.

(b)(ii) More interference / crosstalk because of the multiple wires. Bits may be skewed and arrive out of order.

(b)(iii) Serial full-duplex.

PART	ANSWER / WORKING	MARKS	GUIDANCE
4(b)(i)	Any four: multiple bits / multiple wires · … fast · short distance · … single room · both directions at the same time · … no delay	B4	
4(b)(ii)	Any two: interference / crosstalk · skewed / out of order · data collisions · more errors	B2	
4(b)(iii)	Any other combination, e.g. serial full-duplex	B1	

Total: 7 marks

5 A computer system has a mouse.

An interrupt is sent to the CPU every time a button on the mouse is clicked.

(c) The mouse is connected using a universal serial bus (USB) connection.

(i) Explain how data is sent using the USB connection.

..... [2]

(ii) Give **two** benefits of using a USB connection for this purpose.

[2]

(iii) Give **one** drawback of using a USB connection for this purpose.

..... [1]

Swipe sideways to read the whole question

How to start USB is serial: that gives (i). For (ii) and (iii) use the USB benefits / drawbacks, linked to a mouse.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(c)(i) The data is sent one bit at a time down a single wire.

(c)(ii) The mouse is powered by the computer through the cable. The mouse is automatically detected and its driver is installed automatically.

(c)(iii) The wire may get in the way and limit the movement of the mouse.

PART	ANSWER / WORKING	MARKS	GUIDANCE
5(c)(i)	one bit at a time · single wire	B2	
5(c)(ii)	Any two: powered by the device · universal · backward compatible · less skewing / errors · different speeds · cannot be inserted incorrectly · automatically detected / driver installed	B2	
5(c)(iii)	slower than parallel // wire gets in the way / limits movement	B1	

Total: 5 marks

11 Common mistakes

✗ "Serial is faster"

✓ "Parallel is faster; serial is more reliable over distance"

✗ Naming only half a method: "half-duplex"

✓ "Serial half-duplex"

Questions about a method want both parts.

✗ "Half-duplex sends one way"

✓ "Both ways, but only one direction at a time"

One way only is simplex.

✗ "Serial is more secure"

✓ "Fewer errors, because bits are not skewed and there is less interference"

Security is not the point.

12 Practice

Practice: easy, medium, hard

1. Describe serial transmission.
2. Name the method: both directions at the same time.
3. What does USB stand for?
1. Give two drawbacks of parallel transmission.
2. A keyboard sends key presses to a computer; nothing is sent back. Which direction method is this?
3. Explain how data is sent using parallel half-duplex. [4]
1. Two computers 40 m apart exchange files, both sending and receiving at once. Identify the most appropriate method and justify it. [5]
2. Give one drawback of a USB connection for an external hard drive.

13 Can I do this?

0 / 4 ticked

- [ ] I can describe serial and parallel and compare them.
- [ ] I can describe simplex, half-duplex and full-duplex.
- [ ] I can choose a method for a scenario and justify both parts.
- [ ] I can explain how USB sends data and give its benefits and drawbacks.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

ANSWER Serial half-duplex

2.

ANSWER Parallel simplex

3.

ANSWER Bits are not skewed / less interference, so fewer errors

Try it yourself 2

1.

ANSWER Serial

2.

ANSWER

Two of: powers the mouse, automatically detected / driver installed, universal, cannot be inserted wrongly

Practice: easy, medium, hard

Easy 1.

ANSWER Data is sent one bit at a time down a single wire

Easy 2.

ANSWER Full-duplex

Easy 3.

ANSWER Universal serial bus

Medium 1.

ANSWER

Skewing (bits arrive out of order); crosstalk / interference; only short distances; more expensive

Medium 2.

ANSWER **Simplex**

Medium 3.

ANSWER

Multiple bits at the same time · down multiple wires · in both directions · but not at the same time

Hard 1.

ANSWER

Serial full-duplex. Serial: long distance (40 m), bits not skewed, less interference so fewer errors. Full-duplex: both computers need to send and receive at the same time, so no waiting.

PART	ANSWER / WORKING	MARKS	GUIDANCE
	serial	B1	
	full-duplex	B1	
	long distance / not skewed / fewer errors (max 2)	B2	
	both directions at the same time	B1	
			Total: 5 marks

Hard 2.

ANSWER **Maximum cable length is short / slower than some other connections**

NOTE 2.3

Error detection: parity, checksum, echo check, ARQ, check digit

1 In this note

SYLLABUS 2.2 METHODS OF ERROR DETECTION

- 2.2.1 Understand the **need to check for errors** after transmission and **how errors can occur**.
- 2.2.2 Describe **parity check** (odd / even, parity byte, parity block), **checksum** and **echo check**.
- 2.2.3 Describe how a **check digit** detects errors in **data entry**.
- 2.2.4 Describe how an **automatic repeat query (ARQ)** checks that data is received without error.

Before this: Serial, parallel and duplex. Next: Encryption.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

Odd and even

Count the 1s in a byte: 3 ones is odd, 4 ones is even.

Quick check: is 1011 0010 odd or even?

Four 1s: even.

Packets

Data is sent in packets, each with a header, payload and trailer.

Quick check: which section holds error checking data?

The trailer.

3 Why errors happen and why we check

Data can be correct when it leaves the sender but wrong when it arrives. During transmission, data can be **lost**, **gained** (extra bits added) or **changed** (a 1 becomes a 0). Causes:

Cause	What happens
Interference	electrical noise from other devices disturbs the signal and flips bits
Crosstalk	signals in wires next to each other interfere (worse in parallel cables)
Skewing	bits sent together in parallel arrive at different times and are read in the wrong order
Data collisions / lost packets	two signals meet, or a packet is dropped or times out on its way

A file with even one wrong bit can be useless (a program that crashes, a wrong bank amount). So the receiver checks the data, and asks for it again if it is wrong.

4 Parity check

Sender and receiver agree on **odd parity** or **even parity**. Each byte has 7 data bits and one **parity bit** (usually the leftmost bit). The parity bit is set so the **number of 1s in the byte** is odd (odd parity) or even (even parity).

GENERAL METHOD **Parity byte check**

1. Before sending, **count the 1s** in the 7 data bits.
2. Set the **parity bit** to 0 or 1 so the byte's total number of 1s matches the agreed parity (odd or even).
3. Send the byte.
4. After transmission, the receiver **counts the 1s** in each byte again.
5. If the count **does not match the agreed parity**, an **error is detected** and the data is sent again.

EXAMPLE **Add the parity bit to the data 110 1001 for even parity, then for odd parity.**

Count the 1s in the 7 data bits.

1101001 has four 1s: already even.

Even parity: parity bit 0 → 0110 1001 (four 1s).

Odd parity: parity bit 1 → 1110 1001 (five 1s).

ANSWER **even: 0, odd: 1**

✗ COMMON MISTAKE

A parity check **cannot find every error**. If **two bits** change (or two bits swap places, a **transposition**), the number of 1s is still odd / even, so the error is **not detected**. A parity byte check also cannot say **which** bit is wrong.

Parity block check

A **parity block** check sends several bytes together, each with a parity bit, plus an extra **parity byte** at the end. Each bit of the parity byte makes its **column** match the parity. The receiver checks every row and every column: the wrong bit is where the **bad row and bad column cross**, so it can be **located and corrected**.

Four bytes sent with even parity:

	Parity bit	bit 1	bit 2	bit 3	bit 4	bit 5	bit 6	bit 7	1s
Byte 1	0	1	0	1	1	0	0	1	4
Byte 2	0	0	1	1	0	1	0	1	4
Byte 3	0	1	1	0	0	0	1	1	4
Byte 4	1	0	0	0	1	1	1	0	4
Parity byte	1	0	0	0	0	0	0	1	2

After transmission one bit has changed:

	Parity bit	bit 1	bit 2	bit 3	bit 4	bit 5	bit 6	bit 7	1s
Byte 1	0	1	0	1	1	0	0	1	4
Byte 2	0	0	1	1	0	1	0	1	4
Byte 3	0	1	1	0	0	1	1	1	5
Byte 4	1	0	0	0	1	1	1	0	4
Parity byte	1	0	0	0	0	0	0	1	2

Byte 3 now has 5 ones (odd), and column bit 5 has an odd number of 1s. The error is the bit where byte 3 meets bit 5, so the receiver can flip it back.

TRY IT YOURSELF

1. Give the even parity bit for the data 011 0001.
2. Give the odd parity bit for the data 011 0001.
3. Two bits in a byte are flipped. Will a parity byte check detect it? Why?

5 Checksum

GENERAL METHOD **Checksum**

1. Before sending, a **checksum value is calculated** from the data using an **algorithm** (e.g. adding up the byte values).
2. The checksum is **sent with the data** (in the packet trailer).
3. The receiver **recalculates** the checksum from the data it received, using the **same algorithm**.
4. The two checksums are **compared**: if they are **different, an error is detected** and the data is requested again; if they match, no error.

EXAMPLE **Bytes with the values 200, 150, 90 and 37 are sent. The checksum algorithm adds the values and keeps the remainder after dividing by 256. Find the checksum.**

Add, then find the remainder after 256.

$200 + 150 + 90 + 37 = 477$

$477 - 256 = 221$

ANSWER **checksum = 221**

6 Echo check

GENERAL METHOD **Echo check**

1. The data is sent to the receiver.
2. The receiver sends a **copy of the data it received back** to the sender.
3. The sender **compares the original data with the copy**.
4. If they **do not match**, an error has occurred and the data is sent again.

✗ COMMON MISTAKE

Drawback: if the copy does not match, it is not known whether the error happened on the way there or on the way back. It also doubles the amount of data sent.

7 Automatic repeat query (ARQ)

An **ARQ** (automatic repeat query / request) uses **acknowledgements** and a **timeout** so that each packet is received without error. The receiver checks each packet with an error detection method (e.g. a checksum).

GENERAL METHOD **ARQ with a positive acknowledgement**

1. The sender sends a packet and **starts a timer**.
2. The receiver **checks the packet for errors**.
3. If it is error free, the receiver sends a **positive acknowledgement** back; the sender then **sends the next packet**.
4. If the sender does **not receive an acknowledgement before the timer ends**, a **timeout** occurs ...
5. ... and the packet is **resent**, until an acknowledgement arrives (or a set number of attempts is reached).

With a **negative acknowledgement** the receiver instead sends a message back when a packet **has an error**, asking for it to be resent.

8 Check digit

A **check digit** finds errors in **data entry** (typing or scanning a number), not in transmission. It is an extra digit added to the end of a code such as a barcode or an ISBN (book number).

GENERAL METHOD **Check digit**

1. The check digit is **calculated from the other digits** using an **algorithm** and **added to the end** of the code.
2. When the code is **entered or scanned**, the check digit is **recalculated** using the **same algorithm**.
3. If the calculated digit **does not match** the check digit in the code, an **error** has occurred (e.g. a digit typed wrongly, or two digits swapped).

EXAMPLE **Find the check digit for the ISBN 978030640615. Multiply the digits by 1, 3, 1, 3 …, add them, then the check digit is the number that makes the total up to the next multiple of 10.**

Weights 1 and 3 alternate.

$9\times1 + 7\times3 + 8\times1 + 0\times3 + 3\times1 + 0\times3 + 6\times1 + 4\times3 + 0\times1 + 6\times3 + 1\times1 + 5\times3$

$= 9 + 21 + 8 + 0 + 3 + 0 + 6 + 12 + 0 + 18 + 1 + 15 = 93$

next multiple of 10 is 100: $100 - 93 = 7$

ANSWER **check digit 7: ISBN 9780306406157**

TRY IT YOURSELF

1. Which error detection method is used for data entry rather than transmission?
2. Which method sends a copy of the data back to the sender?
3. In ARQ, what happens if no acknowledgement arrives before the timer ends?

9 Summary

- Errors: data lost, gained or changed, by interference, crosstalk, skewing, collisions.
- Parity: parity bit makes the number of 1s odd / even; receiver recounts. Misses even numbers of flips and transpositions.
- Parity block: parity bit per byte + parity byte per column; the bad row and column locate (and correct) the bit.
- Checksum: value calculated by an algorithm, sent with the data, recalculated and compared.
- Echo check: receiver sends a copy back; sender compares.
- ARQ: acknowledgement + timer; no acknowledgement → timeout → resend.
- Check digit: data ENTRY; calculated from the digits, recalculated on entry, compared.

IF YOU SEE …

"an odd or even process"	→ parity check
"a value calculated … before and after transmission"	→ checksum
"a copy is sent back"	→ echo check
"acknowledgement and timeout"	→ ARQ
"a value appended … checked on data entry"	→ check digit

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

10 Ways they test it

TYPE 1 How errors occur

> *"Describe how an error can occur in the data during transmission" [2-3]*

Spot it "how errors occur".

1. A cause (interference / crosstalk / skewing) AND its effect (data lost, gained or changed).

TYPE 2 Name the method

> *a table of statements to name [5]; "tick the method that does not use a calculated value" [1]*

Spot it "identify".

1. Use the trigger phrases in the summary. The echo check is the one with no calculated value.

TYPE 3 Describe a method

> *"Explain how the odd parity check detects errors" [4]; "describe the checksum process" [5]; "explain how ARQ operates using positive acknowledgement" [5]*

Spot it "explain how ... detects".

1. Write the method steps in order: before sending, during, after, compare, what happens if wrong.

TYPE 4 Parity bits

> *"Give the parity bit for each byte" [3]; "identify the byte with an error"*

Spot it a byte table.

1. Count the 1s in the data bits; for odd parity add a bit so the total is odd.

TYPE 5 **Limits of parity**

> *"Explain why the error may not be detected" [2]*

Spot it "not detected".

1. Two bits flipped / swapped (transposition) → the number of 1s is still odd / even → it still meets the parity.

11 What the examiner looks for

"Explain how the odd parity check detects errors" [4]

Marking points (one mark each, up to the marks shown)

- The number of 1s / 0s is counted
- A parity bit is added to each byte / 7 bits before transmission …
- … to make the number of 1s in each byte odd
- After transmission, if the number is odd no error is detected
- After transmission, if the number is even an error is detected

KEYWORDS **parity bit** **count the 1s** **odd** **after transmission**

"Describe the process of the checksum error detection method" [5]

Marking points (one mark each, up to the marks shown)

- The checksum is calculated from the data …
- … using an algorithm
- The checksum value is transmitted with the data
- The checksum is recalculated after transmission / by the receiver
- If the values do not match an error is detected // if they match no error
- … the data is requested to be resent if there is an error

KEYWORDS **algorithm** **transmitted with the data** **recalculated** **compared**

Wording trap · Check digit vs transmission

THE QUESTION **2210/12/M/J/26 Q4** ↗ Paper 1 · Computer systems **2 marks**

An odd parity byte check is used. There is an error that is not detected. Identify two other error detection methods that could be used.

✓ CREDITED

- Parity block check
- Checksum
- Echo check
- ARQ

✗ NOT CREDITED

- check digit

WHY

A check digit is for data ENTRY. This question is about transmission, so it is not accepted.

From: 2210/12/M/J/26 Q4(b)(ii) mark scheme

12 Past-paper questions, solved

2210/12/M/J/24 Q6 ↗ Paper 1 · Computer systems **5 marks** ⤢ Full size

6 The table contains statements about error detection methods.

Complete the table by giving the correct error detection method for each statement.

error detection method	statement
.....	An odd or even process can be used.
.....	A value is calculated from the data, using an algorithm. This happens before and after the data is transmitted.
.....	A copy of the data is sent back to the sender by the receiver.
.....	Acknowledgement and timeout are used.
.....	A value is appended to data that has been calculated using the data. This value is checked on data entry.

Swipe sideways to read the whole question

How to start Match each statement to its trigger phrase: odd or even, value calculated before and after, copy sent back, acknowledgement and timeout, value appended and checked on data entry.

▾ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

parity check · checksum · echo check · automatic repeat query (ARQ) · check digit

PART	ANSWER / WORKING	MARKS	GUIDANCE
6	parity (check / bit / byte / block) · checksum · echo check · ARQ · check digit, one mark each	B5	

Total: 5 marks

0478/11/O/N/23 Q4 ↗ Paper 1 · Computer systems **5 marks** ⤢ Full size

4 Data is transmitted between a computer and a printer.

(b) An odd parity check is used to detect errors in the data transmission.

Explain how the odd parity check detects errors.

..... [4]

(c) Another error detection method sends the data from the computer to the printer, then a copy of the data received is sent back from the printer to the computer. The two sets of data are compared to see if they match.

State the name of this type of error detection method.

..... [1]

Swipe sideways to read the whole question

How to start (b) is the five steps of the parity method; four of them earn the marks. (c) "a copy … sent back" = echo check.

▼ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

(b) Before transmission the number of 1s in each 7 bits is counted, and a parity bit is added to each byte to make the number of 1s odd. After transmission the receiver counts the 1s in each byte. If the number is odd, no error is detected; if it is even, an error is detected.

(c) Echo check.

PART	ANSWER / WORKING	MARKS	GUIDANCE
4(b)	Any four: number of 1s counted · parity bit added to each byte before transmission · … to make the number of 1s odd · after transmission odd = no error · even = error detected	B4	
4(c)	Echo (check)	B1	

Total: 5 marks

2210/13/O/N/23 Q5 ↗ Paper 1 · Computer systems **7 marks** ⤢ Full size

5 Errors can occur when data is transmitted.

(a) Give **one** reason an error may occur when data is transmitted.

..... [1]

(b) Some error detection methods use a calculated value to check for errors.

Tick (✓) **one** box to show which error detection method does **not** use a calculated value to check for errors.

A Check digit ☐

B Checksum ☐

C Echo check ☐

D Parity check ☐

[1]

(c) An automatic repeat request (ARQ) can be used to make sure that data is received free of errors. It can use a positive or negative acknowledgement method to do this.

Explain how an ARQ operates using a positive acknowledgement method.

..... [5]

Swipe sideways to read the whole question

How to start (c) is the ARQ method: timer, check, acknowledgement, next packet, timeout, resend.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a) Interference.

(b) C (echo check).

(c) When the sender transmits a packet it starts a timer. The receiver checks the packet for errors. If it is error free, the receiver sends an acknowledgement back to the sender, and the next packet is sent. If the sender does not receive an acknowledgement before the timer ends, a timeout occurs and the packet is resent, until an acknowledgement is received.

PART	ANSWER / WORKING	MARKS	GUIDANCE
5(a)	interference // crosstalk	B1	
5(b)	C	B1	
5(c)	Any five: timer started on sending · receiver checks for errors · acknowledgement sent if error free · next packet sent · no acknowledgement before timer ends … · timeout · packet resent · until acknowledged / max attempts	B5	

Total: 7 marks

2210/12/O/N/24 Q5 ↗ Paper 1 · Computer systems — **4 marks** — ⤢ Full size

5 A barcode scanning system uses a check digit to check for errors in data on input.

(a) Explain how the barcode scanning system operates to check for errors.

..... [4]

Swipe sideways to read the whole question

How to start Follow the method: calculated, added, recalculated on scanning with the same algorithm, compared.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

A check digit is calculated from the barcode digits using an algorithm (e.g. modulo 11) and added to the end of the barcode. When the barcode is scanned, the check digit is recalculated using the same algorithm. If the recalculated digit does not match the check digit, an error has occurred in scanning; if they match, there is no error.

PART	ANSWER / WORKING	MARKS	GUIDANCE
5(a)	Any four: calculated from the barcode data · using an algorithm (e.g. modulo 11) · added to the barcode · recalculated when scanned · same algorithm · do not match = error / match = no error	B4	

Total: 4 marks

13 Common mistakes

✗ "The parity bit makes the byte odd"

✓ "... makes the NUMBER OF 1s in the byte odd"

✗ "A checksum is the number of 1s"

✓ "A value calculated from the data using an algorithm"

Counting 1s is parity.

✗ Check digit for a transmission question

✓ Parity, checksum, echo check or ARQ

Check digit = data entry only.

✗ "ARQ checks the data" and nothing else

✓ Timer · acknowledgement · timeout · resend

The marks are for the process.

14 Practice

Practice: easy, medium, hard

1. Give the even parity bit for 101 1000.
2. Name the error detection method that uses acknowledgement and timeout.
3. Give two ways data can be affected by an error in transmission.
1. Describe how an echo check works. [3]
2. Find the checksum for byte values 120, 64 and 100 (add, remainder after 256).
3. Give one limitation of a parity byte check.
1. Explain how a parity block check finds AND corrects a single-bit error. [4]
2. A barcode 978030640615 is typed as 978030460615 (two digits swapped). Explain how the check digit 7 shows the error.

15 Can I do this?

0 / 5 ticked

- [ ] I can say how errors occur in transmission.
- [ ] I can add parity bits and explain parity byte and parity block checks.
- [ ] I can describe checksum and echo check.
- [ ] I can describe ARQ with positive acknowledgement and timeout.
- [ ] I can describe how a check digit works and calculate one.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

ANSWER 1 (three 1s, so add a 1 to make four)

2.

ANSWER 0 (three 1s is already odd)

3.

ANSWER No: the number of 1s is still odd / even, so it still matches the parity

Try it yourself 2

1.

ANSWER Check digit

2.

ANSWER Echo check

3.

ANSWER A timeout occurs and the packet is resent

Practice: easy, medium, hard

Easy 1.

ANSWER 1 (three 1s, add one to make four)

Easy 2.

ANSWER ARQ (automatic repeat query)

Easy 3.

ANSWER Two of: lost, gained, changed

Medium 1.

ANSWER

Receiver sends a copy of the data back; sender compares it with the original; if they don't match an error is detected

Medium 2.

1. 120 + 64 + 100 = 284
2. 284 − 256 = 28

ANSWER **28**

Medium 3.

ANSWER

It cannot detect two bits changing / a transposition; it cannot locate which bit is wrong

Hard 1.

ANSWER

Each byte has a parity bit; a parity byte is added for each column; the receiver checks every row and column; the bad row and bad column cross at the wrong bit, which is flipped

PART	ANSWER / WORKING	MARKS	GUIDANCE
	parity bit per byte	B1	
	parity byte / column parity	B1	
	row and column checked	B1	
	bit where they cross is the error → corrected	B1	
			Total: 4 marks

Hard 2.

ANSWER

The check digit is recalculated from the typed digits with the same algorithm; it no longer equals 7, so an error is detected

NOTE 2.4

Encryption: symmetric and asymmetric

1 In this note

SYLLABUS 2.3 ENCRYPTION

- 2.3.1 Understand the **need for and purpose of encryption** when transmitting data.
- 2.3.2 Understand how data is encrypted using **symmetric** and **asymmetric** encryption.

Before this: Error detection. Next chapter: Hardware.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

Packets travel through many devices

A packet passes through many routers on the internet. Any of them, or a hacker listening on the network, could read it.

Quick check: can a packet be intercepted on its way?

Yes.

3 Why data is encrypted

Data sent across a network can be **intercepted**: a third party captures it on the way (e.g. with packet sniffing software). Encryption does not stop the interception, but it makes the data **meaningless** to anyone who does not have the key.

Encryption uses an **algorithm** and a **key** to scramble the **plain text** (the readable data) into **cipher text** (scrambled, meaningless data). **Decryption** uses a key to turn the cipher text back into plain text.

Plain text: the original, readable data. **Cipher text**: the encrypted, scrambled data. **Key**: a value used by the encryption algorithm to encrypt or decrypt the data.

EXAMPLE **A very simple encryption algorithm shifts each letter along the alphabet. The key is 3. Encrypt SEND HELP.**

Move each letter 3 places on: S → V, E → H ...

S E N D → V H Q G

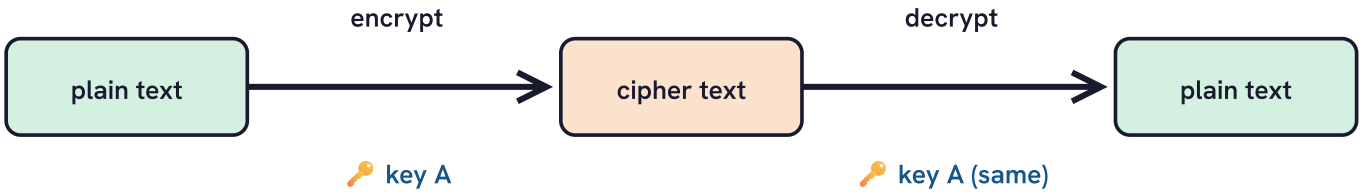
H E L P → K H O S

ANSWER **VHQG KHOS**

Anyone who intercepts VHQG KHOS sees nonsense. The receiver, who knows the key is 3, shifts each letter back 3 places to read it. Real encryption algorithms use keys that are hundreds of bits long, so they cannot be guessed.

4 Symmetric encryption

In **symmetric encryption** the **same key** is used to **encrypt and decrypt** the data.



the key must be shared with the receiver first

Symmetric: one shared key.

GENERAL METHOD **How symmetric encryption works**

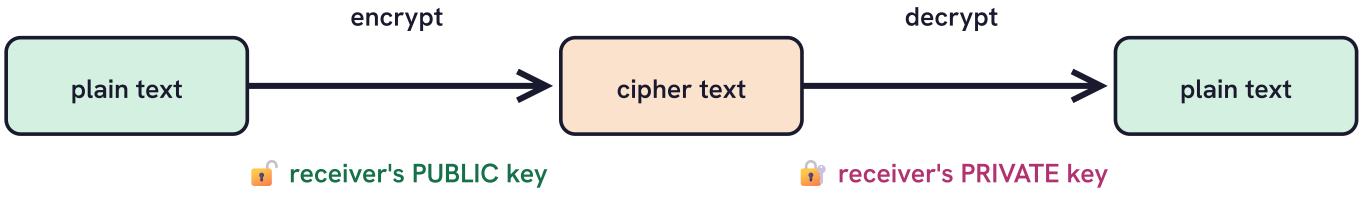
1. A **key** is generated (using an algorithm).
2. The sender uses the key and an **encryption algorithm** to turn the **plain text into cipher text**.
3. The cipher text is transmitted.
4. The **key is also sent** to the receiver (separately).
5. The receiver uses the **same key** to decrypt the cipher text back into plain text.

✗ COMMON MISTAKE

The weakness: the key itself has to be sent to the receiver. If the key is intercepted, anyone can decrypt the data.

5 Asymmetric encryption

Asymmetric encryption uses **two different keys** that are a matched pair: a **public key** and a **private key**. Data encrypted with the public key can **only be decrypted with the matching private key**.



anyone can have the public key; only the receiver has the private key

Asymmetric: the receiver's public key encrypts, only the receiver's private key decrypts.

GENERAL METHOD

How asymmetric encryption works

1. The receiver has a key pair. The **public key** is given to **anyone** who asks; the **private key** is kept **secret** and never sent.
2. The sender gets the receiver's public key and uses it to **encrypt** the plain text into cipher text.
3. The cipher text is transmitted. The public key **cannot decrypt** it.
4. The receiver uses their **private key** to **decrypt** the cipher text.

	Symmetric	Asymmetric
Keys	**one key**, shared	**two keys**: public and private
Encrypt with	the shared key	the **public key**
Decrypt with	the same shared key	the **private key**
Who knows the keys	sender and receiver both know the key	anyone can know the public key; **only the receiver knows the private key**
Security	the key must be sent, so it could be intercepted	**more secure**: the private key is never sent (**no key exchange**)
Speed	faster	slower (more complex)

TRY IT YOURSELF

1. What is the encrypted, scrambled data called?
2. In asymmetric encryption, which key decrypts the data?
3. Give the purpose of encryption.

6 Summary

- Purpose: if data is intercepted, it is meaningless / cannot be understood. Encryption does not stop interception.
- Encryption: algorithm + key turn plain text into cipher text; decryption turns it back.
- Symmetric: one shared key encrypts and decrypts; the key must be sent, so it could be intercepted.
- Asymmetric: public key encrypts, private key decrypts; the private key is never sent, so it is more secure.

IF YOU SEE …

"purpose of encryption"	→ if intercepted · cannot be understood / meaningless
"how symmetric works"	→ same key encrypts and decrypts · plain → cipher · algorithm · key sent to receiver
"differences symmetric / asymmetric"	→ one shared key vs public + private · public encrypts, private decrypts · who knows them

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

7 Ways they test it

TYPE 1 **Purpose**

> *"State the purpose of encrypting data" [1]*

Spot it "purpose".

1. "If it is intercepted, it cannot be understood." Not "to stop hackers" (it does not stop interception).

TYPE 2 **Describe a type**

> *"Explain how data is encrypted using symmetric encryption" [4]*

Spot it "symmetric" or "asymmetric".

1. Start with the key fact (same key / public + private), then the method steps.

TYPE 3 **Differences**

> *"Describe the differences between symmetric and asymmetric encryption" [4]*

Spot it "differences".

1. Points from both columns of the comparison table.

TYPE 4 **Cloze**

> *"Complete the paragraph about asymmetric encryption" [4-8]*

Spot it a word list.

1. Words to expect: algorithm, plain text, cipher text, meaningless, public, private.

TYPE 5 **Why asymmetric**

> *"Give one reason a person would use asymmetric instead of symmetric" [1]*

Spot it "instead of".

1. More secure // no need to exchange (send) the key.

8 What the examiner looks for

"Describe the differences between symmetric and asymmetric encryption" [4]

Marking points (one mark each, up to the marks shown)

- Symmetric has a shared key ...
- ... to encrypt and decrypt
- Both the sender and receiver know the key
- Asymmetric has different keys // a public key and a private key
- ... the public key encrypts the data and the private key decrypts it
- ... anyone can know the public key but only the intended receiver knows the private key

KEYWORDS **same key** **public key** **private key** **encrypt** **decrypt**

"Explain how data is encrypted using symmetric encryption" [4]

Marking points (one mark each, up to the marks shown)

- The data is encrypted and decrypted using the same key (1 mark), then any three:
- Plain text is encrypted into cipher text // cipher text is decrypted into plain text
- Data is encrypted using an algorithm ...
- ... that uses a key
- The key can be generated using an algorithm
- The key is transmitted to the receiver

KEYWORDS **same key** **plain text** **cipher text** **algorithm**

Wording trap · Purpose of encryption

THE QUESTION **0478/12/F/M/24 Q7** ↗ Paper 1 · Computer systems **1 mark**

State the purpose of encrypting data.

✓ CREDITED

- If the data is intercepted, it cannot be understood
- to make the data meaningless (to a third party)

✗ NOT CREDITED

- to stop the data being intercepted
- to stop hackers
- to keep it safe (alone)

WHY

Encryption does not prevent interception; it makes intercepted data useless.

From: 0478/12/F/M/24 Q7(a)(i) mark scheme

9 Past-paper questions, solved

2210/12/M/J/24 Q2 ↗ Paper 1 · Computer systems **5 marks** ⤢ Full size

2 Data can be transmitted from one device to another.

(c) Data is often encrypted when it is transmitted from one device to another.

(i) Explain how data is encrypted using symmetric encryption.

..... [4]

(ii) Give the purpose of encryption.

..... [1]

Swipe sideways to read the whole question

How to start (i) One mark is reserved for "same key": say it first. Then three steps of the method.

▾ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(c)(i) The data is encrypted and decrypted using the same key. The plain text is encrypted into cipher text using an encryption algorithm that uses the key. The key is generated using an algorithm and is transmitted to the receiver, who uses it to decrypt the cipher text back into plain text.

(c)(ii) To make the data meaningless if it is intercepted.

PART	ANSWER / WORKING	MARKS	GUIDANCE
2(c)(i)	same key to encrypt and decrypt (1) + any three: plain text → cipher text · algorithm … · … that uses a key · key generated by an algorithm · key transmitted to the receiver	B4	
2(c)(ii)	to help keep the data secure // to make the data meaningless	B1	

Total: 5 marks

0478/12/F/M/24 Q7 ↗ Paper 1 · Computer systems — **5 marks** — ⤢ Full size

7 Data is transmitted using the internet.

(a) The data is encrypted before transmission.

(i) State the purpose of encrypting data.

..... [1]

(ii) Describe the differences between symmetric and asymmetric encryption.

..... [4]

Swipe sideways to read the whole question

How to start (ii) needs points about BOTH types. Two about symmetric, two about asymmetric is a safe plan.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a)(i) If the data is intercepted, it cannot be understood.

(a)(ii) Symmetric encryption uses one shared key to both encrypt and decrypt, and both the sender and receiver know it. Asymmetric encryption uses two different keys, a public key and a private key: the public key encrypts the data and the private key decrypts it. Anyone can know the public key, but only the receiver knows the private key.

PART	ANSWER / WORKING	MARKS	GUIDANCE
7(a)(i)	if intercepted, it cannot be understood	B1	
7(a)(ii)	Four from: shared key … · … to encrypt and decrypt · both know the key · public and private key · public encrypts, private decrypts · anyone can know the public key, only the intended receiver the private key	B4	

Total: 5 marks

6 Data can be encrypted using asymmetric encryption.

(a) Complete the paragraph about asymmetric encryption.

Use the terms from the list.

Some of the terms in the list will **not** be used. You may use a term more than once.

algorithm binary cipher text compression error
hardware hexadecimal meaningless plain text private
public readable transmission unreadable

Data is encrypted using an encryption key. This is a type of .....

that scrambles the ..... and turns it into

..... . This makes the data ..... .

A ..... key is used to encrypt the data. This key cannot be used to decrypt the data. A ..... key is used to decrypt the data. Any device is able to request the ..... key, but only your device knows the ..... key.

[8]

(b) Data can also be encrypted using symmetric encryption.

Give **one** reason why a person would use asymmetric encryption instead of symmetric encryption.

.....

..... [1]

Swipe sideways to read the whole question

How to start Read the whole paragraph first. Two gaps must be opposite keys (public / private). The last sentence tells you which key anyone can request.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a) algorithm · plain text · cipher text · meaningless · public · private · public · private

(Data is encrypted using an encryption key. This is a type of **algorithm** that scrambles the **plain text** and turns it into **cipher text**. This makes the data **meaningless**. A **public** key is used to encrypt the data ... A **private** key is used to decrypt the data. Any device is able to request the **public** key, but only your device knows the **private** key.)

(b) It is more secure, because the private key is never sent.

PART	ANSWER / WORKING	MARKS	GUIDANCE
6(a)	algorithm · plain text · cipher text · meaningless · public/private · private/public (opposite) · public · private	B8	
6(b)	more secure // no need to worry about key exchange	B1	

Total: 9 marks

10 Common mistakes

✗ "Encryption stops data being intercepted" ✓ "Intercepted data cannot be understood"

✗ "Asymmetric: the private key encrypts" ✓ "The public key encrypts, the private key decrypts"

For sending data to someone.

✗ "Encryption is a key" ✓ "An algorithm that uses a key"

✗ "Coded" instead of "cipher text" ✓ "Cipher text"

Use the exact term.

11 Practice

Practice: easy, medium, hard

1 What is unencrypted, readable data called?

2 How many keys does symmetric encryption use?

3 Encrypt CAT with the shift-3 algorithm.

1 Explain why symmetric encryption is less secure than asymmetric. [2]

2 Describe how asymmetric encryption keeps an email secret. [3]

3 Decrypt KHOOR (shift-3 algorithm).

1 A bank sends account details to a customer. Explain why encryption is needed and which type is most suitable. [4]

12 Can I do this?

0 / 3 ticked

- [ ] I can state the purpose of encryption correctly.
- [ ] I can explain symmetric encryption.
- [ ] I can explain asymmetric encryption and compare it with symmetric.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

ANSWER Cipher text

2.

ANSWER The private key

3.

ANSWER If the data is intercepted it cannot be understood / is meaningless

Practice: easy, medium, hard

Easy 1.

ANSWER Plain text

Easy 2.

ANSWER One (the same key encrypts and decrypts)

Easy 3.

ANSWER FDW

Medium 1.

ANSWER

The key has to be sent to the receiver, so it could be intercepted; the private key in asymmetric is never sent

Medium 2.

ANSWER

Sender encrypts with the receiver's public key; cipher text sent; only the receiver's private key can decrypt it

Medium 3.

ANSWER HELLO

Hard 1.

ANSWER

The data could be intercepted; encryption makes it meaningless to a third party; asymmetric is more suitable: the public key encrypts, only the private key decrypts and it is never sent, so no key exchange can be intercepted

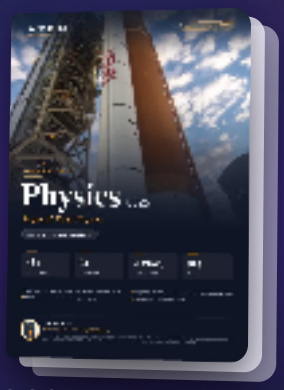
PART	ANSWER / WORKING	MARKS	GUIDANCE
	data could be intercepted	B1	
	meaningless / cannot be understood	B1	
	asymmetric	B1	
	private key never sent // no key exchange	B1	

Total: 4 marks

3

Hardware

NEW JUST LAUNCHED



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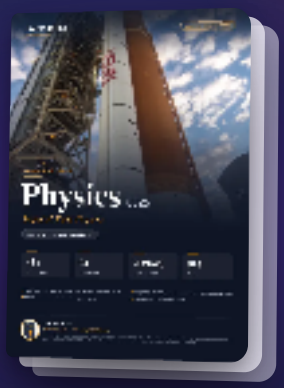

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NOTE 3.1

The CPU and Von Neumann architecture

1 In this note

SYLLABUS 3.1 COMPUTER ARCHITECTURE

- 3.1.1 Understand the **role of the CPU** and what is meant by a **microprocessor**.
- 3.1.2a Understand the purpose of the components in a CPU with a **Von Neumann architecture**: **ALU**, **CU**, the registers **PC**, **MAR**, **MDR**, **CIR**, **ACC**, and the **address**, **data** and **control** buses.

Next: The fetch-decode-execute cycle.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

Programs are instructions

A program is a list of instructions. Before it runs it is copied from storage into RAM.

Quick check: where is a program while it is running?

In RAM (main memory).

Everything is binary

Instructions, data and memory addresses are all stored as binary numbers.

Quick check: what is an address?

A number that identifies one location in memory.

3 The CPU and the microprocessor

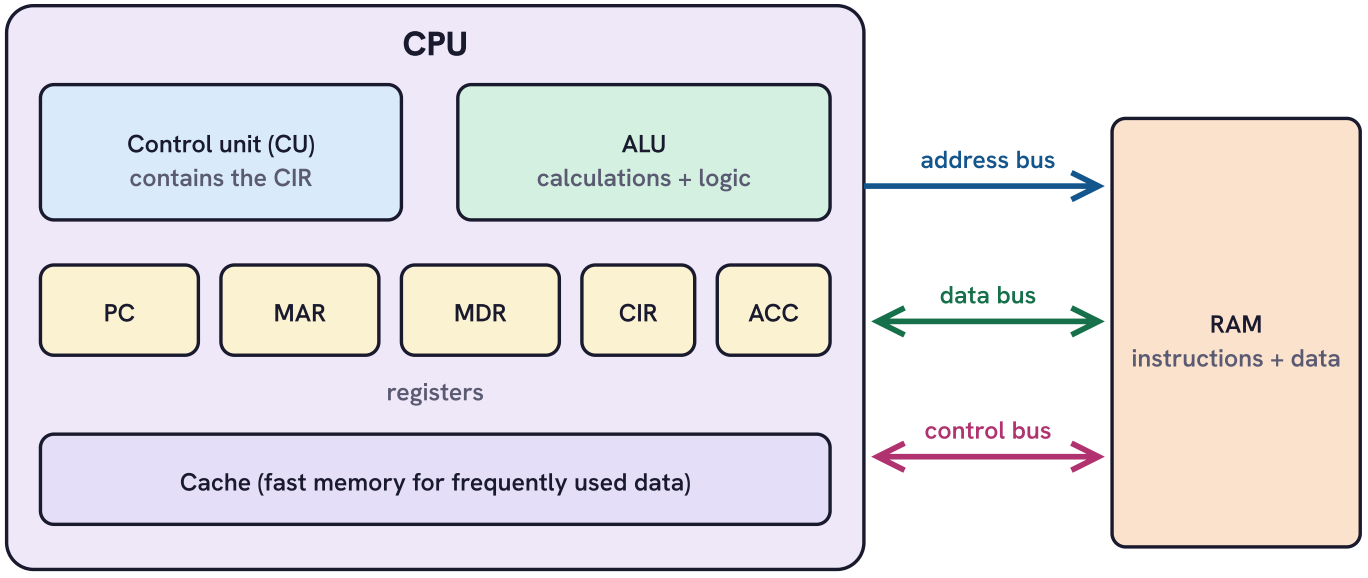
The **central processing unit (CPU)** is the part of the computer that **processes instructions and data**. It takes the data that is input, processes it by running the program's instructions (the **fetch-decode-execute cycle**), so that the result can be output.

A **microprocessor** is a type of **integrated circuit on a single chip**. In most computers the CPU is a microprocessor; simpler devices (a washing machine, a microwave) have a microprocessor that does one job.

> **Role of the CPU**: to process instructions and data (by running the fetch-decode-execute cycle).

4 Von Neumann architecture

Almost every computer uses the **Von Neumann architecture**. Its key idea is that the **program instructions and the data are stored together in the same memory** (RAM), and the CPU fetches them one at a time to process them.



The address bus goes one way (CPU → memory); the data and control buses go both ways. Instructions and data are stored together in the same memory.

The parts of a Von Neumann CPU and how it connects to RAM.

The two units

Unit	Purpose
Control unit (CU)	**sends control signals** to manage the **flow of data** through the CPU and to **manage the fetch-decode-execute cycle**; it **decodes** the instructions (using the instruction set)
Arithmetic logic unit (ALU)	**carries out the calculations** (e.g. add, subtract) and the **logical operations** (e.g. AND, OR, comparing two values); it **executes** the instructions and stores interim results in the accumulator

The registers

A **register** is a tiny, very fast storage location **inside the CPU**. Each register **temporarily stores** one item: an address, an instruction or some data, so it can be accessed immediately during the cycle.

Register	What it stores
Program counter (PC)	the **address of the next instruction** to be fetched
Memory address register (MAR)	the **address** in memory of the instruction or data that is **about to be fetched** (or the address data is to be written to)
Memory data register (MDR)	the **data or instruction** that has just been **fetched from memory** (or is waiting to be written to memory)
Current instruction register (CIR)	the **instruction currently being decoded and executed**; it is built into the CU
Accumulator (ACC)	the **result of a calculation** by the ALU (interim results)

> A memory hook for which registers hold **addresses**: **PC** and **MAR** ("A" for address). **MDR** holds **data** ("D" for data). **CIR** holds the **instruction**; **ACC** holds **answers**.

The buses

A **bus** is a set of parallel wires that **transmits** data, addresses or signals between the parts of the computer.

Bus	What it carries	Direction
Address bus	**addresses** (e.g. from the MAR to RAM)	one way: CPU → memory
Data bus	**data and instructions** (e.g. from RAM to the MDR)	both ways
Control bus	**control signals** from the control unit (e.g. read, write, clock)	both ways

TRY IT YOURSELF

1. Which register holds the address of the next instruction?
2. Which unit carries out calculations and logical operations?
3. Which bus carries addresses?
4. State the purpose of a register.

5 Summary

- CPU: processes instructions and data (runs the FDE cycle). Microprocessor: integrated circuit on a single chip.
- Von Neumann: instructions and data stored together in the same memory.
- CU: sends control signals, manages the FDE cycle, decodes. ALU: calculations and logical operations.
- PC: address of next instruction. MAR: address about to be fetched. MDR: data / instruction fetched. CIR: current instruction. ACC: results.
- Address bus (one way): addresses. Data bus: data and instructions. Control bus: signals.

IF YOU SEE …

"describe the role of the CPU"	→ processes instructions / data · runs the FDE cycle
"purpose of the ALU"	→ calculations · logical operations · executes instructions · results in the accumulator
"purpose of a register"	→ temporarily stores data / instruction / address · fast access during the FDE cycle

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

6 Ways they test it

TYPE 1 **Role / purpose**

> *"Describe the role of the CPU" [2]; "describe the purpose of the ALU" [3]; "state the purpose of a register" [1]*

Spot it "role", "purpose".

1. Use the definitions in the tables: one mark per separate point.

TYPE 2 **Name a component**

> *"State the name of the component that sends signals ..." [1]; "circle three components built into the CPU" [3]*

Spot it "name", "identify", "circle".

1. Built into the CPU: CU, ALU, registers, cache, clock. NOT RAM, ROM, HDD, motherboard.

TYPE 3 **Register table**

> *a table of register names and descriptions to complete [6]*

Spot it a table.

1. Watch for addresses (PC, MAR) vs data (MDR) vs instruction (CIR) vs results (ACC).

TYPE 4 **Buses**

> *"circle three buses" [3]; "describe the address bus" [2]*

Spot it "bus".

1. Address, data, control: say what each carries.

7 What the examiner looks for

"Describe the purpose of the ALU" [3]

Marking points (one mark each, up to the marks shown)

- To execute instructions
- To perform calculations // e.g. addition, subtraction
- To perform logical operations // e.g. AND, OR, comparisons
- To store interim results of calculations
- Stores / reads / writes data to / from the accumulator

KEYWORDS **calculations** **logical operations** **accumulator**

Wording trap · Components inside the CPU

THE QUESTION **2210/13/O/N/23 Q3** ↗ Paper 1 · Computer systems **3 marks**

Circle three components that are built into the CPU: accumulator (ACC) · control unit (CU) · graphics card · hard disk drive (HDD) · motherboard · program counter (PC) · random access memory (RAM) · read only memory (ROM)

✓ CREDITED

- Accumulator (ACC)
- Control unit (CU)
- Program counter (PC)

✗ NOT CREDITED

- RAM or ROM (primary storage, but outside the CPU)
- motherboard (the CPU sits on it)
- HDD, graphics card

WHY

RAM is directly accessed by the CPU but it is not built into it.

From: 2210/13/O/N/23 Q3(a) mark scheme

8 Past-paper questions, solved

0478/13/M/J/24 Q8 ↗ Paper 1 · Computer systems **9 marks** ⤢ Full size

8 A student has a computer that has a central processing unit (CPU).

(a) Describe the role of the CPU in the computer.

..... [2]

(b) The CPU contains registers.

(i) State the purpose of a register.

..... [1]

(ii) Give **three** registers that are built into the CPU.

[3]

(c) One component in the CPU is the arithmetic logic unit (ALU).

Describe the purpose of the ALU.

..... [3]

Swipe sideways to read the whole question

How to start Each part is a definition from the notes. Count the marks: (c) wants three separate points.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a) To process instructions and data, by running the fetch-decode-execute cycle.

(b)(i) To temporarily store data, an instruction or an address. (ii) Program counter, memory address register, accumulator.

(c) To execute instructions: it performs the calculations, such as addition, and the logical operations, such as comparing values, and stores the interim results in the accumulator.

PART	ANSWER / WORKING	MARKS	GUIDANCE
8(a)	process instructions / data · run the FDE cycle	B2	
8(b)(i)	temporarily store data / instruction / address // immediate access during FDE	B1	
8(b)(ii)	Any three: MAR · MDR · ACC · PC · CIR	B3	
8(c)	Any three: execute instructions · calculations · logical operations · interim results · accumulator	B3	

Total: 9 marks

6 The table contains names and descriptions of components in a central processing unit (CPU).

Complete the table by giving the missing component names and descriptions.

Component name	Description
.....	sends signals to manage the flow of data through the CPU
program counter	....
.....	stores the address of the data that is about to be fetched from random access memory (RAM) into the CPU
.....	transmits data between the RAM and the CPU
accumulator	....
.....	stores an instruction when it is being decoded

[6]

Swipe sideways to read the whole question

How to start Four rows need a name, two need a description. "Address … about to be fetched" is the MAR; "transmits data" is a bus.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

Control unit (CU) · program counter: stores the address of the next instruction to be fetched · memory address register (MAR) · data bus · accumulator: stores the interim result of a calculation · current instruction register (CIR)

PART	ANSWER / WORKING	MARKS	GUIDANCE
6	CU · MAR · data bus · CIR; PC: address of the next instruction; ACC: interim result of a calculation	B6	

Total: 6 marks

9 Common mistakes

✗ "The MAR stores instructions" ✓ "The MAR stores addresses"

✗ "RAM is part of the CPU" ✓ "RAM is primary storage outside the CPU"

✗ "The CPU stores data" ✓ "The CPU processes instructions and data"

Storing is memory's job.

✗ "The ALU controls the CPU" ✓ "The CU sends control signals; the ALU calculates"

10 Practice

Practice: easy, medium, hard

1. What does MDR stand for?
2. Which register holds the result of a calculation?
3. Name the three buses.
1. State what is meant by a microprocessor.
2. Describe the role of the control unit. [2]
3. Explain the key idea of the Von Neumann architecture.
1. Compare what the PC and the MAR store. [2]
2. Which bus is one-way, and why?

11 Can I do this?

0 / 4 ticked

- [ ] I can describe the role of the CPU and define a microprocessor.
- [ ] I can give the purpose of the CU and the ALU.
- [ ] I can say what each of PC, MAR, MDR, CIR, ACC stores.
- [ ] I can describe the three buses.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

ANSWER **Program counter (PC)**

2.

ANSWER **Arithmetic logic unit (ALU)**

3.

ANSWER **Address bus**

4.

ANSWER

To temporarily store data / an instruction / an address so it can be accessed immediately

Practice: easy, medium, hard

Easy 1.

ANSWER **Memory data register**

Easy 2.

ANSWER **Accumulator (ACC)**

Easy 3.

ANSWER **Address bus, data bus, control bus**

Medium 1.

ANSWER **An integrated circuit on a single chip**

Medium 2.

ANSWER

Sends control signals to manage the flow of data through the CPU; manages / decodes during the FDE cycle

Medium 3.

ANSWER **Program instructions and data are stored together in the same memory**

Hard 1.

ANSWER

PC: the address of the NEXT instruction to be fetched. MAR: the address of the instruction / data being fetched NOW (or written to)

Hard 2.

ANSWER **The address bus: addresses only go from the CPU to memory**

NOTE 3.2

The fetch-decode-execute cycle

1 In this note

SYLLABUS 3.1 COMPUTER ARCHITECTURE

- 3.1.2b Describe the **fetch-decode-execute (FDE) cycle**, including the **role of each component** in the process: storing data and addresses in registers, using **buses** to transmit them, using the **units** to fetch, decode and execute.

Before this: The CPU and Von Neumann architecture. Next: CPU performance and embedded systems.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

The registers

PC: address of the next instruction. MAR: address being fetched. MDR: data fetched. CIR: current instruction. ACC: results.

Quick check: which register holds the address of the next instruction?

The program counter (PC).

The buses

Address bus: addresses. Data bus: data and instructions. Control bus: signals.

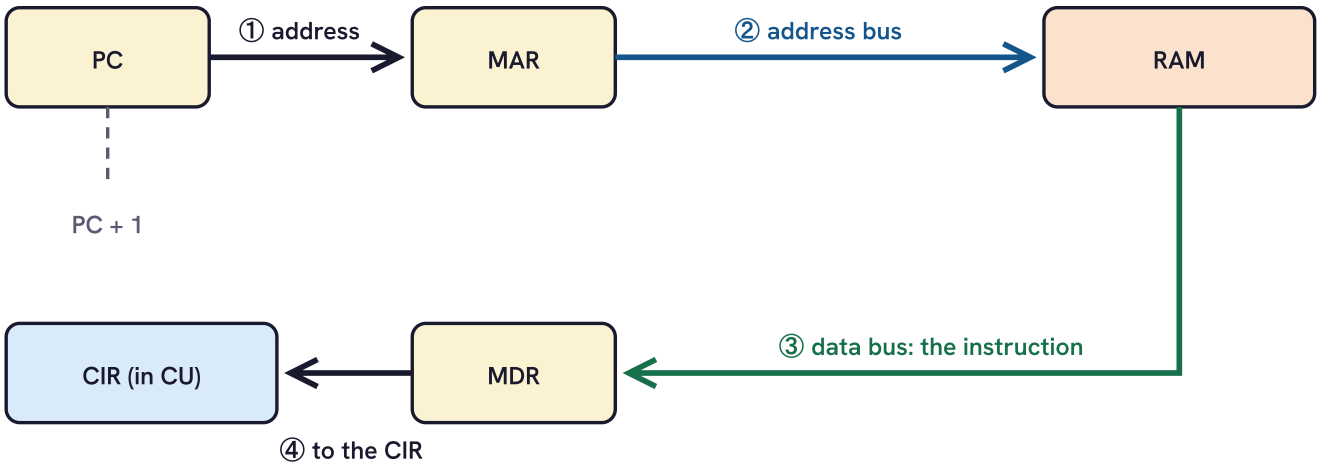
Quick check: which bus brings the instruction from RAM?

The data bus.

3 The cycle

The CPU runs every program by repeating three stages over and over, billions of times a second: **fetch** the next instruction from RAM, **decode** it to work out what it means, then **execute** it. This is the **fetch-decode-execute (FDE) cycle**.

1 Fetch



The fetch stage, in order ① to ④. The PC is increased by 1 so it points to the next instruction.

GENERAL METHOD

The fetch stage

1. The **program counter (PC)** holds the address of the next instruction. This address is **copied to the MAR**.
2. The **PC is incremented** (increased by 1) so it holds the address of the instruction after this one.
3. The address in the MAR is sent to **RAM** along the **address bus**.
4. The control unit sends a **read signal** along the **control bus**.
5. The instruction stored at that address is sent from RAM to the **MDR** along the **data bus**.
6. The instruction is copied from the MDR to the **CIR** (in the control unit).

2 Decode

GENERAL METHOD **The decode stage**

1. The instruction is in the **CIR**, in the **control unit**.
2. The control unit **decodes** the instruction using the **instruction set** (the list of machine code commands the CPU understands).
3. The instruction is split into the **opcode** (what to do, e.g. ADD) and the **operand** (what to do it to: data or an address).

3 Execute

GENERAL METHOD **The execute stage**

1. The control unit sends **control signals** to the parts that are needed to carry out the instruction.
2. If the instruction needs data from memory, its address goes to the MAR and the data comes back into the MDR.
3. If it is a calculation or comparison, the **ALU** carries it out and the result goes to the **accumulator (ACC)**.
4. The cycle then **starts again** with the next fetch.

Stage	Registers used	Buses used
Fetch	PC, MAR, MDR, CIR	address bus (MAR → RAM), data bus (RAM → MDR), control bus (read signal)
Decode	CIR (in the CU)	data bus (MDR → CIR)
Execute	ACC, MAR, MDR (if more data is needed)	any, depending on the instruction

TRY IT YOURSELF

1. Which register is incremented during the fetch stage?

2 Along which bus is the address sent from the MAR to RAM?

3 What does the control unit use to decode an instruction?

4 Summary

- Fetch: PC → MAR; PC + 1; MAR → RAM (address bus); instruction RAM → MDR (data bus); MDR → CIR.
- Decode: the CU decodes the instruction in the CIR using the instruction set (opcode + operand).
- Execute: the CU sends signals; the ALU calculates; results in the ACC. Then the cycle repeats.

IF YOU SEE …

"registers used in the fetch stage"	→ PC · MAR · MDR · CIR
"describe the decode stage"	→ MDR → CIR / CU · data bus · split into opcode and operand · CU decodes · instruction set

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

5 Ways they test it

TYPE 1 **Fetch paragraph**

> *"Complete the paragraph about fetching an instruction" [7]*

Spot it a word list.

1 Follow the fetch method in order: address · MAR · RAM · MDR · data · CIR · CU.

TYPE 2 **Registers per stage**

> *"Give two registers used in the fetch stage" [2]; "one register used in the execute stage" [1]*

Spot it "stage".

1. Fetch: PC, MAR, MDR, CIR. Execute: ACC (also MAR, MDR).

TYPE 3 **Describe a stage**

> *"Describe what happens at the decode stage" [3]*

Spot it "decode".

1. MDR → CIR on the data bus; split into opcode and operand; CU decodes using the instruction set.

TYPE 4 **Diagram**

> *"Complete and annotate the diagram to show how the data is decoded" [4]; draw the fetch stage [4]*

Spot it "annotate".

1. Boxes for each register, arrows in order, and label each arrow with the bus.

TYPE 5 **Correct the statement**

> *"Two statements are not correct. Suggest a corrected statement" [4]*

Spot it "incorrect".

1. Typical traps: "MAR stores instructions" (addresses), "MDR gets data from the PC" (from RAM via the data bus).

6 What the examiner looks for

"Describe what happens at the decode stage of the cycle" [3]

Marking points (one mark each, up to the marks shown)

- The CIR / CU receives the instruction from the MDR ...
- ... using the data bus
- The instruction is separated into opcode and operand
- The control unit decodes the instruction ...
- ... using an instruction set

KEYWORDS **CIR** **control unit** **opcode** **operand** **instruction set**

The fetch stage drawn as a diagram [4]

Marking points (one mark each, up to the marks shown)

- The registers MAR, MDR and PC shown
- Address sent from PC to MAR; PC is incremented
- Address sent from MAR to RAM ... using the address bus
- Data / instruction sent from RAM to MDR ... using the data bus
- Data / instruction sent from MDR to CIR / CU
- Control unit sending a control signal ... using the control bus

KEYWORDS **PC** **MAR** **address bus** **MDR** **data bus** **CIR**

7 Past-paper questions, solved

2210/12/M/J/24 Q5 ↗ Paper 1 · Computer systems **8 marks** ⤢ Full size

5 Instructions are processed by a central processing unit (CPU) in a computer.

(a) Complete the paragraph about fetching an instruction into the CPU to be processed.

Use the terms from the list.

Some of the terms in the list will **not** be used. You should only use a term once.

address arithmetic logic unit (ALU) binary control unit (CU)

current instruction register (CIR) data denary driver

fetch interrupt memory address register (MAR)

memory data register (MDR) random access memory (RAM)

read only memory (ROM) secondary storage signal

The program counter contains the ……

of the next instruction to be processed; this is then sent to the

…… using the address bus. The address is then

sent to the …… .

Once the address is received, the instruction stored at the location is

sent to the ……, using the

…… bus. The instruction is then

sent to the …… that is built into the

…… .

[7]

(b) The CPU uses an instruction set to decode the instruction.

State what is meant by an instruction set.

……

…… [1]

Swipe sideways to read the whole question

How to start Walk through the fetch method: what does the PC hold, where does it go, which bus, where does the instruction land?

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a) address · memory address register (MAR) · random access memory (RAM) · memory data register (MDR) · data · current instruction register (CIR) · control unit (CU)

(b) A list of all the machine code commands that can be processed by the CPU.

PART	ANSWER / WORKING	MARKS	GUIDANCE
5(a)	address · MAR · RAM · MDR · data · CIR · CU, one mark each in the correct place	B7	
5(b)	a list of (machine code) commands that can be processed by the CPU	B1	

Total: 8 marks

5 A central processing unit (CPU) performs the fetch–decode–execute (FDE) cycle.

(a) Give the name of **two** registers that are used in the fetch stage of the cycle.

[2]

(b) Describe what happens at the decode stage of the cycle.

..... [3]

(c) Give **one** register in the CPU that is used in the execute stage of the cycle.

..... [1]

(d) Buses are used in the CPU to transmit data through the FDE cycle.

Circle **three** buses that are used in the CPU.

fetch	address	register	execute
data	decode	calculation	
central	value	binary	control

[3]

Swipe sideways to read the whole question

How to start (b) is the decode method: three points. (d) circle the three real bus names.

▾ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

(a) Program counter (PC); memory address register (MAR).

(b) The instruction is sent from the MDR to the CIR in the control unit along the data bus. It is split into the opcode and the operand, and the control unit decodes it using the instruction set.

(c) Accumulator (ACC).

(d) address · data · control

PART	ANSWER / WORKING	MARKS	GUIDANCE
5(a)	Any two: PC · MAR · MDR · CIR	B2	
5(b)	Any three: MDR → CIR / CU · data bus · opcode and operand · CU decodes · instruction set	B3	
5(c)	Any one: ACC · MAR · MDR	B1	
5(d)	data · address · control	B3	

Total: 9 marks

2 A computer has a central processing unit (CPU).

The CPU includes the registers:
- Program counter (PC)
- Memory address register (MAR)
- Memory data register (MDR)
- Accumulator (ACC)
- Current instruction register (CIR).

(a) The table contains **five** statements about the role of registers in the fetch–decode–execute cycle of a CPU.

Letter	Statement
A	PC stores the address of the next instruction to be accessed
B	MAR stores the instructions of the program that is running
C	MDR stores the data passed to it from the PC
D	ACC stores the result of each calculation
E	CIR stores the instruction currently being executed

Two of the statements are **not** correct.

Identify the letter of each incorrect statement.

Suggest a corrected statement for each.

Incorrect statement 1 .....

Corrected statement .....

Incorrect statement 2 .....

Corrected statement .....

[4]

Swipe sideways to read the whole question

How to start Check each statement against the register table: who holds addresses, who holds data, where does data come from?

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

Incorrect statement 1: **B**. Corrected: the MAR stores the address of the instruction / data to be fetched, not the instructions.

Incorrect statement 2: **C**. Corrected: the MDR stores data passed to it from RAM along the data bus (from the address in the MAR), not from the PC.

PART	ANSWER / WORKING	MARKS	GUIDANCE
2(a)	B … MAR stores addresses, not instructions · C … data comes from RAM / the address in the MAR (data bus), not the PC	B4	

Total: 4 marks

8 Common mistakes

✗ "The PC sends the instruction to the MAR" ✓ "The PC's ADDRESS is copied to the MAR"

The PC never holds an instruction.

✗ "The address goes on the data bus" ✓ "Addresses go on the address bus"

✗ Forgetting the PC is incremented ✓ "PC + 1" in the fetch stage

It earns a mark in diagrams.

✗ "The ALU decodes the instruction" ✓ "The control unit decodes it using the instruction set"

9 Practice

Practice: easy, medium, hard

1. Name the three stages of the cycle, in order.
2. Which register receives the instruction from RAM?
3. Which register holds the instruction while it is decoded?
1. Describe the fetch stage. [4]
2. What are the two parts an instruction is split into when it is decoded?
1. An instruction says ADD the value at address 50 to the accumulator. Describe what happens in the execute stage. [3]
2. Explain why the PC is incremented during the fetch stage.

10 Can I do this?

0 / 3 ticked

- [ ] I can describe the fetch stage step by step with registers and buses.
- [ ] I can describe the decode and execute stages.
- [ ] I can draw and annotate the fetch stage.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

ANSWER **Program counter (PC)**

2.

ANSWER **Address bus**

3.

ANSWER **The instruction set**

Practice: easy, medium, hard

Easy 1.

ANSWER **Fetch, decode, execute**

Easy 2.

ANSWER **MDR (memory data register)**

Easy 3.

ANSWER **CIR (current instruction register)**

Medium 1.

ANSWER

PC address copied to MAR; PC incremented; address sent to RAM on the address bus; instruction returned to MDR on the data bus; copied to CIR

Medium 2.

ANSWER **Opcode and operand**

Hard 1.

ANSWER

CU sends signals; address 50 goes to the MAR → RAM; the value returns to the MDR on the data bus; the ALU adds it to the ACC; result stored in the ACC

Hard 2.

ANSWER **So it holds the address of the next instruction, ready for the next cycle**

NOTE 3.3

CPU performance and embedded systems

1 In this note

SYLLABUS 3.1 COMPUTER ARCHITECTURE

- 3.1.3 Understand what is meant by a **core**, **cache** and **clock** in a CPU and explain how they can **affect the performance** of a CPU.
- 3.1.4 Understand the purpose and use of an **instruction set** for a CPU.
- 3.1.5 Describe the purpose and characteristics of an **embedded system** and identify devices in which they are commonly used.

Before this: The fetch-decode-execute cycle. Next: Input and output devices.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

The FDE cycle

The CPU fetches, decodes and executes one instruction, then repeats.

Quick check: what does a faster CPU let you do?

Run more fetch-decode-execute cycles every second.

3 What makes a CPU faster

Three features of a CPU decide how many instructions it can process per second. For each one, learn **what it is** and **how it affects performance**: the examiner almost always wants the link to **FDE cycles**.

Feature	What it is	Effect on performance
Clock	sends out **timing signals** (clock pulses) that keep the parts of the CPU in step. Clock speed is measured in **hertz**: 3.5 GHz = 3.5 billion cycles per second	**higher clock speed** → **more FDE cycles per second** → instructions processed faster
Core	a complete **processing unit** (with its own ALU, CU and registers). A quad-core CPU has four	**more cores** → **more instructions processed at the same time** (each core runs its own FDE cycle simultaneously)
Cache	small, **very fast memory** inside / next to the CPU that stores **frequently used data and instructions** (levels L1, L2, L3)	**bigger cache** → frequently used data is **accessed faster than from RAM** → less waiting

✗ COMMON MISTAKE

Not always. Doubling the cores does not always double the speed: the program must be able to split its work between cores, and the cores have to communicate. Very high clock speeds also make the CPU hot. If the question says "explain", one sentence on a limit can earn the extra mark.

EXAMPLE **Comparing two CPUs**

CPU A: 4 cores, 3.2 GHz, 8 MB cache. CPU B: 2 cores, 3.6 GHz, 4 MB cache. Which is likely to perform better on a program that can use many cores, and why?

> CPU A has twice as many cores, so it can run twice as many FDE cycles at the same time.
>
> CPU A also has a bigger cache, so more frequently used data is stored close to the CPU and accessed faster than from RAM.
>
> CPU B has the faster clock (more cycles per second per core), but 3.6 is only 12.5% more than 3.2.

ANSWER **CPU A: more cores and more cache outweigh the slightly lower clock speed.**

4 Instruction sets

An **instruction set** is the **list of all the commands (machine code instructions)** that a particular CPU can **process**. Each command is made of an **opcode** (the operation, e.g. ADD, LOAD, JUMP) and usually an **operand** (the data or address it works on).

The control unit uses the instruction set to **decode** each instruction in the FDE cycle. A program written in a high-level language must be translated into instructions from the CPU's instruction set before it can run, which is why machine code made for one type of CPU will not run on another.

> **Instruction set**: a list of all the commands that can be processed by a CPU, used to decode instructions.

5 Embedded systems

An **embedded system** is a computer system **built into a larger device** to perform **one dedicated function**. It has a **microprocessor** (or microcontroller), and its program is stored as **firmware** in ROM, so it usually **cannot be reprogrammed** by the user.

Characteristic	Why
performs a **single, dedicated function**	it only controls one device: e.g. keeping a freezer cold
built into a larger device	it is part of the machine, not a separate computer
has **dedicated hardware** + a microprocessor	only the parts needed for its job
runs **firmware** / cannot (easily) be **reprogrammed**	the program is fixed in ROM
small, **cheap**, **low power**	easy to mass-produce; can run on batteries
often **real-time** and **automatic**	reacts to sensor input without a user

Devices that commonly contain embedded systems:

Domestic	Transport / other
washing machine, microwave oven, fridge / freezer, central heating, security alarm, smart TV	car engine management, ABS brakes, traffic lights, vending machine, digital camera, lift (elevator), set-top box

A **general-purpose computer** (a laptop) can run any program you install. An **embedded system** does one job inside another device. If the question asks you to "identify" embedded systems from a list, cross out the laptops, PCs and servers.

TRY IT YOURSELF

1. What is the effect of a higher clock speed?
2. Where is the program of an embedded system stored?
3. Is a smartphone an embedded system?

6 Summary

- Clock: timing signals; higher clock speed = more FDE cycles per second.
- Core: a processing unit; more cores = more instructions processed at the same time.
- Cache: fast memory for frequently used data; bigger cache = faster access than RAM.
- Instruction set: list of all the machine code commands a CPU can process; used to decode.
- Embedded system: one dedicated function, built into a larger device, microprocessor, firmware, cannot be reprogrammed.

IF YOU SEE …

"explain how the cores affect performance"	→ more cores · more FDE cycles at the same time · simultaneously
"characteristics of an embedded system"	→ dedicated function · built into a device · firmware · cannot be reprogrammed · small / low power

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

7 Ways they test it

TYPE 1 Effect on performance

> *"Explain how the number of cores / cache / clock speed can affect performance" [2] each*

Spot it "explain".

1 Two marks: what it is + the effect, linked to FDE cycles.

TYPE 2 Interpret a spec

> *"The CPU has a clock speed of 3.5 GHz. Explain what this means" [1]*

Spot it a number.

1 3.5 billion FDE cycles (clock pulses) per second.

TYPE 3 Instruction set

> *"State what is meant by an instruction set" [1]*

Spot it "instruction set".

1 A list of all the commands that can be processed by the CPU.

TYPE 4 Embedded system

> *"Describe two characteristics of an embedded system" [4]; "circle three embedded systems" [3]*

Spot it a device scenario.

1 Two marks per characteristic: state it, then expand it.

8 What the examiner looks for

"Explain how these three components can affect the performance of the CPU" (cores, clock, cache) [6]

Marking points (one mark each, up to the marks shown)

- More cores … more FDE cycles can be performed at the same time / simultaneously
- Higher clock speed … more FDE cycles can be performed per second
- Bigger cache … more frequently used data / instructions can be stored … and accessed faster than from RAM

KEYWORDS **FDE cycles** **simultaneously** **per second** **frequently used** **faster than RAM**

TOO VAGUE "more cores make the computer faster" with no reason; "cache stores data" (all memory does: say which data and why it helps)

9 Past-paper questions, solved

0478/12/F/M/24 Q2 ↗ Paper 1 · Computer systems **6 marks** ⤢ Full size

2 A computer has a central processing unit (CPU).

The CPU includes the registers:
- Program counter (PC)
- Memory address register (MAR)
- Memory data register (MDR)
- Accumulator (ACC)
- Current instruction register (CIR).

(b) The computer has a single core 3.5 GHz processor and an 8 kB cache.

(i) State what is meant by a 3.5 GHz processor.

..... [1]

(ii) The CPU is changed to a dual-core 3.5 GHz processor.

Explain how the number of cores affects the performance of a CPU.

..... [2]

(iii) The amount of cache is increased to 64 kB.

Explain how the amount of cache affects the performance of a computer.

..... [2]

Swipe sideways to read the whole question

How to start One point per mark: what the number means, then the effect of each feature, linked to FDE cycles.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(i) The CPU can perform 3.5 billion fetch-decode-execute cycles every second.

(ii) Each core can perform its own FDE cycle, so several instructions are processed at the same time.

(iii) The cache stores frequently used data and instructions, which can be accessed faster than from RAM.

PART	ANSWER / WORKING	MARKS	GUIDANCE
2(b)(i)	3.5 billion FDE cycles / clock pulses per second	B1	
2(b)(ii)	each core performs an FDE cycle · simultaneously / more instructions at once	B2	
2(b)(iii)	stores frequently used data / instructions · accessed faster than RAM	B2	

Total: 5 marks

2210/12/O/N/23 Q4 ↗ Paper 1 · Computer systems **4 marks** ⤢ Full size

4 A washing machine is an example of an embedded system.

(a) Give **two** characteristics of an embedded system.

[2]

(b) Circle **three** other examples of an embedded system.

freezer laptop

personal computer (PC) security light system smartphone

vending machine web server

[3]

Swipe sideways to read the whole question

How to start Pick characteristics from the list and expand each one with a reason or example.

▼ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

It performs a single, dedicated function, for example only controlling the security light. It is built into a larger device and its program is stored as firmware, so it cannot be reprogrammed by the user. It uses little power and is small and cheap to make.

PART	ANSWER / WORKING	MARKS	GUIDANCE
4	Any two characteristics, two marks each: dedicated function · microprocessor · dedicated hardware · firmware · built into a larger device · cannot be reprogrammed · low power · small / cheap · real-time	B4	

Total: 4 marks

10 Common mistakes

✗	✓
"Cache is extra storage"	"Cache is fast memory for frequently used data, accessed faster than RAM"
"More cores = computer goes faster"	"More cores = more FDE cycles at the same time"
"Clock speed is the time of the computer"	"Clock speed = number of FDE cycles per second"
"An embedded system can be reprogrammed by the user"	"Its firmware is fixed; it usually cannot be reprogrammed"

Say the reason.

11 Practice

Practice: easy, medium, hard

1. A CPU has a clock speed of 2 GHz. How many cycles is that per second?
2. Give two devices that contain an embedded system.
3. What is a core?
1. Explain how increasing the cache size can improve performance. [2]
2. State what is meant by an instruction set.
1. A quad-core CPU is replaced by an eight-core CPU but a program does not run faster. Suggest why. [2]
2. Explain why an embedded system usually cannot be reprogrammed. [2]

12 Can I do this?

0 / 3 ticked

- [ ] I can explain the effect of clock speed, cores and cache on performance.
- [ ] I can define an instruction set.
- [ ] I can describe characteristics of an embedded system and give examples.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

ANSWER More FDE cycles per second, so instructions are processed faster

2.

ANSWER In ROM, as firmware

3.

ANSWER No: it is general purpose (it runs many apps)

Practice: easy, medium, hard

Easy 1.

ANSWER 2 billion

Easy 2.

ANSWER e.g. washing machine, microwave

Easy 3.

ANSWER A processing unit inside the CPU that can run its own FDE cycle

Medium 1.

ANSWER

More frequently used data / instructions stored in cache; accessed faster than from RAM

Medium 2.

ANSWER A list of all the commands a CPU can process

Hard 1.

ANSWER

The program may not be able to split its work across more cores / it uses one core; cores must communicate

Hard 2.

ANSWER **Its program is firmware stored in ROM; it is designed for one dedicated function**

NOTE 3.4

Input and output devices

1 In this note

SYLLABUS 3.2 INPUT AND OUTPUT DEVICES

- 3.2.1 Understand what is meant by an **input device** and why it is required.
- 3.2.2 Understand what is meant by an **output device** and why it is required.

Before this: CPU performance and embedded systems. Next: Sensors.

> The syllabus only asks **what** each device is, **why** it is needed and **where** it is used. You do not need to describe how a device works inside.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

Input → process → output

A computer takes data in, processes it, and gives results out.

Quick check: which part does the processing?

The CPU.

3 Input devices

An **input device** **captures data** from the user or the surroundings and **sends it to the computer** to be processed. Input devices are needed because the computer can only process

data it has been given, and most data starts outside the computer (a key press, a sound, a picture).

Input device	Typical use
Keyboard	typing text and commands into a word processor or a form
Mouse	pointing, clicking and selecting on a desktop computer
Touch screen	selecting options on a smartphone, a ticket machine or a self-service checkout
Microphone	recording speech, voice commands to a smart speaker, video calls
Digital camera	taking photos and videos, video calls, scanning documents with a phone
Barcode scanner	reading the product code at a shop checkout or in a library
QR code scanner	opening a web link or a payment from a QR code (often the phone camera)
2D / 3D scanner	copying a printed document (2D); copying the shape of an object for 3D printing (3D)
Sensor	measuring a physical quantity automatically, e.g. temperature (next note)

4 Output devices

An **output device** **receives data from the computer** and **presents it** in a form the user can understand (a picture, sound, printout) or **uses it to make something happen** (an actuator

moves a valve). Output devices are needed so the results of processing can be seen, heard or acted on.

Output device	Typical use
Screen / monitor	displaying documents, games, video
Speaker / headphones	playing music, alarms and the sound of a video call
Printer (inkjet, laser)	printing documents and photos on paper
3D printer	making a solid object, layer by layer, e.g. a prototype or a spare part
Projector	showing a presentation on a large screen in a classroom
LED / LCD light	an indicator light (charging, on/off), a digital display
Actuator	making a physical movement in a control system: opening a valve, turning a motor, switching a heater

> **Not input or output:** HDD, SSD, USB flash drive, CD/DVD are **storage**; RAM, ROM, registers are memory. A touch screen is both input and output. An **actuator is an output device**; a **sensor is an input device**.

TRY IT YOURSELF

1. Is a printer an input or output device?
2. Is a microphone an input or output device?
3. Which output device moves a valve in a control system?

5 Summary

- Input device: captures data and sends it to the computer to be processed.
- Output device: receives data from the computer and presents it / makes something happen.
- Inputs: keyboard, mouse, touch screen, microphone, camera, barcode / QR scanner, 2D/3D scanner, sensor.
- Outputs: screen, speaker, printer, 3D printer, projector, LED, actuator.

IF YOU SEE …

"circle three output devices"	→ speaker · printer · actuator (not DVD, SSD, sensor)
"identify two input devices built into a smartphone"	→ touch screen · microphone · camera · sensor

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

6 Ways they test it

TYPE 1 **Circle the devices**

> *"Circle three devices that are output devices" [3]*

Spot it a list.

1. Cross out storage and memory first: they are distractors.

TYPE 2 **Devices in a gadget**

> *"Identify two input devices that can be built into the smartwatch" [2]*

Spot it a device scenario.

1. Choose devices that make sense for that gadget: a smartwatch has a touch screen, microphone, sensors.

TYPE 3 **Input / output / storage**

> *"Tick to show whether a barcode scanner is input, output, process or storage" [1]*

Spot it a tick box.

1. Ask: does data go IN to the computer or OUT of it?

7 What the examiner looks for

Wording trap · Output devices

THE QUESTION **2210/12/M/J/23 Q1** ↗ Paper 1 · Computer systems — **3 marks**

Circle three devices that are output devices: actuator · DVD · keyboard · microphone · mouse · printer · scanner · sensor · SSD · speaker

✓ CREDITED

- Actuator
- Printer
- Speaker

✗ NOT CREDITED

- DVD, SSD (storage)
- keyboard, microphone, mouse, scanner, sensor (input)

WHY

Remember that the actuator is an output: it moves something in response to the computer's signal.

From: 2210/12/M/J/23 Q1 mark scheme

8 Past-paper questions, solved

2210/12/O/N/24 Q4 ↗ Paper 1 · Computer systems **3 marks** ⤢ Full size

4 A student has a smartwatch.

(a) The smartwatch has built-in input and output devices.

Identify **two** input devices that can be built into the smartwatch.

[2]

(b) Identify **one** output device that can be built into the smartwatch.

..... [1]

Swipe sideways to read the whole question

How to start Picture a smartwatch: what do you touch, speak into, and what does it show or play?

▼ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

(a) Touch screen; microphone (also accepted: button, camera, a sensor such as a heart-rate sensor).

(b) Screen (also: speaker, LED).

PART	ANSWER / WORKING	MARKS	GUIDANCE
4(a)	Any two: touchscreen · microphone · button · camera · sensor	B2	
4(b)	Any one: screen · speaker · LED · actuator	B1	

Total: 3 marks

9 Common mistakes

✗ "An SSD is an output device"

✓ "An SSD is secondary storage"

✗ "An actuator is an input"	✓ "An actuator is an output: it moves something"
✗ "Keyboard" for a smartwatch	✓ "Touch screen"

Pick devices that suit the gadget.

10 Practice

Practice: easy, medium, hard

1. Is a 3D printer an input or output device?
2. Name an input device used at a shop checkout.
1. Explain why a computer needs input devices.
2. Give one use of a projector.
1. A touch screen is described as both input and output. Explain why.

11 Can I do this?

0 / 2 ticked

- [ ] I can define an input device and give examples and uses.
- [ ] I can define an output device and give examples and uses.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

ANSWER **Output**

2.

ANSWER **Input**

3.

ANSWER **Actuator**

Practice: easy, medium, hard

Easy 1.

ANSWER **Output**

Easy 2.

ANSWER **Barcode scanner**

Medium 1.

ANSWER **To capture data and send it to the computer so it can be processed**

Medium 2.

ANSWER **Showing a presentation on a large screen to a class**

Hard 1.

ANSWER **It displays output (screen) and captures input when the user touches it**

NOTE 3.5

Sensors

1 In this note

SYLLABUS 3.2 INPUT AND OUTPUT DEVICES

- 3.2.3 Understand what is meant by a **sensor** and its purposes; identify the **type of data** captured by each sensor and where each is used: **acoustic, accelerometer, flow, gas, humidity, infra-red, level, light, magnetic field, moisture, pH, pressure, proximity, temperature**.

Before this: Input and output devices. Next: Primary and secondary storage.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

Input devices

An input device captures data and sends it to the computer.

Quick check: is a sensor input or output?

Input.

3 What a sensor is

A **sensor** is an **input device** that **measures a physical quantity** from its surroundings (temperature, light, sound ...) and sends the reading to a computer or microprocessor. It

captures data automatically, with no person entering it. If the reading is analogue it is converted to digital before the microprocessor can process it.

Why use sensors?	
data is collected **without human intervention**	nobody has to stand and watch
readings are taken **continuously** (24/7)	the system reacts the moment something changes
readings are **accurate** and taken **faster** than a human	no human error
they work in **dangerous** places	e.g. inside a chemical plant or a nuclear reactor

4 The fourteen sensors you must know

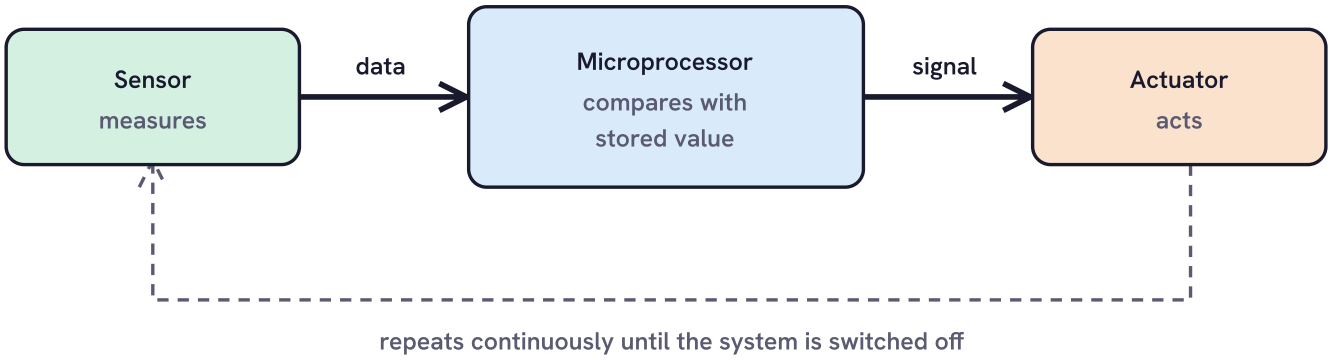
For each sensor, learn **what it measures** and **one use**. Exam questions give a scenario and ask for "the most appropriate sensor", so match the quantity that changes.

Sensor	Measures	Example use
Acoustic	sound	detecting breaking glass in a burglar alarm; a dripping, leaking pipe
Accelerometer	acceleration / movement and tilt	rotating a phone screen; fitness trackers; air-bag deployment in a crash
Flow	rate of flow of a liquid or gas	monitoring water through a pipe; fuel flow in an engine
Gas	presence / level of a gas (e.g. CO_2, carbon monoxide)	carbon monoxide alarm; gas leak detector
Humidity	water vapour in the air	greenhouse; spray-painting room; museum display case
Infra-red	infra-red radiation (heat / a broken beam)	motion detection in a security system; automatic doors
Level	how full a container is	fuel tank gauge; refilling a water tank or an animal's water bowl
Light	light intensity	street lights switching on at dusk; phone screen brightness; barcode scanner
Magnetic field	changes in a magnetic field	counting vehicles over a bridge / into a car park; phone compass
Moisture	water in a substance (e.g. soil)	automatic watering of plants
pH	acidity / alkalinity	soil in a greenhouse; water in a swimming pool or a fish tank
Pressure	force applied / pressure	a car on a car-park barrier; weighing; burglar alarm pad under a carpet
Proximity	how close an object is	parking sensors on a car; phone screen turning off at your ear
Temperature	temperature	central heating; a kettle; a freezer; a climate-controlled room

Moisture vs humidity: **moisture** is water in a solid (soil); **humidity** is water vapour in the air. Level vs pressure vs moisture can all detect an empty water bowl, and the mark scheme accepts any of them.

5 Sensor + microprocessor: how a system reacts

In an automated system the sensor and a **microprocessor** work in a loop. Questions often ask for this as a 6-mark description, so learn the steps.



The control loop used by almost every automated system.

GENERAL METHOD **Describing a sensor-controlled system**

1. The **sensor** continually takes readings and sends the (digitised) data to the **microprocessor**.
2. The microprocessor **compares** the reading with a **stored value** (or range).
3. If the reading is outside the range, the microprocessor sends a **signal** to an **actuator** (e.g. to open a valve, switch on a heater).
4. If the reading is within the range, **no action** is taken.
5. The process **repeats continuously** until the system is switched off.

EXAMPLE **A greenhouse that keeps the soil damp**

Describe how a moisture sensor and a microprocessor keep the soil damp.

The moisture sensor continually sends readings of the soil moisture to the microprocessor.

The microprocessor compares each reading with the stored minimum moisture level.

If the reading is below it, the microprocessor sends a signal to an actuator to open the water valve.

When the reading reaches the stored level, the microprocessor signals the actuator to close the valve.

This repeats continuously.

ANSWER **Five marking points: sensor · compare · actuator opens · stops · repeats.**

TRY IT YOURSELF

1. Which sensor counts cars entering a car park?
2. Which sensor measures the acidity of soil?
3. Which sensor turns a phone's screen sideways?

6 Summary

- A sensor is an input device that measures a physical quantity and sends the data to a microprocessor.
- Benefits: no human needed, continuous, accurate, fast, works in dangerous places.
- 14 sensors: acoustic, accelerometer, flow, gas, humidity, infra-red, level, light, magnetic field, moisture, pH, pressure, proximity, temperature.
- Control loop: sensor → microprocessor compares with stored value → signal to actuator → repeat.

IF YOU SEE …

"identify the most appropriate sensor"	→ name the quantity that changes
"describe how the sensor and microprocessor are used" [6]	→ continually · digital data · compare · stored value · signal · actuator · repeats

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

7 Ways they test it

TYPE 1 **Which sensor?**

> *"Identify the most appropriate sensor for this system" [1]*

Spot it a scenario.

1. One word: the sensor's name from the list of 14.

TYPE 2

Sensor uses table

> *"Complete the table by giving a suitable use for each type of sensor" [4]*

Spot it a table.

1. A specific use: "monitoring the temperature in a greenhouse", not just "measures temperature".

TYPE 3

Benefits

> *"Give two benefits of using sensors in this type of system" [2]*

Spot it "benefits".

1. no human needed · continuous · accurate · fast · dangerous places

TYPE 4

Control loop

> *"Describe how the sensor and the microprocessor are used to ..." [6]*

Spot it "describe how".

1. Follow the five-step method, using the scenario's own words (water bowl, valve).

8 What the examiner looks for

"Describe how the sensor and the microprocessor are used to automatically refill the water bowl" [6]

Marking points (one mark each, up to the marks shown)

- Sensor continually sends digitised data to the microprocessor
- Microprocessor compares the data to stored value(s)
- If the value is outside the range / matches, the microprocessor sends a signal to release water
- … bowl filled by a set amount // for a certain time
- Actuator used to release the water
- Whole process repeats until turned off

KEYWORDS **continually** **compares** **stored value** **signal** **actuator** **repeats**

TOO VAGUE "the sensor decides to refill the bowl" (the microprocessor decides); "the sensor sends a signal to the actuator"

9 Past-paper questions, solved

0478/13/M/J/24 Q6 ↗ Paper 1 · Computer systems **9 marks** ⤢ Full size

6 A sensor is an input device that is used to capture data from its surrounding environment.

(a) Circle **three** other input devices.

touch screen hard disk drive (HDD) headphones

speaker microphone actuator

universal serial bus (USB) drive printer keyboard

[3]

(b) Sensors can be used in an automated system.

Give **two** benefits of using sensors in this type of system.

[2]

(c) The table contains different types of sensors and a use for each.

Complete the table by giving a suitable use for each type of sensor. The first one has been done for you.

type of sensor	use
acoustic	to monitor whether a water pipe has cracked and is leaking and dripping onto the floor
temperature	
humidity	
infra-red	
magnetic field	

[4]

Swipe sideways to read the whole question

How to start (a) cross out storage and outputs. (c) give a specific situation for each sensor.

▾ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

(a) touch screen · microphone · keyboard

(b) Data can be collected without human intervention; readings can be taken continuously, 24/7.

(c) Temperature: monitoring the temperature in a climate-controlled room. Humidity: checking the air in a greenhouse is moist enough. Infra-red: detecting a person approaching automatic doors. Magnetic field: counting vehicles that cross a bridge.

PART	ANSWER / WORKING	MARKS	GUIDANCE
6(a)	touch screen · microphone · keyboard	B3	
6(b)	Any two: no human intervention · faster · accurate · continuous · dangerous environments	B2	
6(c)	One suitable use per sensor (temperature, humidity, infra-red, magnetic field)	B4	

Total: 9 marks

2210/11/M/J/23 Q5 ↗ Paper 1 · Computer systems **7 marks** ⤢ Full size

5 A farm has an automated drinking system for its animals. The drinking system has a water bowl that contains the water. When the water bowl is empty, it is automatically refilled.

The system uses a sensor and a microprocessor.

(a) Identify the most appropriate sensor for this system.

..... [1]

(b) Describe how the sensor and the microprocessor are used to automatically refill the water bowl.

..... [6]

Swipe sideways to read the whole question

How to start (a) What changes when the bowl empties? (b) Use the control-loop method.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a) A level sensor.

(b) The level sensor continually sends digitised readings to the microprocessor. The microprocessor compares each reading with the stored value for an empty bowl. If they match, the microprocessor sends a signal to an actuator to open a valve and release water. The bowl is filled for a set time or until the stored full level is reached, then the valve is closed. The whole process repeats until the system is turned off.

PART	ANSWER / WORKING	MARKS	GUIDANCE
5(a)	Any one: level · pressure · moisture	**B1**	
5(b)	Any six: continually sends digitised data · compares to stored value · if outside range / matches sends signal · filled by set amount / for a set time · actuator releases water · repeats until stopped	**B6**	

Total: 7 marks

10 Common mistakes

✗ "Heat sensor"

✓ "Temperature sensor"

Use the syllabus names.

✗ "Motion sensor"

✓ "Infra-red sensor" (or accelerometer if the device itself moves)

✗ "The sensor turns on the heater"

✓ "The microprocessor sends a signal to the actuator"

Sensors only measure.

✗ Forgetting the loop repeats ✓ "The process repeats continuously"

It is a mark every time.

11 Practice

Practice: easy, medium, hard

1 Which sensor detects carbon monoxide?

2 Which sensor would switch on street lights at night?

3 Which sensor helps a driver park without hitting a wall?

1 Give two benefits of using sensors instead of people to monitor a chemical tank.

2 Give a use for a flow sensor.

1 Describe how a temperature sensor and a microprocessor keep a freezer below −18 °C. [5]

12 Can I do this?

0 / 3 ticked

- [ ] I can name all 14 sensors, what each measures and a use.
- [ ] I can give benefits of using sensors.
- [ ] I can describe a sensor + microprocessor control system.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

ANSWER **Magnetic field (or pressure)**

2.

ANSWER **pH**

3.

ANSWER **Accelerometer**

Practice: easy, medium, hard

Easy 1.

ANSWER **Gas**

Easy 2.

ANSWER **Light**

Easy 3.

ANSWER **Proximity**

Medium 1.

ANSWER **Works continuously; no human in a dangerous place (also: accurate, fast)**

Medium 2.

ANSWER **e.g. monitoring the rate of water through a pipe**

Hard 1.

ANSWER

Sensor continually sends readings; microprocessor compares with −18 °C; if above, signal to actuator to switch on the compressor; when below, switch off; repeats

NOTE 3.6

Primary and secondary storage

1 In this note

SYLLABUS 3.3 DATA STORAGE

- 3.3.1 Understand what is meant by **primary storage**, including the role of **RAM** and **ROM**, why a computer needs both and the difference between them.
- 3.3.2 Understand what is meant by **secondary storage**.
- 3.3.3 Describe the operation of **magnetic**, **optical** and **solid-state (flash memory)** storage and give examples of each.

Before this: Sensors. Next: Virtual memory and cloud storage.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

Volatile

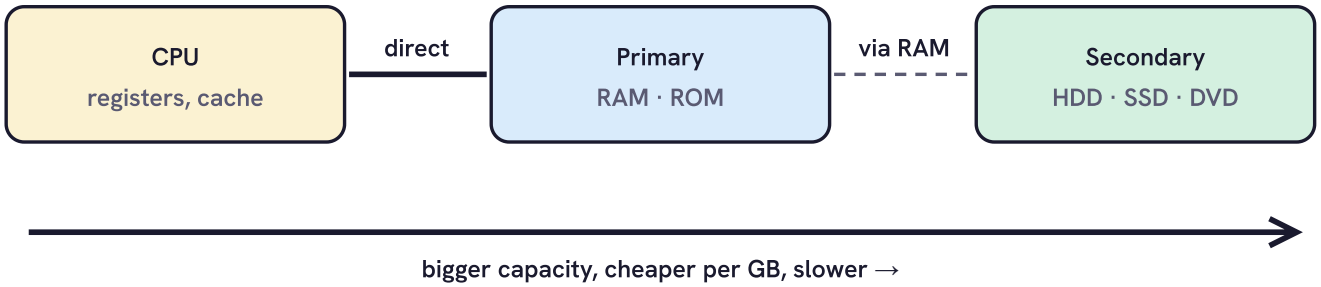
Volatile memory loses its contents when the power is turned off. **Non-volatile** keeps them.

Quick check: is a USB flash drive volatile?

No: it is non-volatile.

3 Primary storage: RAM and ROM

Primary storage is memory that is **directly accessed by the CPU**. There are two types: RAM and ROM.



Primary storage is directly accessed by the CPU. Secondary storage is not: its data is copied into RAM first.

Where primary and secondary storage sit.

	RAM (random access memory)	ROM (read only memory)
volatile?	**volatile**: contents lost when power is off	**non-volatile**: contents kept
can it be changed?	read and **written to**	**read only**: contents cannot (normally) be changed
what it stores	the **data and programs currently in use**, including parts of the operating system	the **start-up instructions**: the **BIOS / bootstrap** and **firmware**
size	large (e.g. 8-32 GB)	small

A computer needs **both**. ROM holds the instructions to **start the computer** (they must survive with the power off, and must not be changed by accident). RAM holds **whatever is running now**: it is much faster than secondary storage, so the CPU can fetch instructions quickly, and it can be written to as the data changes.

4 Secondary storage

Secondary storage is **not directly accessed by the CPU** and is **non-volatile**. It is needed to store data, files and software **permanently**: otherwise everything would have to be re-installed or re-entered every time the computer was switched on. It also provides the space for virtual memory.

Magnetic storage (hard disk drive, HDD)

GENERAL METHOD

How a hard disk drive works

1. Data is stored on **platters**, round disks coated in a magnetic material, which **spin** at high speed.
2. Each platter is divided into concentric **tracks**, and each track into **sectors**.
3. A **read/write head** on an arm moves across the platter to the correct track.
4. The head uses an **electromagnet** to magnetise tiny areas (writing) or to sense their magnetisation (reading).
5. The direction of the magnetisation of each area represents **1 or 0**.

Optical storage (CD, DVD, Blu-ray)

GENERAL METHOD

How optical storage works

1. The disk **spins**.
2. To write, a **laser** burns **pits** into the reflective surface; the unburnt areas are **lands**. The pits are laid in a **spiral track**.
3. To read, a laser is shone onto the surface: pits and lands **reflect the light differently**, which a sensor detects.
4. The pits and lands represent the **binary values**.
5. CD and DVD use a **red laser**; **Blu-ray** uses a **blue laser** with a shorter wavelength, so the pits are smaller and more data fits.

Solid-state storage (SSD, SD card, USB flash drive)

GENERAL METHOD **How solid-state (flash memory) storage works**

1. It has **no moving parts**: data is stored in **transistors** on silicon chips, laid out in a **grid**.
2. It uses **NAND or NOR** technology.
3. Each transistor has a **control gate** and a **floating gate**.
4. The gates control the **flow of electrons**: when electrons are trapped in the floating gate the value changes between 1 and 0.
5. The electrons stay trapped with the power off, so it is **non-volatile**.

	Magnetic (HDD)	Optical	Solid state (SSD)
moving parts	yes	yes	**none**
access speed	medium	slowest	**fastest**
capacity	very large	small (≈ 0.7-100 GB)	large
cost per GB	**cheap**	cheapest (disks)	more expensive
durability	can be damaged if dropped	scratches easily	**robust** (no moving parts)
power / noise / heat	more power, some noise	noisy drive	**low power**, silent, cool
good for	servers, cheap large storage	distributing films / software, archive	laptops, phones, portable use

TRY IT YOURSELF

1. Which storage type uses pits and lands?
2. Which storage type uses floating gates?
3. Which type of memory stores the bootstrap?

4 State the characteristic that makes RAM primary storage.

5 Summary

- Primary = directly accessed by the CPU: RAM (volatile, data in use) and ROM (non-volatile, read only, bootstrap / BIOS / firmware).
- Secondary = not directly accessed, non-volatile, permanent storage.
- Magnetic: spinning platters, tracks and sectors, read/write head with electromagnets.
- Optical: laser, pits and lands, spiral track; red laser CD/DVD, blue laser Blu-ray.
- Solid state: NAND/NOR, transistors with control and floating gates, electrons trapped; no moving parts.

IF YOU SEE …

"why does a computer need RAM?"	→ store data / software currently in use · temporarily · faster than secondary storage
"why does it need ROM?"	→ store the BIOS / bootstrap / firmware · non-volatile · should not change
"describe how optical storage works"	→ disk spun · laser · pits burnt · spiral track · pits and lands = binary

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

6 Ways they test it

TYPE 1 Which storage type?

> *"Complete the table by writing the type of storage for each statement" [6]*

Spot it operation keywords.

1. pits/lands/laser = optical; platters/tracks/electromagnets = magnetic; NAND/NOR/gates/transistors = solid state.

TYPE 2 Why RAM / ROM

> *"Explain why a computer needs RAM" [3]; "why the smartwatch needs ROM" [2]*

Spot it "why".

1. Use the RAM vs ROM table: role + one characteristic.

TYPE 3 Describe operation

> *"Describe how the data is stored on the optical disk" [4]*

Spot it "describe how".

1. Follow the method boxes in order.

TYPE 4 Compare / choose

> *"Describe three differences between solid-state and optical storage" [6]; "most suitable storage for a smartphone; explain" [4]*

Spot it "differences", "suitable".

1. Compare the SAME property for both types. For a choice, link each property to the scenario.

7 What the examiner looks for

"Identify the most suitable type of secondary storage for the smartphone. Explain your choice" [4]

Marking points (one mark each, up to the marks shown)

- Solid state (1 mark), then any three:
- small / thin … so it fits easily into the smartphone
- no moving parts … so it is durable; data less likely to be lost if the phone is dropped
- fast read/write … so files and apps load quickly
- low power … so it does not drain the battery
- runs cool and quietly

KEYWORDS **no moving parts** **durable** **low power** **battery** **fast**

TOO VAGUE listing features without linking them to the smartphone

8 Past-paper questions, solved

0478/13/M/J/24 Q4 ↗ Paper 1 · Computer systems **6 marks** ⤢ Full size

4 The table contains statements about types of secondary storage.

Complete the table by writing the correct type of secondary storage for each statement.

type of secondary storage	statement
.....	Pits and lands are created on a reflective surface.
.....	NAND or NOR technology is used.
.....	Platters are spun that are divided into tracks and sectors.
.....	Electromagnets are used to read and write data.
.....	Transistors are used as control gates and floating gates.
.....	A red or blue laser is used to read and write data.

[6]

Swipe sideways to read the whole question

How to start Look for the keyword in each statement and map it with the operation methods.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

optical · solid state · magnetic · magnetic · solid state · optical

PART	ANSWER / WORKING	MARKS	GUIDANCE
4	optical (pits and lands) · solid-state (NAND/NOR) · magnetic (platters) · magnetic (electromagnets) · solid-state (control and floating gates) · optical (red or blue laser)	B6	

Total: 6 marks

2210/12/M/J/24 Q9 ↗ Paper 1 · Computer systems **8 marks** ⤢ Full size

9 A company uses both solid-state and optical secondary storage.

(a) Explain why a computer needs secondary storage.

..... [2]

(b) Describe **three** differences between solid-state and optical storage.

[6]

Swipe sideways to read the whole question

How to start (b) is six marks: three properties, each stated for BOTH types.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a) To store data and files permanently, otherwise programs would need to be installed again every time the computer was used.

(b) Solid-state has no moving parts, whereas optical has moving parts (the disk spins). Solid-state is faster to access data, whereas optical is slower. Solid-state stores data in transistors using NAND/NOR gates, whereas optical uses a laser to burn pits and lands onto a disk.

PART	ANSWER / WORKING	MARKS	GUIDANCE
9(a)	Any two: store permanently · otherwise reinstall each time · allow software to be installed · virtual memory	B2	
9(b)	Any six (max 3 for one type): moving parts · access speed · power · noise · durability · capacity · cost per GB · how data is stored	B6	

Total: 8 marks

2210/12/O/N/25 Q1 ↗ Paper 1 · Computer systems **4 marks** ⤢ Full size

1 A toy store gives each of the toys it sells a unique code. The codes are 3-digit hexadecimal codes, for example A4B.

A computer is used to store a database of the codes. The computer has 12-bit registers.

(e) The hexadecimal code for each toy is stored in a barcode that is displayed on each toy.

Each time a customer buys a toy, the barcode is scanned and the amount of stock stored in the database for that toy is reduced by 1.

An item of hardware is used in this system to receive the hexadecimal code from the barcode scanner and find it in the database. The item of hardware is built into a single chip.

(iv) A backup of the database is made at the end of each day using optical storage.

Describe how the database is written to the optical storage.

..... [4]

Swipe sideways to read the whole question

How to start Follow the optical method: four marking points.

▾ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

The disk is spun. A laser is shone onto the disk and burns pits into its surface in a spiral track. The pits and the unburnt lands represent the binary values.

PART	ANSWER / WORKING	MARKS	GUIDANCE
1(e)(iv)	Any four: disk spun · laser shone · pits burnt · in a spiral track · pits and lands represent binary	B4	

Total: 4 marks

9 Common mistakes

✗ "ROM stores the operating system"

✓ "ROM stores the BIOS / bootstrap"

The OS is on secondary storage and loaded into RAM.

✗ "RAM is permanent storage"

✓ "RAM is volatile: data in use, lost when power is off"

✗ "An SSD uses lasers"

✓ "An SSD uses transistors with control and floating gates"

✗ "Solid state is faster" (only one side)

✓ "Solid state is faster … optical is slower"

Differences need both sides.

10 Practice

Practice: easy, medium, hard

1. Is RAM volatile or non-volatile?
2. Name two examples of optical storage.
3. What are platters divided into?
1. State two differences between RAM and ROM.
2. Why does a Blu-ray disk hold more data than a DVD?
1. A video editor needs fast, large storage in a laptop that is carried every day. Recommend a storage type and justify it. [3]

11 Can I do this?

0 / 4 ticked

- [ ] I can explain primary storage, and why a computer needs both RAM and ROM.
- [ ] I can explain why secondary storage is needed.
- [ ] I can describe how magnetic, optical and solid-state storage work.
- [ ] I can compare storage types and choose one for a scenario.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

ANSWER Optical

2.

ANSWER Solid state

3.

ANSWER ROM

4.

ANSWER It is directly accessed by the CPU

Practice: easy, medium, hard

Easy 1.

ANSWER Volatile

Easy 2.

ANSWER e.g. CD, DVD (also Blu-ray)

Easy 3.

ANSWER Tracks and sectors

Medium 1.

ANSWER

RAM volatile / ROM non-volatile; RAM can be written to / ROM read only (also contents)

Medium 2.

ANSWER A blue laser has a shorter wavelength, so pits are smaller and closer together

Hard 1.

ANSWER

Solid state: no moving parts so durable when carried; fast access for large video files; low power for battery

NOTE 3.7

Virtual memory and cloud storage

1 In this note

SYLLABUS 3.3 DATA STORAGE

- 3.3.4 Describe what is meant by **virtual memory**, how it is created and used and why it is necessary.
- 3.3.5 Understand what is meant by **cloud storage**.
- 3.3.6 Explain the **advantages and disadvantages** of storing data on the cloud in comparison to storing it **locally**.

Before this: Primary and secondary storage. Next: Network hardware.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

RAM

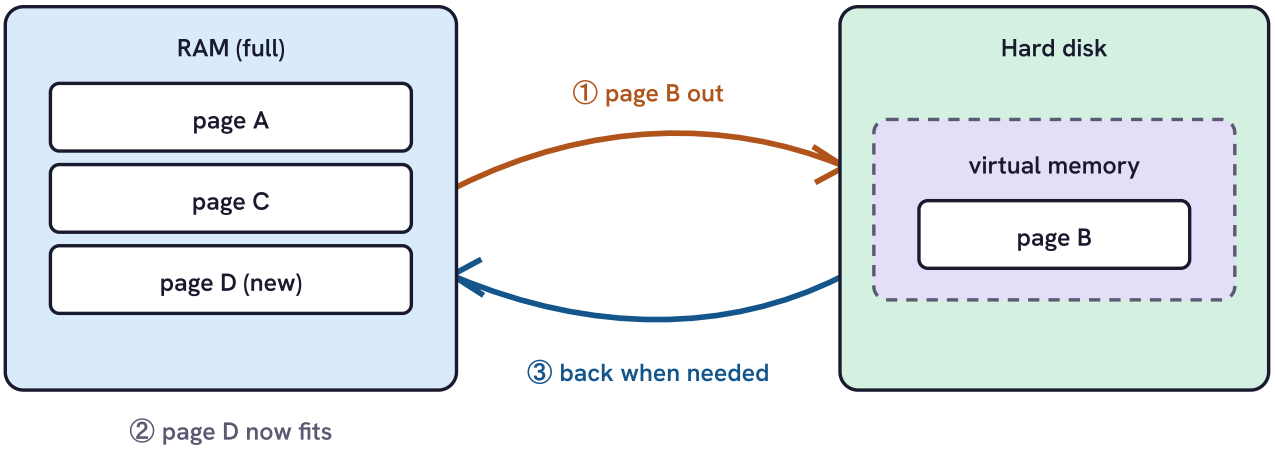
RAM holds the data and programs currently in use. It is fast but limited in size.

Quick check: what happens if you open more programs than RAM can hold?

Without virtual memory, the computer could crash or refuse to open them.

3 Virtual memory

Virtual memory is an area of **secondary storage** (usually the hard disk or SSD) that is used **as if it were RAM** when RAM is full. It is created by **partitioning** part of the secondary storage. Data is moved in blocks called **pages**.



Pages are swapped between RAM and virtual memory.

GENERAL METHOD **How virtual memory is used**

1. RAM becomes **full**.
2. Pages of data that are **not needed immediately** are **transferred from RAM to virtual memory**.
3. This **frees space in RAM** for the new data or program that is needed now.
4. When a page in virtual memory is **needed again**, it is **transferred back into RAM** (another page may be moved out to make room).

Why it is necessary	Its drawback
stops the computer **crashing** when RAM is full; lets **more / larger programs** run than RAM alone allows	secondary storage is **much slower** than RAM, so heavy use slows the computer ("disk thrashing" when pages keep swapping)

4 Cloud storage

Cloud storage is storage that is **accessed remotely**, usually over the **internet**, on a **collection of servers** owned and maintained by a **third party** (e.g. Google Drive, iCloud, OneDrive). The cloud still needs **physical servers and storage**: the data is just not on your own device. Storing data on your own device or your own server is **storing it locally**.

Advantages of the cloud (vs local)	Disadvantages of the cloud (vs local)
data can be **accessed from any location** and any device with an internet connection	needs an **internet connection**: no or unstable connection = no access
the **third party maintains** the hardware and its security; you do not	you **rely on the third party**: its security, and whether it stays in business
storage can be **increased easily** without buying new hardware	an **ongoing fee** (subscription) is often charged
no need to buy, house and power your own storage hardware	data may be **less secure** / stored in another country
the provider **backs up** the data	uploading / downloading large files can be **slow**
easy to **share** and collaborate on files	

TRY IT YOURSELF

1. Where is virtual memory created?
2. What are the blocks of data moved by virtual memory called?
3. Give one disadvantage of cloud storage.

5 Summary

- Virtual memory: a partition of secondary storage used as RAM when RAM is full.
- Pages not needed now move RAM → virtual memory; moved back when needed.
- Necessary: prevents crashing, more programs run. Drawback: slower than RAM.
- Cloud: remote collection of servers, third party, accessed over the internet; still physical servers.
- Cloud vs local: anywhere access, no maintenance, scalable, backed up · needs internet, third party, fees, security.

IF YOU SEE …

"explain how virtual memory can be used in this scenario"	→ partition · page B to VM · space for D · B back when needed
"explain two advantages of cloud storage"	→ point + consequence for the scenario ("… so employees can work from home")

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

6 Ways they test it

TYPE 1 **VM scenario**

> *"Pages A, B, C in RAM; page D needs to be sent; explain how virtual memory can be used" [4]*

Spot it named pages.

1. Use the letters given: page B to VM, D into RAM, B back later.

TYPE 2 **Name it**

> *"Give the name of the partitioned section of the secondary storage" [1]*

Spot it "partitioned".

1. Virtual memory.

TYPE 3 **Cloud definition**

> *"Describe what is meant by cloud storage" [2]*

Spot it "cloud".

1. collection of servers · remote · accessed over the internet · third party

TYPE 4 **Cloud pros / cons**

> *"Explain two advantages for the owners ..." [4]; "one disadvantage to employees" [2]*

Spot it "explain".

1. Two marks each: the point, then "... meaning that" for the people in the question.

7 What the examiner looks for

"Explain two advantages for the owners of the company of storing its data in cloud storage" [4]

Marking points (one mark each, up to the marks shown)

- Data can be accessed from any location ... meaning employees can work from anywhere with a connection
- Hardware is owned/maintained by a third party ... so the company is not responsible for maintenance / security
- Storage can be increased easily ... without buying new hardware
- No need to house the hardware ... saving the cost of the space
- The cloud system backs up the data ... so the company does not need to

KEYWORDS **any location** **third party** **maintain** **increase** **back up**

8 Past-paper questions, solved

0478/13/M/J/23 Q10 ↗ Paper 1 · Computer systems **4 marks** ⤢ Full size

10 A computer has pages A, B and C that are stored in RAM. Page D needs to be sent to the RAM but the RAM is full.

Page B is **not** needed immediately.

Explain how virtual memory can be used in this scenario.

..... [4]

Swipe sideways to read the whole question

How to start Follow the method with the question's letters.

▼ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

Part of the secondary storage is partitioned to create virtual memory. Page B, which is not needed immediately, is sent from RAM to virtual memory. This makes space in RAM for page D. When page B is needed again (once another page has been processed), it is sent back from virtual memory to RAM.

PART	ANSWER / WORKING	MARKS	GUIDANCE
10	Any four: secondary storage partitioned · page B sent to VM · makes space for page D · once another page not required · page B sent back to RAM when required	B4	

Total: 4 marks

2 A company employee is editing a video for the company's website.

Data is stored in the random access memory (RAM) when the video is edited.

The RAM becomes full and pages of data are transmitted to a partitioned section of the secondary storage to stop the computer from crashing.

(a) Give the name of the partitioned section of the secondary storage that is used in this process.

..... [1]

(b) The secondary storage is a hard disk drive (HDD). An HDD is an example of magnetic storage.

One feature of magnetic storage is that it uses platters.

Give **three** other features of magnetic storage.

[3]

(c) Give the reasons why an HDD is an example of secondary storage.

..... [2]

Swipe sideways to read the whole question

How to start (b) the question already gives platters, so give three other features. (c) two reasons from the definition of secondary storage.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a) Virtual memory.

(b) The platters are divided into tracks and sectors. The platters rotate (it has moving parts). It uses a read/write head with an electromagnet.

(c) It is not directly accessed by the CPU, and it stores data permanently until the user deletes it (non-volatile).

PART	ANSWER / WORKING	MARKS	GUIDANCE
2(a)	Virtual memory	**B1**	
2(b)	Any three: tracks / sectors · platters rotate / moving parts · read/write head · electromagnet · magnetised dots	**B3**	
2(c)	not directly accessed by the CPU · stores data permanently / non-volatile	**B2**	

Total: 6 marks

6 A company uses cloud storage to store its data.

(a) Tick (✓) **one** box to show which is **not** a characteristic of cloud storage.

A Data is accessed through a network ☐

B Data is stored locally ☐

C Data is stored remotely ☐

D Physical servers are used to store the data ☐

[1]

(b) Explain **two** advantages for the owners of the company of storing its data in cloud storage.

1 .....

.....

.....

.....

2 .....

.....

.....

.....

[4]

(c) Explain **one** disadvantage to employees of the company storing data in the cloud.

.....

.....

.....

..... [2]

Swipe sideways to read the whole question

How to start (b) and (c) are point + expansion: say what happens for the owners / the employees.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a) B (data is stored locally).

(b) 1: The data can be accessed from any location, meaning employees can work from anywhere with an internet connection. 2: The hardware is maintained by a third party, meaning the company is not responsible for maintaining it or its security.

(c) An internet connection is needed, and if it is unavailable or unstable the employees cannot access the data.

PART	ANSWER / WORKING	MARKS	GUIDANCE
6(a)	B	B1	
6(b)	Two advantages with expansion: any location ... work anywhere · third party ... not responsible · increase storage ... no new hardware · no need to house hardware ... saves cost · backs up ... company need not	B4	
6(c)	internet connection needed ... if unavailable, no access // pressured to work out of hours ... access from anywhere	B2	

Total: 7 marks

9 Common mistakes

✗ "Virtual memory is extra RAM"

✓ "Virtual memory is part of secondary storage used as RAM"

✗ "Virtual memory makes the computer faster"

✓ "It stops it crashing; it is slower than RAM"

✗ "The cloud has no hardware"

✓ "Cloud data is on physical servers owned by a third party"

✗ "You can access it anywhere" with no expansion

✓ "... so employees can work from home"

Explain = point + effect.

10 Practice

Practice: easy, medium, hard

1. Is cloud storage accessed locally or remotely?
2. What is virtual memory used for?
1. Explain why virtual memory is necessary. [2]
2. Give two advantages of storing photos on the cloud instead of a phone.
1. Explain one disadvantage of a computer relying heavily on virtual memory. [2]

11 Can I do this?

0 / 3 ticked

- [ ] I can describe how virtual memory is created and used, and why it is necessary.
- [ ] I can describe cloud storage.
- [ ] I can explain advantages and disadvantages of cloud storage vs local storage.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

ANSWER On secondary storage (a partition of the hard disk / SSD)

2.

ANSWER Pages

3.

ANSWER Needs an internet connection (also: relies on third party, fee, security)

Practice: easy, medium, hard

Easy 1.

ANSWER Remotely

Easy 2.

ANSWER As extra RAM when RAM is full

Medium 1.

ANSWER

When RAM is full, pages can be moved out so new data fits; stops the computer crashing

Medium 2.

ANSWER

Access from any device / location; frees phone storage; backed up if the phone is lost

Hard 1.

ANSWER

Secondary storage is slower than RAM, so moving pages back and forth slows the computer

NOTE 3.8

Network hardware

1 In this note

SYLLABUS 3.4 NETWORK HARDWARE

- 3.4.1 Understand that a computer needs a **network interface card (NIC)** to access a network.
- 3.4.2 Understand what is meant by, and the purpose of, a **media access control (MAC) address**, including its structure.
- 3.4.3 Understand what is meant by, and the purpose of, an **internet protocol (IP) address**, and that there are different types: **static / dynamic**, **IPv4 / IPv6**.
- 3.4.4 Describe the role of a **router** in a network.

Before this: Virtual memory and cloud storage.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

Hexadecimal

One hex digit = 4 bits; two hex digits = 1 byte.

Quick check: how many bits in 12 hex digits?

48 bits.

Packets

Data on a network is sent in packets, each with the destination address in its header.

Quick check: why does a packet need an address?

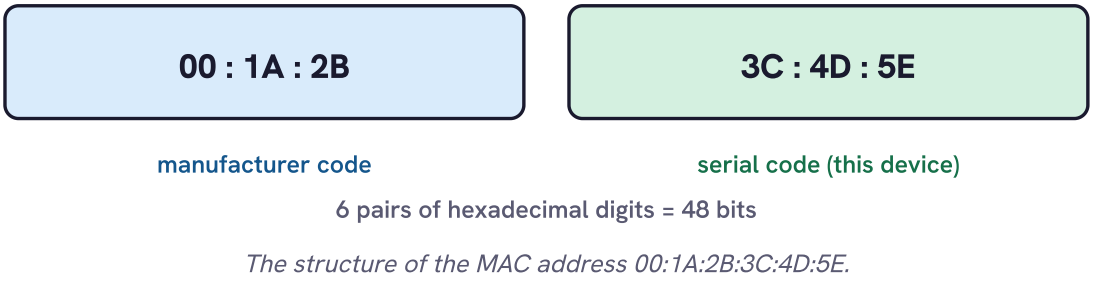
So routers can send it to the right device.

3 Network interface card (NIC)

A **network interface card (NIC)** is the component in a device that **allows it to connect to a network**. It can be wired (an Ethernet port) or wireless (a **WNIC**). Every NIC is given a **MAC address** when it is **manufactured**.

4 MAC address

A **media access control (MAC) address** is a **unique** address **assigned by the manufacturer** that identifies a device on a network. It is **usually written in hexadecimal** (12 hex digits, 48 bits), in pairs separated by colons or dashes. Because it is set at manufacture it normally **does not change**.



The structure of the MAC address 00:1A:2B:3C:4D:5E.

It has two parts: the **manufacturer code** (identifies who made the device) and the **serial code** (identifies this particular device from that manufacturer).

5 IP address

An **internet protocol (IP) address** is an address **allocated by the network** (normally by the **router**) that is used to **identify a device on a network** so data can be sent to it. Unlike a MAC address it can change, for example when the device joins a different network.

Static IP address	Dynamic IP address
does not change: the same every time the device connects	**can change** each time the device connects to the network
set manually / reserved	allocated **automatically** by the router (from a pool)
used for servers (a web server must always be found at the same address)	used for most home devices; addresses are reused, so fewer are needed

	IPv4	IPv6
size	**32 bits**	**128 bits**
written as	**denary**, **4 groups** of numbers **0-255**, separated by **dots**	**hexadecimal**, **8 groups** of 4 hex digits (0000-FFFF), separated by **colons**
example	192.168.1.25	2001:0db8:85a3:0000:0000:8a2e:0370:7334 shortened: 2001:db8:85a3::8a2e:370:7334
number of addresses	about 4.3 billion (2^{32}): **running out**	**far more** (2^{128})
shortening	all digits shown	leading zeros dropped; **a double colon** :: can replace consecutive groups of zeros (once only)

> Similarities to remember: both IPv4 and IPv6 identify a device on a network, both are unique on that network, both can be static or dynamic, both can be assigned by a router, both can be public or private.

6 Router

A **router** **sends data to a specific destination** on a network: it reads the destination IP address in each packet's header and **forwards the packet** towards it. A router can **assign IP addresses** to the devices connected to it, and it **connects a local network to the internet** (a home router joins every device in the house to the internet).

Term	One-line meaning
NIC	component that lets a device connect to a network
MAC address	unique hex address set by the manufacturer: manufacturer code + serial code
IP address	address allocated by the network to identify a device; static or dynamic; IPv4 or IPv6
Router	forwards packets to their destination; assigns IP addresses; connects a LAN to the internet

TRY IT YOURSELF

1. Which address is assigned by the manufacturer?

2 How many bits is an IPv6 address?

3 Which device assigns dynamic IP addresses on a home network?

4 Is 192.168.1.300 a valid IPv4 address?

7 Summary

- NIC: needed to connect to a network; given a MAC address at manufacture.
- MAC: unique, set by the manufacturer, hex, 48 bits; manufacturer code + serial code.
- IP: allocated by the network to identify a device; static (same) or dynamic (can change each time).
- IPv4: 32-bit, 4 denary groups 0-255, dots. IPv6: 128-bit, 8 hex groups, colons, :: shortening, more addresses.
- Router: forwards packets to the destination, assigns IP addresses, connects a LAN to the internet.

IF YOU SEE …

"describe the characteristics of an IPv4 address"	→ denary · 0-255 · 32 bits · 4 groups · dots · unique · static or dynamic
"describe two differences between IPv4 and IPv6"	→ state each property for BOTH: bits · denary vs hex · dots vs colons · groups

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

8 Ways they test it

TYPE 1 Identify

> *"Identify the component needed to access a network" [1]; "the type of address allocated by the manufacturer" [1]*

Spot it "identify".

1. NIC · MAC address · router.

TYPE 2 Terms table

> *"Complete the table by giving the missing term or definition" [5]*

Spot it a table.

1. Use the one-line meanings; firewall also appears (chapter 5).

TYPE 3 IPv4 / IPv6

> *"Describe the characteristics of an IPv4 address" [4]; "two differences" [4]; "give an example" [1]*

Spot it "IPv4", "IPv6".

1. Comparisons need both sides. An example must follow the format exactly.

TYPE 4 Dynamic

> *"Describe what is meant by a dynamic IP address" [3]*

Spot it "dynamic".

1. identifies a device · can change · each time it connects

9 What the examiner looks for

"Describe the characteristics of an IPv4 address" [4]

Marking points (one mark each, up to the marks shown)

- It is denary based … with numbers between 0 and 255
- It is 32 bits
- 4 sets / groups of numbers … separated by dots
- Any two: unique · can be static or dynamic · can be public or private · contains the network prefix and host number

KEYWORDS **denary** **0-255** **32 bits** **4 groups** **dots**

10 Past-paper questions, solved

2210/11/M/J/23 Q6 ↗ Paper 1 · Computer systems **6 marks** ⤢ Full size

6 A user wants to connect their computer to a network.

(a) (i) Identify the component in the computer that is needed to access a network.

..... [1]

(ii) Identify the type of address that is allocated to the component by the manufacturer, which is used to uniquely identify the device.

..... [1]

(b) A dynamic internet protocol (IP) address is allocated to the computer when it is connected to the network.

(i) Identify the device on the network that can connect multiple devices and automatically assign them an IP address.

..... [1]

(ii) Describe what is meant by a dynamic IP address.

..... [3]

Swipe sideways to read the whole question

How to start Four short identify answers and one 3-mark description.

▾ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

(a)(i) Network interface card (NIC). (ii) MAC address.

(b)(i) Router. (ii) An IP address that uniquely identifies the device on the network, but it can change: a new one may be allocated each time the device connects to the network.

PART	ANSWER / WORKING	MARKS	GUIDANCE
6(a)(i)	NIC // WNIC	B1	
6(a)(ii)	MAC address	B1	
6(b)(i)	Router	B1	
6(b)(ii)	uniquely identifies a device · can change · each time it is connected	B3	

Total: 6 marks

0478/13/M/J/23 Q9 ↗ Paper 1 · Computer systems **5 marks** ⤢ Full size

9 A device can be given an internet protocol (IP) address. This can be an IPv4 or IPv6.

(a) Give **one** similarity between IPv4 and IPv6.

..... [1]

(b) Describe **two** differences between IPv4 and IPv6.

[4]

Swipe sideways to read the whole question

How to start (b) each difference = 2 marks: the IPv4 side and the IPv6 side.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a) Both are used to identify a device on a network.

(b) 1: IPv4 is 32 bits, whereas IPv6 is 128 bits. 2: IPv4 is written in denary separated by dots, whereas IPv6 is written in hexadecimal separated by colons.

PART	ANSWER / WORKING	MARKS	GUIDANCE
9(a)	Any one: identify a device · static / dynamic · unique · assigned by a router · public / private	B1	
9(b)	Two differences, both sides each: denary / hex · dots / colons · 32 / 128 bit · 4 / 8 groups · 0-255 / 0000-FFFF · IPv6 :: shortening · fewer / more addresses	B4	

Total: 5 marks

3 **Five** network terms or definitions are given in the table.

Complete the table by giving the missing term or definition.

Term	Definition
router	....
.....	This address is assigned by the network and used to identify a device on a network.
network interface card (NIC)	....
.....	This address is assigned by the manufacturer and is used to uniquely identify the device.
.....	This can be hardware or software based and filters traffic coming into and out of a network.

[5]

Swipe sideways to read the whole question

How to start Three definitions and two terms. "Assigned by the network" = IP; "assigned by the manufacturer" = MAC.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

Router: a device that forwards packets to their correct destination on a network. IP address. NIC: a component in a device that enables it to connect to a network. MAC address. Firewall.

PART	ANSWER / WORKING	MARKS	GUIDANCE
3	router definition · IP address · NIC definition · MAC address · firewall // proxy server	B5	

Total: 5 marks

11 Common mistakes

✗ "A MAC address is assigned by the router"	✓ "MAC: by the manufacturer. IP: by the network / router"
✗ "IPv6 uses dots"	✓ "IPv6 uses colons and hexadecimal"
✗ IPv4 example 256.1.1.1	✓ every group 0-255, e.g. 10.245.3.99
✗ "A dynamic IP address changes all the time"	✓ "It can change each time the device connects"

12 Practice

Practice: easy, medium, hard

1 How many groups of numbers are in an IPv4 address?

2 What number base is a MAC address usually written in?

3 What does NIC stand for?

1 Name the two parts of a MAC address.

2 Give one reason why IPv6 was introduced.

1 Explain why a web server should have a static IP address. [2]

2 Shorten 2001:0db8:0000:0000:0000:0000:0000:0001.

13 Can I do this?

0 / 4 ticked

- [ ] I know a device needs a NIC to access a network.
- [ ] I can describe a MAC address and its structure.
- [ ] I can describe IP addresses: static vs dynamic, IPv4 vs IPv6.
- [ ] I can describe the role of a router.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

ANSWER **MAC address**

2.

ANSWER **128**

3.

ANSWER **Router**

4.

ANSWER **No: 300 is greater than 255**

Practice: easy, medium, hard

Easy 1.

ANSWER **4**

Easy 2.

ANSWER **Hexadecimal**

Easy 3.

ANSWER **Network interface card**

Medium 1.

ANSWER **Manufacturer code and serial code**

Medium 2.

ANSWER **IPv4 addresses are running out; IPv6 has far more addresses**

Hard 1.

ANSWER **Its address must not change so users / DNS can always find it at the same IP**

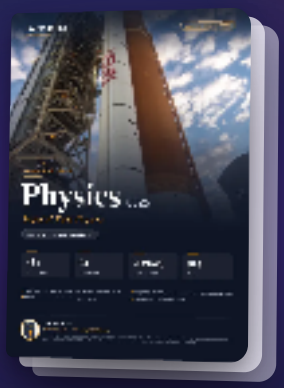
Hard 2.

ANSWER **2001:db8::1**

4

Software

NEW JUST LAUNCHED



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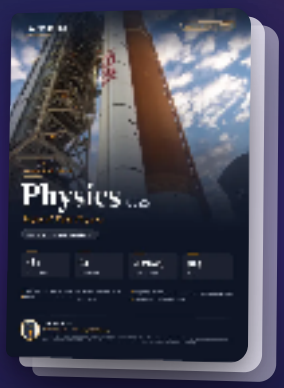

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NOTE 4.1

System and application software

1 In this note

SYLLABUS 4.1 TYPES OF SOFTWARE AND INTERRUPTS

- 4.1.1 Describe the difference between **system software** and **application software** and give examples of each.
- 4.1.2 Describe the role and basic **functions of an operating system**.

Next: Firmware and interrupts.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

Hardware vs software

Hardware is the physical parts you can touch. **Software** is the programs: the instructions that tell the hardware what to do.

Quick check: is a printer driver hardware or software?

Software.

3 System software and application software

Software means the **programs / instructions** used to operate a computer. There are two types.

	System software	Application software
purpose	provides the services that **the computer requires**: it **manages and maintains** the hardware and software	provides the services that **the user requires**: it lets the user **perform tasks**
examples	**operating system**; **utility software** such as anti-virus, firewall, defragmentation, backup, compression	word processor, spreadsheet, database, web browser, photo / video editor, email client, games, social media app

> A test you can use: **would the computer still need it if nobody used it for work?** Yes → system software. If it only exists to do a job for the user → application software. A web browser is an application; an anti-virus is a utility (system).

4 The operating system

The **operating system (OS)** is the system software that **manages the hardware**, performs the **basic functions** of the computer and provides a **platform for applications to run on** and an **interface** for the user. Examples: Windows, macOS, Linux, Android, iOS.

Function	What it means
Managing files	creating, naming, saving, moving, copying and deleting files and folders; organising storage
Handling interrupts	giving each interrupt a priority, queueing it and calling the interrupt service routine (next note)
Providing an interface	a GUI (windows, icons, menus, pointer) or a command-line interface so the user can communicate with the computer
Managing peripherals and drivers	communicating with input / output devices through their drivers; sending data to and receiving it from hardware; using buffers
Managing memory	allocating RAM to each process and freeing it; preventing two processes using the same memory; virtual memory
Managing multitasking	switching the CPU between several running processes so they appear to run at once
Providing a platform for running applications	letting application software run and communicate with the hardware
Providing system security	usernames and passwords, access rights, firewall, security updates
Managing user accounts	allowing several user accounts with their own files, settings and permissions

✗ COMMON MISTAKE

Not an OS function: loading the bootstrap. The bootstrap / BIOS is **firmware** that loads the operating system (next note). Learn the nine functions above by name: questions ask you to tick the odd one out.

TRY IT YOURSELF

1. Is anti-virus system or application software?
2. Which type of software manages inputs and outputs for the computer?

3 Give one function of an operating system that relates to memory.

5 Summary

- Software = programs / instructions used to operate a computer.
- System software: services the computer requires (OS, utilities). Application software: services the user requires.
- OS functions: files · interrupts · interface · peripherals and drivers · memory · multitasking · platform for apps · security · user accounts.

IF YOU SEE …

"describe the difference between system and application software"	→ computer requires … whereas … user requires · + one example of each
"identify one function of the OS and describe its purpose"	→ name it, then one sentence from the table

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

6 Ways they test it

TYPE 1 **Difference + examples**

> *"Describe the difference between system software and application software. Give an example of each" [4]*

Spot it "difference".

1 Two marks for the contrast ("whereas"), one per example.

TYPE 2 **Which is utility?**

> *"Tick one box to show which software is an example of utility software" [1]*

Spot it a list.

1. Utilities maintain the computer: anti-virus, defragmenter, backup, compression.

TYPE 3 **OS functions**

> *"Give two functions of an operating system" [2]; "identify one function and describe its purpose" [2]; "which is not a function" [1]*

Spot it "function".

1. Use the syllabus names exactly.

TYPE 4 **Purpose of the OS**

> *"Describe the purpose of the operating system" [3]*

Spot it "purpose".

1. basic functions · manages the hardware · platform for software · user interface

7 What the examiner looks for

Wording trap · Not an OS function

THE QUESTION **0478/11/O/N/24 Q7** ↗ Paper 1 · Computer systems — **1 mark**

Tick one box to show which of these is not a function of the operating system. A managing files · B providing an interface · C handling interrupts · D loading the bootstrap

✓ CREDITED

- D: loading the bootstrap

✗ NOT CREDITED

- A, B, C (all are syllabus OS functions)

WHY

The bootstrap is firmware: it runs before the operating system and loads it.

From: 0478/11/O/N/24 Q7(a)(i) mark scheme

8 Past-paper questions, solved

2210/12/M/J/23 Q10 ↗ Paper 1 · Computer systems **5 marks** ⤢ Full size

10 A user has both system software and application software installed on their computer.

(a) Describe the difference between system software and application software.

Give an example of each software in your answer.

..... [4]

(b) State which component in the computer would store both types of software when the power is turned off.

..... [1]

Swipe sideways to read the whole question

How to start (a) contrast + one example each. (b) where does software live with the power off?

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a) System software provides the services that the computer requires, for example an operating system or anti-virus utility, whereas application software provides the services that the user requires, for example a word processor.

(b) Secondary storage (e.g. the hard disk drive or SSD).

PART	ANSWER / WORKING	MARKS	GUIDANCE
10(a)	computer requires … whereas user requires · system example (OS / utility) · application example	B4	
10(b)	Secondary storage // HDD // SSD	B1	

Total: 5 marks

3 A computer has an operating system (OS).

(a) Complete the table by writing each missing OS function name and description.

Function name	Description
managing memory	…… …… …… ……
…… ……	allows application software to run on the computer
managing peripherals	…… …… …… ……

[3]

Swipe sideways to read the whole question

How to start Two descriptions and one function name are missing.

▾ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

Managing memory: allocates memory to each process and stops two processes accessing the same memory. Platform for running applications (allows application software to run). Managing peripherals: transmits data to and receives data from the hardware, using buffers.

PART	ANSWER / WORKING	MARKS	GUIDANCE
3(a)	managing memory description · platform for running applications · managing peripherals description	B3	

Total: 3 marks

2210/13/O/N/23 Q1 ↗ Paper 1 · Computer systems — **3 marks** — ⤢ Full size

1 A mobile telephone has built-in input and output devices.

(d) The mobile telephone has an operating system.

Describe the purpose of the operating system.

..... [3]

Swipe sideways to read the whole question

How to start Three marks: three separate points about what the OS does.

▾ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

It manages the phone's hardware, such as the touch screen and memory. It provides a platform for apps to run on. It provides a user interface so the user can communicate with the phone.

PART	ANSWER / WORKING	MARKS	GUIDANCE
1(d)	Any three: basic functions · manages the hardware · platform to run software · user interface · any example function	B3	

Total: 3 marks

9 Common mistakes

✗ "A web browser is system software" ✓ "A web browser is application software"

✗ "The OS loads the bootstrap" ✓ "The bootstrap (firmware) loads the OS"

✗ "Memory" as an OS function ✓ "Managing memory"

Name the function, not just the hardware.

10 Practice

Practice: easy, medium, hard

1. Is a spreadsheet system or application software? [1]
2. Give two examples of utility software. [2]
3. Describe what is meant by multitasking. [1]

2 State what is meant by software.

1 A school wants each student to have their own files that others cannot open. Which two OS functions make this possible? [2]

11 Can I do this?

0 / 2 ticked

- [ ] I can describe the difference between system and application software with examples.
- [ ] I can name and describe the functions of an operating system.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

ANSWER System (utility) software

2.

ANSWER Operating system (system software)

3.

ANSWER Managing memory (or managing multitasking)

Practice: easy, medium, hard

Easy 1.

ANSWER Application

Easy 2.

ANSWER e.g. anti-virus, defragmentation (also backup, compression, firewall)

Medium 1.

ANSWER

The OS switches the CPU between several processes so they appear to run at the same time

Medium 2.

ANSWER Programs / instructions used to operate a computer

Hard 1.

ANSWER Managing user accounts; providing system security (also managing files)

NOTE 4.2

Firmware and interrupts

1 In this note

SYLLABUS 4.1 TYPES OF SOFTWARE AND INTERRUPTS

- 4.1.3 Understand how **hardware**, **firmware** and an **operating system** are required to run **applications software**.
- 4.1.4 Describe the role and operation of **interrupts**: how one is **generated**, how it is **handled using an interrupt service routine**, and what happens as a result.

Before this: System and application software. Next: Programming languages and translators.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

ROM

ROM is non-volatile, read-only primary storage. It keeps its contents with the power off.

Quick check: what does ROM store?

The start-up instructions: the BIOS / bootstrap (firmware).

The FDE cycle

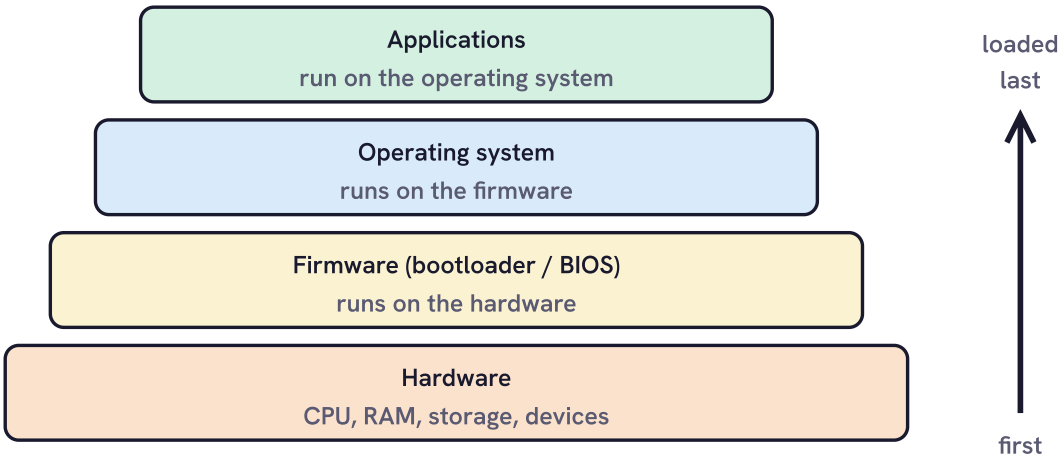
The CPU fetches, decodes and executes one instruction at a time.

Quick check: when can the CPU check for interrupts?

At the end of each fetch-decode-execute cycle.

3 Hardware, firmware, OS, applications

Firmware is software **permanently stored in ROM** that **controls the hardware**. The most important firmware is the **bootloader** (also called the bootstrap / BIOS): the instructions that **start up the computer** and load the operating system.



Each layer runs on the one below it.

GENERAL METHOD **What happens when you switch on**

1. The **hardware** powers up and the CPU runs the **bootloader**, which is **firmware stored in ROM**.
2. The bootloader **loads the operating system** from secondary storage into RAM: the OS **runs on the firmware**.
3. The OS gives a **platform** for the **applications**, which **run on the operating system**.

4 Interrupts

An **interrupt** is a **signal sent to the CPU** to show that **something needs its attention**. Interrupts let the computer react straight away to events (a key press, a printer running out of

paper) instead of checking every device all the time. They are managed by the **operating system** (its **interrupt handler**).

Hardware interrupts (from a device)	Software interrupts (from a program)
pressing a key on the keyboard; **moving the mouse** or clicking a button; plugging in a device; printer out of paper / ink; paper jam	**division by zero**; **two processes trying to access the same memory location**; a program asking for input / output; a null value error

GENERAL METHOD **How an interrupt is handled**

1. A device or program **generates an interrupt** (e.g. a key is pressed) and it is **sent to the CPU**.
2. The interrupt is given a **priority** and placed in the **interrupt queue**.
3. The CPU **finishes its current fetch-decode-execute cycle**, then **checks the interrupt queue**.
4. If the interrupt has a **higher priority** than the current task, the CPU **saves the current task** (the contents of its registers) and **calls the interrupt service routine (ISR)** for that interrupt.
5. The **ISR handles the interrupt** (e.g. reads the key, shows the "out of paper" message).
6. The CPU checks the queue again; when there are no more higher-priority interrupts it **restores the saved task** and carries on.
7. If the interrupt has a **lower priority**, the CPU simply continues the current task and the interrupt waits in the queue.

Interrupt service routine (ISR) (also called the interrupt handler): the sequence of instructions that handles one particular interrupt.

EXAMPLE **A printer runs out of paper**

Describe what happens.

The printer sends an interrupt to the CPU.

The interrupt is given a priority and placed in the interrupt queue.

The CPU finishes its current FDE cycle and checks the queue: the paper interrupt has a higher priority.

The CPU saves its current task and calls the ISR for the printer.

The ISR displays a message telling the user to add paper; the CPU then restores the saved task.

ANSWER

Result: the user sees "Out of paper" straight away, and the program they were using carries on.

TRY IT YOURSELF

1. Where is the bootloader stored?
2. Is division by zero a hardware or software interrupt?
3. What is the name of the program that services an interrupt?

5 Summary

- Applications run on the OS; the OS runs on the firmware; the bootloader (firmware, in ROM) runs on the hardware.
- Interrupt: a signal to the CPU that something needs attention; managed by the OS.
- Hardware interrupts: key press, mouse, printer. Software: division by zero, two processes same memory.
- Handling: priority → queue → CPU finishes FDE cycle → checks queue → saves task → ISR → restores task.

IF YOU SEE …

"explain how the processor manages the current program and the interrupt" [5]	→ priority · queue · finish FDE cycle · check queue · store task · ISR · restore
"state the purpose of an interrupt"	→ to indicate something needs the attention of the CPU

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

6 Ways they test it

TYPE 1 **Layers cloze**

> *"... software is run on the operating system. The ... system is run on the firmware, which is run on the ..." [4]*

Spot it a word list.

1 Applications → OS → firmware → hardware.

TYPE 2 **Firmware**

> *"State the purpose of firmware" [1]; "give one example" [1]*

Spot it "firmware".

1. Purpose: permanently stores instructions to start the computer / control the hardware. Example: bootloader, BIOS.

TYPE 3 **Examples**

> *"Give two examples of a hardware / software interrupt" [2]*

Spot it "examples".

1. Use the table.

TYPE 4 **Handling**

> *"Describe how interrupts are used when a key is pressed" [5]; the printer paragraph [7]*

Spot it "describe how".

1. Follow the handling method in order, naming the device from the question.

7 What the examiner looks for

"Describe how interrupts are used when a key is pressed on a keyboard" [5]

Marking points (one mark each, up to the marks shown)

- Key press generates the interrupt
- Interrupt is given a priority
- Interrupt is sent to the CPU ... and placed in a queue
- CPU stops its current task (at the end of the FDE cycle) to check the queue / service the interrupt ...
- ... using an interrupt service routine
- If the key press is the highest priority the interrupt is processed

KEYWORDS **priority** **queue** **interrupt service routine**

8 Past-paper questions, solved

2210/11/M/J/23 Q4 ↗ Paper 1 · Computer systems **4 marks** ⤢ Full size

4 Complete the statements about different types of software.

Use the terms from the list.

Some of the terms in the list will **not** be used. You should only use a term once.

application assembly language bootloader central processing unit (CPU)
firmware hardware operating output system user

..... software provides the services that the computer requires; an example is utility software.

..... software is run on the operating system.

The ..... system is run on the firmware, which is run on the ..... .

[4]

Swipe sideways to read the whole question

How to start Use the layer diagram: who runs on whom?

▼ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

System software provides the services that the computer requires … **Application** software is run on the operating system. The **operating** system is run on the firmware, which is run on the **hardware**.

PART	ANSWER / WORKING	MARKS	GUIDANCE
4	System · Application · Operating · Hardware	B4	

Total: 4 marks

9 A printer runs out of ink and needs a new ink cartridge. An interrupt is sent and a message is generated to notify the user that the ink cartridge is empty.

(a) Complete the paragraph about the use of an interrupt in this process.

Use the terms from the list.

Some of the terms in the list will **not** be used. You should only use a term once.

binary clock computer data error

fetch–decode–execute cycle hexadecimal higher interrupt queue

interrupt service routine (ISR) lower printer priority level

secondary storage sorting transmission

The ..... sends an interrupt to the

..... . The interrupt is given a

..... . The processor completes its current

..... and checks the

..... to see if there is an interrupt with

..... priority than the current task. If there is, it stores the current task and fetches the interrupt. It then calls the

..... , which is a sequence of instructions that handles the interrupt. The interrupt is handled, which generates a message to the user to notify them that the ink cartridge is empty.

[7]

(b) Handling interrupts is one function of an operating system.

Give **two** functions of an operating system that relate to memory.

1 .....

2 .....

[2]

Swipe sideways to read the whole question

How to start (a) follow the handling method. (b) which OS functions are about memory?

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a) printer · computer · priority level · fetch-decode-execute cycle · interrupt queue · higher · interrupt service routine (ISR)

(b) Managing memory; managing multitasking.

PART	ANSWER / WORKING	MARKS	GUIDANCE
9(a)	printer · computer · priority level · FDE cycle · interrupt queue · higher · ISR	B7	
9(b)	memory management · multitasking	B2	

Total: 9 marks

9 An interrupt is a type of signal that is used in a computer.

(a) State the name of the type of software that manages interrupts.

..... [1]

(b) Describe how interrupts are used when a key is pressed on a keyboard.

..... [5]

(c) Interrupts can be hardware based or software based.

A key press is one example of a hardware interrupt.

(i) Give **two** other examples of a hardware interrupt.

[2]

(ii) Give **two** examples of a software interrupt.

[2]

Swipe sideways to read the whole question

How to start (b) is the handling method for a key press. (c) two of each kind.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a) The operating system.

(b) Pressing the key generates an interrupt, which is sent to the CPU. It is given a priority and placed in the interrupt queue. The CPU finishes its current FDE cycle and checks the queue. If the key press has the highest priority, the CPU saves its current task and services the interrupt using an interrupt service routine.

(c)(i) Moving the mouse; a printer running out of paper. (ii) Division by zero; two processes accessing the same memory location.

PART	ANSWER / WORKING	MARKS	GUIDANCE
9(a)	Operating system // interrupt handler	**B1**	
9(b)	Any five: key press generates · priority · sent to CPU · queue · CPU stops current task / checks queue · ISR · highest priority processed	**B5**	
9(c)(i)	Any two: moving / clicking the mouse · plugging in a device · paper jam · out of paper	**B2**	
9(c)(ii)	Any two: division by zero · two processes same memory location · null value	**B2**	

Total: 10 marks

9 Common mistakes

✗ "The CPU stops immediately"

✓ "The CPU finishes its current FDE cycle first"

✗	✓
"The interrupt is always handled straight away"	"Only if it has a higher priority than the current task"
"Firmware is stored in RAM"	"Firmware is permanently stored in ROM"
"Typing a letter" as a software interrupt	A key press is a hardware interrupt

10 Practice

Practice: easy, medium, hard

1. Which software runs directly on the hardware?
2. Give one example of a hardware interrupt.
1. State the purpose of an interrupt.
2. Explain why the CPU saves its current task before servicing an interrupt.
1. A program divides a number by zero while a user is moving the mouse. Explain how the CPU decides which interrupt to service first. [2]

11 Can I do this?

0 / 3 ticked

- [ ] I can explain how hardware, firmware and the OS are needed to run applications.
- [ ] I can give examples of hardware and software interrupts.
- [ ] I can describe how an interrupt is handled using an ISR.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

ANSWER In ROM (it is firmware)

2.

ANSWER Software

3.

ANSWER Interrupt service routine (ISR) / interrupt handler

Practice: easy, medium, hard

Easy 1.

ANSWER Firmware (the bootloader)

Easy 2.

ANSWER e.g. a key press

Medium 1.

ANSWER To indicate that something needs the attention of the CPU

Medium 2.

ANSWER So it can restore it and carry on from the same point afterwards

Hard 1.

ANSWER

Each interrupt is given a priority and placed in a queue; the CPU services the highest priority one first

NOTE 4.3

Programming languages and translators

1 In this note

SYLLABUS 4.2 TYPES OF PROGRAMMING LANGUAGE, TRANSLATORS AND IDES

- 4.2.1 Explain what is meant by a **high-level language** and a **low-level language**, including the advantages and disadvantages of each.
- 4.2.2 Understand that **assembly language** is a low-level language that uses **mnemonics**, and that an **assembler** translates it into machine code.
- 4.2.3 Describe the operation of a **compiler** and an **interpreter**: how each translates and how **errors are reported**.
- 4.2.4 Explain the advantages and disadvantages of a compiler and an interpreter.

Before this: Firmware and interrupts. Next: Integrated development environments (IDEs).

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

Machine code

The CPU can only execute **machine code**: binary instructions from its instruction set.

Quick check: can the CPU run Python directly?

No: it must be translated into machine code first.

3 High-level and low-level languages

A **high-level language** is **close to human language** (English words and maths symbols), e.g. Python, Java, Visual Basic. A **low-level language** is **close to the language processed by the computer**: **machine code** (binary) or **assembly language**.

The same job at three levels	Code
high-level	`Total ← Price + Tax`

assembly language (low-level)	`LDA Price`
	`ADD Tax`
	`STO Total`

machine code (low-level)	`0001 1010`
	`0011 1011`
	`0010 1100`

	High-level language	Low-level language
advantages	**easier to read, write and understand** → fewer mistakes, written faster **easier to debug** **machine independent** (portable): runs on different types of computer programmer can focus on the problem, not the hardware	**direct manipulation of the hardware** / memory **more memory efficient**, **faster to execute** can use specialised / machine-specific instructions (machine code) needs no translator
disadvantages	**cannot directly manipulate the hardware** may be less efficient (uses more memory, slower) needs a compiler or interpreter	**hard to read and write** **hard to debug** **machine dependent**: only works on one type of CPU needs knowledge of the hardware

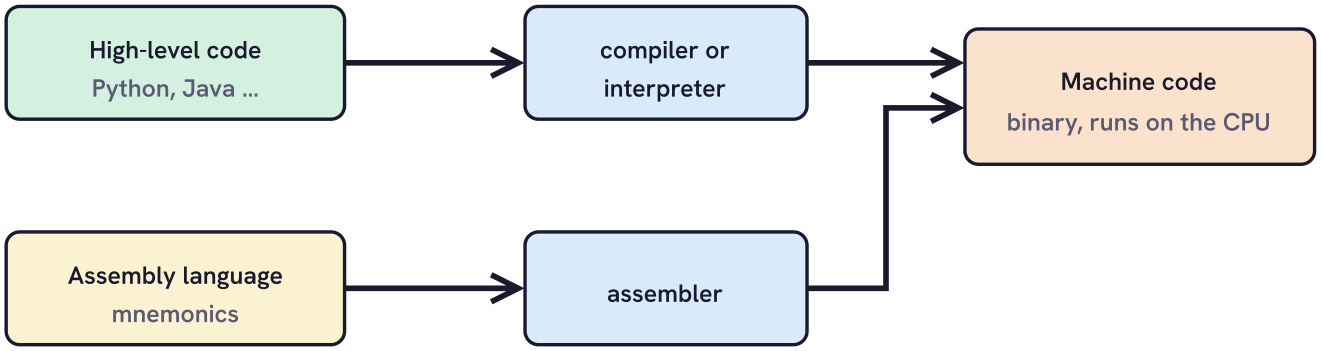
> Choosing: a program that must be written **quickly**, be **easy to maintain** or run on **many computers** → high-level. A program that must **control hardware directly**, use **little memory** or run **very fast** (e.g. an embedded system in a vending machine) → low-level.

4 Assembly language and the assembler

Assembly language is a **low-level language** that uses **mnemonics**: short codes such as LDA (load), ADD, STO (store) that stand for machine code instructions. Each assembly instruction

usually matches one machine code instruction. An **assembler** is the translator that converts assembly language into machine code.

5 Compilers and interpreters



Every program must become machine code before the CPU can execute it.

	Compiler	Interpreter
how it translates	translates the **whole code at once before executing** it	translates and executes the code **line by line**
output	produces an **executable file** (object code) that runs without the compiler	**no executable file**: the interpreter is needed every time it runs
errors	produces an **error report for the whole code**, listing all errors; nothing runs until they are fixed	**stops execution when an error is found**; once it is corrected, execution can continue from that point
speed of running	the executable runs **fast** (already translated)	**slower**: every line is translated each time it runs
best used	to translate the **final program** for distribution (the source code is not given away)	**while developing** a program: test and debug parts as you go

Advantages of an interpreter during development	Advantages of a compiler for the final program
errors are found **line by line**, where they happen → easy to debug can **correct and continue** without retranslating everything can **test sections** of incomplete code	executable file **runs without the translator** **runs faster** users **cannot see the source code** (harder to copy) all errors reported at once

TRY IT YOURSELF

1. Which translator converts assembly language into machine code?
2. Which translator produces an executable file?
3. Which translator stops when it finds an error?
4. Is a high-level language machine dependent or independent?

6 Summary

- High-level: close to English; easy to read, write, debug; machine independent; can't manipulate hardware directly.
- Low-level (machine code, assembly): close to the computer; direct hardware control, memory efficient, fast; hard to read/debug, machine dependent.
- Assembly language uses mnemonics; an assembler translates it.
- Compiler: whole code at once, executable file, error report of all errors; used for the final program.
- Interpreter: line by line, stops at an error, no executable; used during development.

IF YOU SEE …

"describe the operation of a compiler and of an interpreter"	→ whole code / executable / error report vs line by line / stops at error
"explain the reasons for your choice" (high or low)	→ match each reason to the scenario: "... so the game can run on any computer"

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

7 Ways they test it

TYPE 1 Choose a level

> *"Tick high-level or low-level. Explain the reasons for your choice" [4]*

Spot it a scenario.

1. No mark for the tick: all four marks are for reasons that match it.

TYPE 2 Low-level / assembly

> *"Describe what is meant by assembly language" [2]; "identify the translator" [1]*

Spot it "assembly".

1. low-level · mnemonics · communicates directly with hardware · assembler

TYPE 3 Which translator?

> *"Identify the translator that converts and executes line by line / creates an executable" [1] each*

Spot it a description.

1. line by line / stops → interpreter; whole code / executable / error report → compiler; mnemonics → assembler.

TYPE 4 Translator cloze

> *"A compiler translates the … at once before … it …" [5]*

Spot it a word list.

1. Use the compiler / interpreter table.

TYPE 5 **Advantages**

> *"Describe the advantages of using an interpreter instead of a compiler during software development" [4]*

Spot it "during development".

1 Line by line errors · correct and continue · no retranslating · test sections.

8 What the examiner looks for

"Describe how the compiler translates the program" [3] and "how it reports errors" [2]

Marking points (one mark each, up to the marks shown)

- It translates the high-level language into low-level language / machine code / object code
- It translates all the code before it is executed
- It creates an executable file
- It creates an error report after trying to compile … displaying all the errors in the code
- … which must be corrected before the code can be executed

KEYWORDS **all the code** **before executed** **executable file** **error report**

9 Past-paper questions, solved

0478/12/F/M/23 Q2 ↗ Paper 1 · Computer systems **8 marks** ⤢ Full size

2 A programmer has designed a three-dimensional (3D) interactive computer game. They are going to develop a program for the game. The program needs to run efficiently, but it must also be developed as soon as possible.

(a) Tick (✓) **one** box to identify whether the programmer should use a high-level language or a low-level language to develop the program.

Explain the reasons for your choice.

High-level language ☐

Low-level language ☐

Reasons for your choice .....

.....

.....

.....

.....

.....

.....

..... [4]

(b) If the programmer chooses a high-level language, they can use a compiler or an interpreter to translate the high-level language into a low-level language.

Describe the operation of a compiler and of an interpreter.

Compiler .....

.....

.....

.....

Interpreter .....

.....

.....

.....

[4]

Swipe sideways to read the whole question

How to start The scenario says "developed as soon as possible", which points to high-level. Then give four reasons with their effect.

▼ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

(a) High-level language. It is easier for the programmer to read and write, so they make fewer mistakes and can write it in a shorter time. It is easier to debug, so errors are found and corrected faster. It is machine independent, so the game can be played on many different computers.

(b) Compiler: translates all the code before executing any of it, produces an executable file, and gives an error report listing all the errors. Interpreter: translates and executes one line at a time, and stops when it finds an error.

PART	ANSWER / WORKING	MARKS	GUIDANCE
2(a)	No mark for choice. Any four matching reasons: easier to read / write … fewer mistakes / quicker · easier to debug … less time · machine independent … any computer (or low-level: memory efficient · direct manipulation …)	B4	
2(b)	Compiler, two from: checks all code before executing · error report for whole code · executable file. Interpreter, two from: one line translated and executed at a time · stops at an error	B4	

Total: 8 marks

3 A programmer writes a program to store and sort all the data for the books in her home library.

(b) The programmer uses an integrated development environment (IDE) to write the program.

One function of the IDE is to provide a translator.

(i) Complete the statements about translators.

Use the terms from the list. Some of the terms will **not** be used. You should only use a term once.

all together	all	assembler	binary	error
executable file	executing	interrupt	line by line	
partial code	some	translating	whole code	

A compiler translates the ..... at once before

..... it. A compiler produces an error report that displays

..... errors.

An interpreter translates and executes the code ..... .

An interpreter stops execution when an ..... is found

and continues once it is corrected.

[5]

Swipe sideways to read the whole question

How to start Five gaps, all from the compiler / interpreter table.

▾ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

A compiler translates the **whole code** at once before **executing** it. A compiler produces an error report that displays **all** errors. An interpreter translates and executes the code **line by line**. An interpreter stops execution when an **error** is found and continues once it is corrected.

PART	ANSWER / WORKING	MARKS	GUIDANCE
3(b)(i)	whole code · executing · all · line by line · error	B5	

Total: 5 marks

2210/12/O/N/25 Q3 ↗ Paper 1 · Computer systems — **4 marks** — ⤢ Full size

3 A programmer uses assembly language to create a program for a coffee machine.

(a) Describe what is meant by assembly language.

..... [2]

(b) Identify the translator needed for assembly language.

..... [1]

(c) Tick (✓) **one** box to show which statement is an advantage of using assembly language.

A It is close to human language. ☐

B It is memory efficient. ☐

C It is easy to debug. ☐

D It is machine independent. ☐

[1]

Swipe sideways to read the whole question

How to start (a) two facts about assembly. (c) which option is a LOW-level advantage?

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a) It is a low-level language that uses mnemonics.

(b) Assembler.

(c) B: it is memory efficient.

PART	ANSWER / WORKING	MARKS	GUIDANCE
3(a)	Any two: low-level · mnemonics · communicates directly with the hardware	B2	
3(b)	Assembler	B1	
3(c)	B	B1	

Total: 4 marks

10 Common mistakes

✗ "A compiler translates line by line" ✓ "An interpreter translates line by line"

✗ "An assembler translates high-level code" ✓ "An assembler translates assembly language"

✗ "High-level is easier" (no reason) ✓ "easier to read and write, so fewer mistakes"

Every reason needs its effect.

✗ "Low-level languages are machine independent" ✓ "High-level languages are machine independent"

11 Practice

Practice: easy, medium, hard

1. Give one example of a low-level language.
2. What are the short codes in assembly language called?
1. Give two reasons a programmer might write a vending machine program in a low-level language.
2. Give two disadvantages of a high-level language.
1. A company sells a finished game. Explain why it is compiled rather than interpreted. [3]

12 Can I do this?

0 / 4 ticked

- [ ] I can explain high- and low-level languages with advantages and disadvantages.
- [ ] I can describe assembly language and the assembler.
- [ ] I can describe how a compiler and an interpreter translate and report errors.
- [ ] I can explain the advantages of each translator.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

ANSWER **Assembler**

2.

ANSWER **Compiler**

3.

ANSWER **Interpreter**

4.

ANSWER **Independent**

Practice: easy, medium, hard

Easy 1.

ANSWER **Assembly language (or machine code)**

Easy 2.

ANSWER **Mnemonics**

Medium 1.

ANSWER

Direct manipulation of hardware; more memory efficient (also faster, specialised hardware)

Medium 2.

ANSWER

Cannot directly manipulate hardware; needs a translator (also less memory efficient)

Hard 1.

ANSWER

Executable runs without the translator; runs faster; users cannot see / copy the source code

NOTE 4.4

Integrated development environments (IDEs)

1 In this note

SYLLABUS 4.2 TYPES OF PROGRAMMING LANGUAGE, TRANSLATORS AND IDES

- 4.2.5 Explain the role of an **IDE** in writing program code and the common functions IDEs provide: **code editors**, **run-time environment**, **translators**, **error diagnostics**, **auto-completion**, **auto-correction**, **prettyprint**.

Before this: Programming languages and translators.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

Translators

A compiler or interpreter turns high-level code into machine code.

Quick check: which translator is handy while you are still testing?

An interpreter.

3 What an IDE is

An **integrated development environment (IDE)** is a **piece of software** that gives a programmer, in one place, the tools needed to **write, edit, translate, test and debug** program code.

Examples: Visual Studio Code, IDLE (Python), PyCharm, Visual Studio. Its role is to make writing correct code **quicker and easier**.

Function	What it does for the programmer
Code editor	lets the programmer **type and amend** the program code
Run-time environment	lets the programmer **run the program** inside the IDE and **see the output**
Translator	a built-in **compiler and / or interpreter** converts the code into machine code
Error diagnostics	**shows where errors are** in the code (underlining, line numbers, messages) so they can be found and fixed
Auto-completion	as the programmer starts typing a command or identifier, the IDE **suggests options to complete it**
Auto-correction	**corrects** a command word with a **minor misspelling** automatically
Prettyprint	**colours key words** and **indents** the code so its structure is easy to read (syntax highlighting)

> In an "identify and describe" question, each function gets **one mark for the name and one for its role**. "It has a compiler" is often given in the question: choose the other functions.

TRY IT YOURSELF

1. Which IDE function suggests how to finish a command as you type?
2. Which IDE function colours the key words?
3. Which IDE function lets you run the program and see the output?

4 Summary

- IDE: software with the tools to write, translate, test and debug code in one place.
- Functions: code editor · run-time environment · translator · error diagnostics · auto-completion · auto-correction · prettyprint.

IF YOU SEE …

"explain the purpose of the IDE" [4]	→ software · write / edit code · test / debug · features like auto-completion · translate
"give two functions and state the role of each" [4]	→ name + what it does, from the table

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

5 Ways they test it

TYPE 1 Name functions

> *"Give three other common functions of an IDE" [3]*

Spot it "functions".

1. Names from the syllabus list.

TYPE 2 Function + role

> *"Describe three other ways the IDE can help the programmer" [6]*

Spot it "describe", "help".

1. Name + what it does for the programmer, for each.

TYPE 3 **Purpose**

> *"Explain the purpose of the IDE" [4]*

Spot it "purpose".

1 Software · write · test / debug · translate · example feature.

6 What the examiner looks for

"Describe three other ways the IDE can help the programmer" [6]

Marking points (one mark each, up to the marks shown)

- Code editor … allows the user to enter and amend code
- Run-time environment … allows the program to be run and its outputs seen
- Error diagnostics … shows the programmer where there are errors
- Auto-completion … gives options / suggestions of key commands
- Auto-correction … corrects a command with a minor misspelling
- Prettyprint … colours the key commands so they are easy to identify

KEYWORDS **code editor** **run-time environment** **error diagnostics** **auto-completion** **auto-correction** **prettyprint**

TOO VAGUE "it helps you code" (no named function); the translator, when the question already gave it

7 Past-paper questions, solved

0478/11/O/N/24 Q6 ↗ Paper 1 · Computer systems **6 marks** ⤢ Full size

6 A computer programmer uses assembly language to create a computer program for an embedded system in a washing machine.

(e) The programmer uses an integrated development environment (IDE) to write the program.

A built-in translator to convert the program into machine code is one way that the IDE helps the computer programmer.

Describe **three** other ways the IDE can help the programmer.

..... [6]

Swipe sideways to read the whole question

How to start The question gave the translator, so choose three other functions: name + role each.

▾ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

Error diagnostics show the programmer where the errors are in the program so they can correct them. Auto-completion gives the programmer suggestions to complete a command as they type it. Prettyprint colours the key commands so they are easy to identify.

PART	ANSWER / WORKING	MARKS	GUIDANCE
6(e)	Six marks, max 4 for naming: code editor · run-time environment · error diagnostics · auto-completion · auto-correction · prettyprint, each with its role	B6	

Total: 6 marks

2210/13/O/N/24 Q7 ↗ Paper 1 · Computer systems — **4 marks** — ⤢ Full size

7 A computer programmer uses an integrated development environment (IDE) when creating a computer program.

Explain the purpose of the IDE.

..... [4]

Swipe sideways to read the whole question

How to start Four separate points about what an IDE is and does.

▾ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

An IDE is a piece of software used to write and edit program code. It is used to test and debug the code, with features such as error diagnostics and auto-completion. It also translates the code into machine code.

PART	ANSWER / WORKING	MARKS	GUIDANCE
7	Any four: piece of software · used to write / edit code · test / debug · features such as auto-completion · translate to machine code	B4	

Total: 4 marks

8 Common mistakes

✗ "Auto-correct finds logic errors"

✓ "Auto-correction fixes minor misspellings of command words"

✗ "Prettyprint prints the code"

✓ "Prettyprint colours / indents the code to make it readable"

✗ "The IDE runs the program" as the only point

✓ name several functions with their roles

9 Practice

Practice: easy, medium, hard

1 What does IDE stand for?

2 Name the IDE function that lets the programmer type and amend code.

1 Describe error diagnostics. [2]

1 A beginner keeps misspelling PRINT and forgetting the end of long variable names. Which two IDE functions help, and how? [4]

10 Can I do this?

0 / 2 ticked

- [ ] I can explain the purpose of an IDE.
- [ ] I can name and describe the seven common IDE functions.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

ANSWER **Auto-completion**

2.

ANSWER **Prettyprint**

3.

ANSWER **Run-time environment**

Practice: easy, medium, hard

Easy 1.

ANSWER **Integrated development environment**

Easy 2.

ANSWER **Code editor**

Medium 1.

ANSWER

An IDE function that shows where errors are in the code, e.g. underlines / gives the line number, so they can be fixed

Hard 1.

ANSWER

Auto-correction corrects the misspelt command; auto-completion suggests the full variable name as they type

5

The Internet and its Uses

1 The internet, the web and browsers
2 Locating web pages and cookies
3 Digital currency and blockchain
4 Cyber security threats
5 Keeping data safe

NOTE 5.1

The internet, the web and browsers

1 In this note

SYLLABUS 5.1 THE INTERNET AND THE WORLD WIDE WEB

- 5.1.1 Understand the difference between the **internet** and the **world wide web**.
- 5.1.2 Understand what is meant by a **uniform resource locator (URL)**.
- 5.1.3 Describe the purpose and operation of **HTTP** and **HTTPS**.
- 5.1.4 Explain the purpose and functions of a **web browser**.

Next: Locating web pages and cookies.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

IP addresses

Every device on the internet is identified by an IP address.

Quick check: who allocates a device's IP address?

The network (the router).

Asymmetric encryption

Data encrypted with a public key can only be decrypted with the matching private key.

Quick check: who holds the private key?

Only its owner (e.g. the web server).

3 The internet and the world wide web

The internet	The world wide web (WWW)
the **infrastructure**: a global network of interconnected networks (cables, routers, servers)	the **collection of websites and web pages** that are **accessed using the internet**
carries many services: email, video calls, online games, file transfer … and the web	is just one of the services that uses the internet

> Think of the internet as the **roads** and the world wide web as the **shops** you reach by using them.

4 URLs

A **uniform resource locator (URL)** is a **text-based address** for a web page. It is easier for people to remember than an IP address. A URL can contain the **protocol**, the **domain name** and the **web page / file name**.



The parts of the URL https://www.examplebooks.com/maths/index.html.

5 HTTP and HTTPS

A **protocol** is a set of rules for transmitting data. **Hypertext transfer protocol (HTTP)** is the protocol used to **request and send web pages** between a web browser and a web server. **HTTPS** (hypertext transfer protocol secure) is HTTP with security added: it uses **SSL / TLS** to **encrypt** the data, so if it is intercepted it cannot be understood. Websites that take passwords or payments should use HTTPS (the padlock in the address bar).

GENERAL METHOD **How HTTPS / SSL secures the connection**

1. The **web browser** asks the **web server** to identify itself.
2. The web server sends back its **digital certificate** (which contains its **public key**).
3. The web browser **authenticates** the certificate (checks it is genuine and in date).
4. If it is authentic, **encrypted** data transmission begins: data is encrypted with the server's public key, and only the server's **private key** can decrypt it.

6 Web browsers

A **web browser** is the software used to access and view web pages. Its **main purpose** is to **render HTML and display web pages**. (**HTML**, hypertext markup language, is the language web pages are written in, with tags such as <head> and <body>.)

Function	Example
storing bookmarks and favourites	jump straight to a site you visit often
recording user history	find a page you visited yesterday
allowing **multiple tabs**	have several web pages open at once
storing cookies	stay logged in; payment details filled in for you
providing **navigation tools**	back, forward, refresh, home buttons
providing an **address bar**	type in a URL

TRY IT YOURSELF

1. Which is the infrastructure: the internet or the world wide web?
2. In https://www.examplebooks.com/maths/index.html, what is the domain name?
3. Which browser function lets you return quickly to a site you use often?

7 Summary

- Internet = infrastructure (network of networks). WWW = collection of web pages accessed using the internet.
- URL = text-based address: protocol + domain name + web page / file name.
- HTTP: protocol to request and send web pages. HTTPS: HTTP + SSL/TLS encryption, digital certificate.
- Browser: main purpose = render HTML and display web pages; bookmarks, history, tabs, cookies, navigation, address bar.

IF YOU SEE …

"describe the difference between the internet and the WWW"	→ infrastructure … whereas … collection of web pages
"explain how HTTPS makes transmission secure"	→ SSL/TLS · encrypts · meaningless if intercepted · public / private key · certificate

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

8 Ways they test it

TYPE 1 **Internet vs WWW**

> *"Describe the difference between the internet and the world wide web" [2]*

Spot it "difference".

1 Two facts, joined by "whereas".

TYPE 2 **URL parts**

> *"Identify the three different parts of the URL" [3]; a labelled URL*

Spot it a URL.

1. protocol · domain name · file (web page) name

TYPE 3 **Browser**

> *"Explain the purpose of the web browser" [2]; "give three other functions" [3]; "which function ..." [1]*

Spot it "browser".

1. Purpose: renders HTML, displays web pages. Functions from the table.

TYPE 4 **SSL paragraph**

> *"The ... asks the ... to identify itself ..." [5]*

Spot it a word list.

1. Follow the HTTPS method.

9 What the examiner looks for

"Explain how HTTPS makes the transmission of data secure" [4]

Marking points (one mark each, up to the marks shown)

- Uses SSL / TLS
- Encrypts the data ...
- ... which stops the data being understood if it is intercepted
- ... using asymmetric encryption: data encrypted with the web server's public key
- ... can only be decrypted with the web server's private key

KEYWORDS **SSL** **encrypts** **intercepted** **public key** **private key**

10 Past-paper questions, solved

2210/12/M/J/24 Q11 ↗ Paper 1 · Computer systems **8 marks** ⤢ Full size

11 A company has a website. Users use the internet and the world wide web to access the website.

(a) Describe the difference between the internet and the world wide web.

..... [2]

(b) The website has a uniform resource locator (URL). The URL has three different parts.

Identify the **three** different parts that are included in the URL.

[3]

(c) One function of a web browser is to provide an address bar for a user to enter a URL.

Give **three** other functions of a web browser.

[3]

Swipe sideways to read the whole question

How to start (c) the address bar is given, so pick three other functions.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a) The internet is the infrastructure, whereas the world wide web is the collection of web pages accessed using it.

(b) Protocol; domain name; web page (file) name.

(c) Storing bookmarks and favourites; recording the user's history; allowing multiple tabs.

PART	ANSWER / WORKING	MARKS	GUIDANCE
11(a)	internet is the infrastructure · WWW is a collection of web pages	B2	
11(b)	protocol · domain name · file name // web page name	B3	
11(c)	Any three: displays web pages · bookmarks · history · tabs · cookies · navigation tools · home page	B3	

Total: 8 marks

2210/12/O/N/24 Q7 ↗ Paper 1 · Computer systems **5 marks** ⤢ Full size

7 A student enters the uniform resource locator (URL) for a web page into their tablet computer.

(e) The data for the web page is transmitted using the secure socket layer (SSL) protocol.

Complete the paragraph about the SSL protocol.

Use only terms from the list.

Not all terms need to be used. Some terms may be used more than once.

encrypted file server hypertext markup language (HTML)

hypertext transfer protocol (HTTP) operating system search engine

unencrypted URL web browser web server

The ..... asks the .....

to identify itself. The ..... sends back its digital

certificate. The ..... authenticates the digital certificate.

If it is authentic, ... data transmission begins.

[5]

Swipe sideways to read the whole question

How to start Follow the HTTPS method: who asks, who answers, who checks.

▼ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

The **web browser** asks the **web server** to identify itself. The **web server** sends back its digital certificate. The **web browser** authenticates the digital certificate. If it is authentic, **encrypted** data transmission begins.

PART	ANSWER / WORKING	MARKS	GUIDANCE
7(e)	web browser · web server · web server · web browser · encrypted	B5	

Total: 5 marks

4 An employee uses a web browser on their computer.

(a) Describe the main purpose of a web browser.

..... [2]

(b) The employee wants his payment details to be automatically filled in when he buys products using the internet.

Identify the function of a web browser that could be used for this purpose.

..... [1]

(c) The employee wants to be able to quickly access websites that he regularly uses.

Identify the function of a web browser that could be used for this purpose.

..... [1]

(d) The web browser uses the secure socket layer (SSL) protocol to transmit personal data securely over the internet.

State how the SSL protocol secures the data for transmission.

..... [1]

Swipe sideways to read the whole question

How to start (b) and (c) each name ONE browser function from the table.

▾ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a) To display web pages, by rendering HTML.

(b) Storing cookies.

(c) Storing bookmarks / favourites.

(d) It encrypts the data.

PART	ANSWER / WORKING	MARKS	GUIDANCE
4(a)	display web pages · by rendering HTML	B2	
4(b)	storing cookies	B1	
4(c)	bookmarks // favourites	B1	
4(d)	encrypts it // uses digital certificates	B1	

Total: 5 marks

11 Common mistakes

✗ "The internet and the WWW are the same" ✓ "The internet is the infrastructure; the WWW is the web pages"

✗ "A browser finds the IP address" ✓ "The DNS finds the IP address; the browser renders HTML"

Next note.

✗ "HTTPS is faster" ✓ "HTTPS encrypts the data (SSL/TLS)"

12 Practice

Practice: easy, medium, hard

1. What does URL stand for? [1]
2. What does the S in HTTPS stand for? [1]
3. Which language are web pages written in? [1]
4. State the main purpose of a web browser. [1]
5. Give two functions of a web browser other than an address bar. [2]
6. Explain why an online shop should use HTTPS. [2]

13 Can I do this?

0 / 4 ticked

- [ ] I can explain the difference between the internet and the WWW.
- [ ] I can name the parts of a URL.
- [ ] I can describe HTTP and how HTTPS secures data.
- [ ] I can give the purpose and functions of a web browser.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

ANSWER The internet

2.

ANSWER www.examplebooks.com

3.

ANSWER Bookmarks / favourites

Practice: easy, medium, hard

Easy 1.

ANSWER Uniform resource locator

Easy 2.

ANSWER Secure

Easy 3.

ANSWER HTML

Medium 1.

ANSWER To render HTML and display web pages

Medium 2.

ANSWER e.g. bookmarks, history (also tabs, cookies, navigation tools)

Hard 1.

ANSWER

Customers enter personal / payment details; HTTPS encrypts them so they are meaningless if intercepted

NOTE 5.2

Locating web pages and cookies

1 In this note

SYLLABUS 5.1 THE INTERNET AND THE WORLD WIDE WEB

- 5.1.5 Describe how web pages are **located, retrieved and displayed** when a user enters a URL: the role of the **web browser**, **IP addresses**, the **domain name server (DNS)**, the **web server** and **HTML**.
- 5.1.6 Explain what is meant by **cookies** and how they are used, including **session** and **persistent** cookies.

Before this: The internet, the web and browsers. Next: Digital currency and blockchain.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

URLs and IP addresses

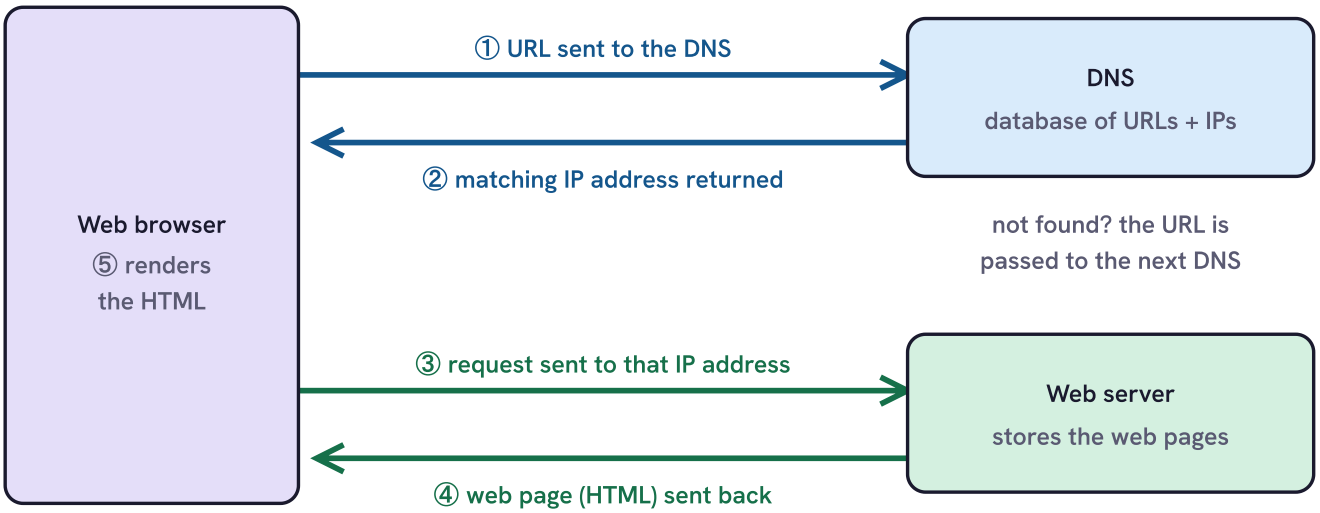
People type URLs; computers find each other by IP address.

Quick check: what has to happen before the browser can contact the web server?

The URL must be turned into the server's IP address.

3 From URL to web page

A **domain name server (DNS)** is a server that stores a **database of URLs (domain names) and their matching IP addresses**. A **web server** is a server that **stores web pages** and sends them to clients that request them.



The five steps, ① to ⑤.

GENERAL METHOD **How a web page is located, retrieved and displayed**

1. The user enters the **URL** into the **address bar** of the **web browser**.
2. The browser sends the URL to a **DNS**.
3. The DNS **searches its database** for the matching **IP address**. If it cannot find it, the URL is **sent to the next DNS** until it is found.
4. The DNS **returns the IP address** to the web browser.
5. The browser sends a **request** to the **web server** at that IP address.
6. The web server sends the web page data, the **HTML** files, back to the browser.
7. The browser **renders the HTML** and **displays** the web page.

4 Cookies

A **cookie** is a **small text file** that is sent between a **web server** and a **web browser** and **stored by the browser**. It lets a website remember information about the user.

Session cookie	Persistent cookie
temporary: stored in **memory (RAM)**, not in secondary storage	**permanent**: stored on the user's **secondary storage**
deleted when the browser is closed	**kept** when the browser is closed, until it **expires** or the user **deletes** it
e.g. holding items in a shopping cart during one visit	e.g. staying logged in; remembering preferences for next time

Uses of cookies	
saving personal details	name, address filled in for you
tracking user preferences	language, dark mode, items you looked at (targeted adverts)
holding items in an online shopping cart	the basket keeps its contents as you browse
storing login details	you stay logged in

TRY IT YOURSELF

1. Which server stores a database of URLs and IP addresses?
2. Which type of cookie is deleted when the browser is closed?
3. What does the browser receive from the web server to display the page?

5 Summary

- URL → DNS → IP address back → request to the web server's IP → HTML back → browser renders it.
- If a DNS can't find the URL, it passes it to another DNS.
- Cookie: small text file, sent between server and browser, stored by the browser.
- Session: in RAM, lost when the browser closes. Persistent: on secondary storage, until it expires / is deleted.
- Uses: personal details, preferences, shopping cart, login details.

IF YOU SEE …

"describe how the web pages are located, retrieved and displayed" [6]	→ browser · URL to DNS · IP returned · request to web server · HTML sent · rendered
"explain the difference between session and persistent cookies"	→ RAM … whereas secondary storage · lost on close … whereas kept until expiry

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

6 Ways they test it

TYPE 1 **Describe / draw**

> *"Draw and annotate a diagram to show the process from entering the URL to displaying the page" [5]; "describe how the web pages are located, retrieved and displayed" [6]*

Spot it "located", "diagram".

1. Boxes: browser, DNS, web server. Number the arrows and say what travels along each.

TYPE 2 **Role of the DNS**

> *"Describe the role of the DNS" [2]*

Spot it "DNS".

1. database of URLs + IPs · finds the IP · next DNS · returns it

TYPE 3 **Cookie cloze**

> *"Cookies are small … files that are sent between a … and a …" [6-7]*

Spot it a word list.

1. Use the two tables.

TYPE 4 **Cookie uses / difference**

> *"Give three functions of a cookie" [3]; "explain the difference between session and persistent cookies" [4]*

Spot it "cookie".

1. Comparisons need both sides.

7 What the examiner looks for

Diagram from entering the URL to displaying the page [5]

Marking points (one mark each, up to the marks shown)

- URL sent from the browser to the DNS
- DNS stores a database of URLs and IPs // finds the IP for the URL
- If not found, sent to the next / a higher DNS
- DNS sends the IP address to the browser
- Browser sends a request to the IP address of the web server
- Web server processes the request; web page (HTML) data sent to the browser
- Browser renders the HTML

KEYWORDS **DNS** **IP address** **web server** **request** **HTML** **render**

8 Past-paper questions, solved

2210/12/M/J/23 Q6 ↗ Paper 1 · Computer systems **9 marks** ⤢ Full size

6 (a) Complete the statements about cookies.

Use the terms from the list.

Some of the terms in the list will **not** be used. Some terms may be used more than once.

compression	executable	hypertext markup language (HTML)
hypertext transfer protocol (HTTP)	image	internet protocol (IP) address
persistent	session	sound
text		
uniform resource locater (URL)	web browser	web server

Cookies are small ..... files that are sent between a ..... and a ..... .

..... cookies are stored in memory and **not** in the user's secondary storage.

When the web browser is closed a ..... cookie is lost, whereas a ..... cookie is **not** lost.

[6]

(b) Give **three** functions of a cookie.

1 .....

2 .....

3 .....

[3]

Swipe sideways to read the whole question

How to start Session = memory, lost when closed; persistent = kept.

▾ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

(a) Cookies are small **text** files that are sent between a **web browser** and a **web server**. **Session** cookies are stored in memory and not in the user's secondary storage. When the web browser is closed a **session** cookie is lost, whereas a **persistent** cookie is not lost.

(b) Saving personal details; storing login details; holding items in an online shopping cart.

PART	ANSWER / WORKING	MARKS	GUIDANCE
6(a)	text · web browser · web server (either order) · session · session · persistent	B6	
6(b)	Any three: personal details · login details · user preferences · shopping cart	B3	

Total: 9 marks

0478/13/M/J/24 Q7 ↗ Paper 1 · Computer systems **6 marks** ⤢ Full size

7 A company has a network that includes a web server.

Data is transmitted across the network using serial half-duplex data transmission.

(e) Customers access the company's web pages that are stored on the web server.

Describe how the web pages are located, retrieved and displayed on a customer's computer.

..... [6]

Swipe sideways to read the whole question

How to start Six marks: follow the seven-step method from the browser to the rendered page.

▾ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

The customer types the URL into the web browser, which sends it to a DNS. The DNS searches its database for the matching IP address (passing the URL to another DNS if it cannot find it) and returns the IP address to the browser. The browser sends a request to the web server at that IP address. The web server sends the HTML for the web page back, and the browser renders the HTML to display the page.

PART	ANSWER / WORKING	MARKS	GUIDANCE
7(e)	Any six: URL into browser · sent to DNS · DNS finds matching IP · next DNS if not found · IP returned · request to web server · HTML sent back · browser renders HTML	B6	

Total: 6 marks

2210/11/M/J/23 Q10 ↗ Paper 1 · Computer systems **4 marks** ⤢ Full size

10 A student uses the internet for their schoolwork to research what is meant by pharming.

(e) A student visits a website that uses session cookies, instead of persistent cookies.

Explain the difference between session cookies and persistent cookies.

..... [4]

Swipe sideways to read the whole question

How to start Four marks: two differences, each stated for both types.

▾ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

Session cookies are stored in memory (RAM), whereas persistent cookies are stored on secondary storage. When the browser is closed a session cookie is lost, whereas a persistent cookie is kept until it expires or the user deletes it.

PART	ANSWER / WORKING	MARKS	GUIDANCE
10(e)	Any four: session in RAM … persistent on secondary storage · session lost when browser closed … persistent not lost … until deleted / expires	B4	

Total: 4 marks

9 Common mistakes

✗ "The DNS sends the web page"	✓ "The DNS sends the IP address; the web server sends the web page"
✗ "Cookies are programs / viruses"	✓ "Cookies are small text files"
✗ "Session cookies are stored on the hard drive"	✓ "Session cookies are stored in RAM"

10 Practice

Practice: easy, medium, hard

1. Which server stores the web pages?
2. Where is a persistent cookie stored?

1 Describe the role of the DNS. [2]

2 Give two uses of cookies.

1 A user closes the browser with items in their basket. When they return the items are gone. Which type of cookie was used? Explain. [2]

11 Can I do this?

0 / 2 ticked

- [ ] I can describe how a web page is located, retrieved and displayed.
- [ ] I can explain cookies, session vs persistent, and their uses.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

ANSWER DNS (domain name server)

2.

ANSWER Session cookie

3.

ANSWER HTML (the web page data)

Practice: easy, medium, hard

Easy 1.

ANSWER Web server

Easy 2.

ANSWER Secondary storage

Medium 1.

ANSWER

Stores a database of URLs and matching IP addresses; finds the IP for a URL and returns it to the browser

Medium 2.

ANSWER e.g. storing login details; holding items in a shopping cart

Hard 1.

ANSWER Session cookie: stored in RAM and deleted when the browser was closed

NOTE 5.3

Digital currency and blockchain

1 In this note

SYLLABUS 5.2 DIGITAL CURRENCY

- 5.2.1 Understand the concept of a **digital currency** and how digital currencies are used.
- 5.2.2 Understand the process of **blockchain** and how it is used to **track digital currency transactions**.

Before this: Locating web pages and cookies. Next: Cyber security threats.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

Encryption

Encryption scrambles data so that only someone with the key can read it.

Quick check: why encrypt a payment?

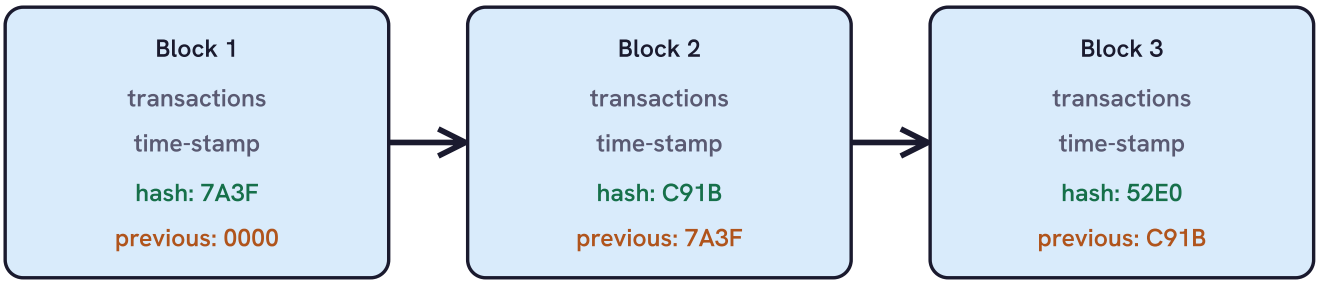
So it is meaningless if intercepted.

3 Digital currency

A **digital currency** is money that **only exists electronically**: there are no coins or notes. It can be used to pay for goods and services online and to transfer value between people. Some digital currencies are **centralised** (controlled by one organisation, like a bank), others are **decentralised** (no single organisation controls them; cryptocurrencies such as Bitcoin). Transactions are usually **encrypted**.

4 Blockchain

A **blockchain**, in its basic form, is a **digital ledger**: a **time-stamped series of records that cannot be altered**. Each new transaction is added to a **block**; each block is **linked to the previous block**, forming a chain. A copy of the chain is kept on many computers, so there is no single place to attack.



Changing block 1 would change its hash, so block 2 would no longer match: the change is detected.

Each block stores the hash of the block before it.

GENERAL METHOD **How a digital currency payment is tracked by blockchain**

1. The payer's device **encrypts** the payment data and sends it to the **digital ledger**.
2. The transaction is recorded with a **time-stamp** (and a digital signature) and stored in a **block** with other transactions.
3. Each block has its own **hash** (unique identifier) and stores the **hash of the previous block**.
4. When the block is full it is **added to the blockchain** on **every computer** that holds a copy.
5. Records **cannot be altered**, only new ones added, so every transaction can be **traced**.

TRY IT YOURSELF

1. Does a digital currency exist physically?
2. What is the name of the process that uses a digital ledger to track digital currency?

3 What does each block store that links it to the chain?

5 Summary

- Digital currency: only exists electronically; may be centralised or decentralised; usually encrypted.
- Blockchain: a digital ledger, a time-stamped series of records that cannot be altered.
- Blocks of transactions, each with its own hash and the previous block's hash; copies on many computers.

IF YOU SEE …

"draw and annotate a diagram to show a payment using digital currency and blockchain" [4]	→ device encrypts · sent to ledger · recorded with time-stamp · stored in a block · block hash · added to the chain on every device

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

6 Ways they test it

TYPE 1 **Features**

> *"Give two other features of digital currency" [2]; "identify the process that uses a digital ledger" [1]*

Spot it "digital currency".

1 only electronic · centralised / decentralised · encrypted; blockchain

TYPE 2 **Cloze**

> *"A digital currency does not exist ..., ... digital ledgers called ..." [4]*

Spot it a word list.

1. physically · blockchains · time-stamp · traced

TYPE 3 **Diagram**

> *"Draw and annotate a diagram to show how a payment is made using digital currency and blockchain" [4]*

Spot it "diagram".

1. Follow the method; label the block hash.

7 Past-paper questions, solved

0478/12/F/M/24 Q5 ↗ Paper 1 · Computer systems — **4 marks** — ⤢ Full size

5 Complete the description of digital currencies using the terms provided.

blockchains changed datachains decentralised
deleted encryption passport physical address
physically records time-stamp traced
transaction-chains virtually

A digital currency does **not** exist ....., it can only be accessed electronically.

Some digital currencies have digital ledgers called ..... . These are decentralised databases where each transaction is stored as a new set of data with a ..... and is linked to the previous set of data. This means that transactions cannot be altered, only new transactions added, which allows the location of the data to be ..... .

[4]

Swipe sideways to read the whole question

How to start Four gaps: one from each line of the definition.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

A digital currency does not exist **physically**, it can only be accessed electronically. Some digital currencies have digital ledgers called **blockchains**. These are decentralised databases where each transaction is stored as a new set of data with a **time-stamp** and is linked to the previous set of data. This means that transactions cannot be altered, only new transactions added, which allows the location of the data to be **traced**.

PART	ANSWER / WORKING	MARKS	GUIDANCE
5	physically · blockchains · time-stamp · traced	B4	

Total: 4 marks

2210/12/O/N/23 Q12 ↗ Paper 1 · Computer systems **3 marks** ⤢ Full size

12 Digital currency can be used to pay for products and services.

Digital currencies are often tracked using digital ledgers.

(a) Give **two** other features of digital currency.

[2]

(b) Identify the process that uses a digital ledger to track the use of digital currency.

..... [1]

Swipe sideways to read the whole question

How to start The question already says digital ledger, so choose two other features.

▾ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a) It only exists electronically; it is usually encrypted.

(b) Blockchain.

PART	ANSWER / WORKING	MARKS	GUIDANCE
12(a)	Any two: only exists electronically · decentralised · centralised · usually encrypted	B2	
12(b)	Blockchain	B1	

Total: 3 marks

8 Common mistakes

✗ "Records in a blockchain can be edited"

✓ "Records cannot be altered, only added"

✗ "Digital currency is money in a bank account"

Bank balances back real notes.

✓ "Digital currency only exists electronically"

9 Practice

Practice: easy, medium, hard

1 Give one example of a decentralised digital currency.

1 Explain why a blockchain is hard to tamper with. [2]

1 Explain how blockchain lets a transaction be traced. [2]

10 Can I do this?

0 / 2 ticked

- [ ] I can explain what a digital currency is and how it is used.
- [ ] I can describe how blockchain tracks transactions.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

ANSWER No: only electronically

2.

ANSWER Blockchain

3.

ANSWER The hash of the previous block

Practice: easy, medium, hard

Easy 1.

ANSWER e.g. Bitcoin (a cryptocurrency)

Medium 1.

ANSWER

Each block holds the previous block's hash, so changing one breaks the chain; copies are held on many computers

Hard 1.

ANSWER

Every transaction is stored, time-stamped, in a block that cannot be altered; following the chain shows the history

NOTE 5.4

Cyber security threats

1 In this note

SYLLABUS 5.3 CYBER SECURITY

- 5.3.1 Describe the processes involved in, and the **aim** of carrying out, a range of cyber security threats: **brute-force attack**, **data interception**, **DDoS**, **hacking**, **malware** (virus, worm, Trojan horse, spyware, adware, ransomware), **pharming**, **phishing**, **social engineering**.

Before this: Digital currency and blockchain. Next: Keeping data safe.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

Packets

Data is sent across a network in packets.

Quick check: can a packet be read on its way?

Yes, if it is intercepted and not encrypted.

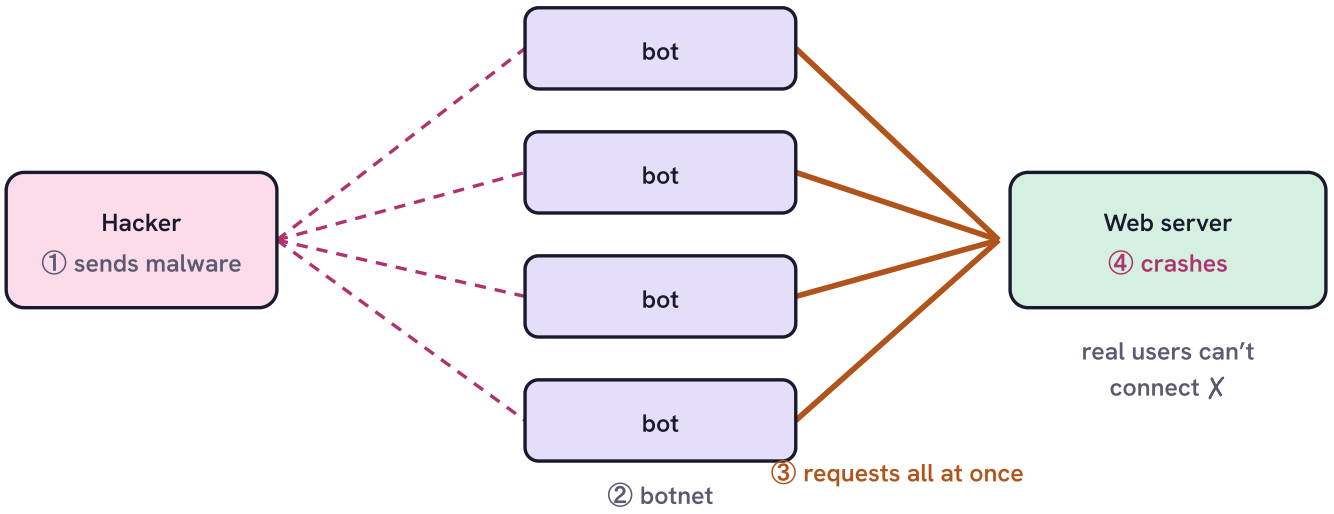
For every threat learn two things: the **process** (how it is done, step by step) and the **aim** (why the attacker does it).

3 Getting into accounts and systems

Threat	Process	Aim
Brute-force attack	**trial and error** to guess a password: combinations are **repeatedly entered** (often automatically by software) **until the correct password is found**	to gain access to an account: steal, view, change or delete data; install malware
Hacking	**gaining unauthorised access** to a computer or system, e.g. by exploiting a weakness	to steal, change or delete data; damage a company's reputation; install malware
Data interception	data is **examined while it is being transmitted**, e.g. with a **packet sniffer**, and copied to a third party, who analyses it	to steal data such as passwords or bank details

4 Denial of service

In a **distributed denial of service (DDoS)** attack, many computers send so many requests to a web server that it cannot cope.



A DDoS attack.

GENERAL METHOD **Process of a DDoS attack**

1. The attacker spreads **malware** that users download onto their computers.
2. Each infected computer becomes a **bot** (zombie); together they form a **botnet**.
3. When the attacker starts the attack, all the bots send **requests to the web server at the same time**.
4. The web server is overloaded and **crashes** / slows, so **real users cannot access the website**.

Aims: to stop a business trading, damage its reputation, revenge, demand a ransom to stop the attack.

5 Malware

Malware (malicious software) is software designed to damage a computer or steal data.

Malware	What it does
Virus	software that **replicates** when the user runs it (it needs an active host program); **deletes, damages or corrupts** data and files; fills storage
Worm	**replicates itself across a network** **without user input**; uses up **bandwidth**; can open back doors and carry other malware
Trojan horse	malware **hidden inside / disguised as genuine software**; when installed, the hidden malware is installed too
Spyware	**records what the user does**, e.g. all key presses (**keylogger**), and **sends it to a third party**, who looks for passwords
Adware	**displays unwanted adverts**; may redirect to fake websites or contain other malware; slows the device
Ransomware	**encrypts the user's data** (locks them out) and demands a **ransom** for the key

> Virus vs worm: a **virus** needs the user to run its host program; a **worm** spreads across a network **on its own**. Phishing is **not** malware.

6 Tricking the user

Threat	Process	Aim
Phishing	a **legitimate-looking email** is sent; the user **clicks a link** in it (or replies) and is taken to a **fake website**, where they **enter personal data**, which is stolen	to obtain personal data: passwords, bank details
Pharming	**malicious code is downloaded** onto the user's computer (or a DNS is changed). When the user **types a genuine web address**, they are **redirected to a fake website**, where they enter personal data	to obtain personal data
Social engineering	**manipulating or deceiving people** into giving away data or making a security mistake, e.g. a phone call pretending to be the bank, or leaving an infected USB stick to be found	to obtain data or access

✗ COMMON MISTAKE

Phishing vs pharming: in **phishing** the user **clicks a link** in an email. In **pharming** the user types the **correct URL** but malware redirects them anyway, so it is harder to spot.

TRY IT YOURSELF

1. Which malware encrypts your files and demands payment?
2. Which malware spreads across a network without the user doing anything?
3. Which threat uses trial and error to guess a password?
4. Is phishing a type of malware?

7 Summary

- Brute force: trial and error until the password is found. Hacking: unauthorised access. Interception: packet sniffer reads data in transit.
- DDoS: malware → bots → botnet → simultaneous requests → server crashes.
- Malware: virus (needs host), worm (spreads itself), Trojan (disguised), spyware (keylogger), adware, ransomware (encrypts, ransom).
- Phishing: email link → fake site. Pharming: malware redirects a typed URL. Social engineering: manipulating people.

IF YOU SEE …

"draw and annotate a diagram to represent a DDoS" [6]	→ malware · bots · botnet · third party starts it · simultaneous requests · server fails · users can't connect
"describe the process of phishing" [4]	→ legitimate-looking email · clicks link · fake website · enters personal data · stolen

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

8 Ways they test it

TYPE 1 **Describe a process**

> *"Describe how a brute-force attack can be used to gain access" [3]; "describe the process of phishing" [4]*

Spot it "describe how / process".

1. Steps in order, from the tables and methods.

TYPE 2 **Diagram**

> *"Draw and annotate a diagram to represent pharming / DDoS / data interception" [4-6]*

Spot it "diagram".

1. Boxes for the computers and servers; an arrow per step, each with a label saying what happens.

TYPE 3 **Aims**

> *"State two aims of carrying out a DDoS attack" [2]*

Spot it "aims".

1. Why, not how.

TYPE 4 **Malware table**

> *"Identify and describe two other examples of malware" [6]*

Spot it "malware".

1. Name + two description points each.

9 What the examiner looks for

"Draw and annotate a diagram to represent the process of pharming" [4]

Marking points (one mark each, up to the marks shown)

- User clicks / opens an attachment or link that triggers a download
- Malicious software is downloaded onto the user's computer
- User enters the (genuine) website address
- User is redirected to a fake website

KEYWORDS **malware downloaded** **enters web address** **redirected** **fake website**

10 Past-paper questions, solved

2210/11/M/J/23 Q8 ↗ Paper 1 · Computer systems **10 marks** ⤢ Full size

8 A manager at a company is concerned about a brute-force attack on its employee user accounts.

(a) Describe how a brute-force attack can be used to gain access to the employee user accounts.

..... [3]

(b) One possible aim for carrying out a brute-force attack is to install malware onto the company network.

(i) State **two** other aims for carrying out a brute-force attack to gain access to the employee user accounts.

[2]

(ii) Identify **three** types of malware that could be installed.

[3]

(c) Give **two** security solutions that could be used to help prevent a brute-force attack being successful.

[2]

Swipe sideways to read the whole question

How to start (a) the process, (b)(i) aims other than installing malware, (b)(ii) three malware names, (c) two solutions (next note).

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a) The attacker uses trial and error to guess the password: combinations are repeatedly entered, often automatically by software, until the correct password is found.

(b)(i) To steal data; to delete or change data. (ii) Virus; worm; ransomware.

(c) Two-step verification; limiting the number of login attempts.

PART	ANSWER / WORKING	MARKS	GUIDANCE
8(a)	trial and error · combinations repeatedly entered · until correct · manual or automatic	B3	
8(b)(i)	Any two: steal / view data · delete · change · lock account / encrypt · damage reputation	B2	
8(b)(ii)	Any three: virus · worm · Trojan horse · spyware · adware · ransomware	B3	
8(c)	Any two: two-step verification · biometrics · firewall / proxy · strong password · limit attempts · drop-down boxes · partial password	B2	

Total: 10 marks

0478/13/M/J/23 Q8 ↗ Paper 1 · Computer systems **5 marks** ⤢ Full size

8 Complete the statements about a distributed denial of service (DDoS) attack.

Use the terms from the list.

Some of the terms in the list will **not** be used. You should only use a term once.

anti-virus	bot	botnet	hacker
internet	malware	secondary storage	
spyware	web browser	web server	website

The attacker encourages people to download ..... onto their computer. This will turn each computer into a ..... , creating a network called a ..... .

When the attacker wants the DDoS to take place, repeated requests are simultaneously sent from the computers to a ..... . This causes it to crash, meaning that users can no longer access the ..... that is stored on this hardware.

[5]

Swipe sideways to read the whole question

How to start Follow the DDoS method: malware → bot → botnet → server → website.

▼ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

The attacker encourages people to download **malware** onto their computer. This will turn each computer into a **bot**, creating a network called a **botnet**. ... repeated requests are simultaneously sent from the computers to a **web server**. This causes it to crash, meaning that users can no longer access the **website** that is stored on this hardware.

PART	ANSWER / WORKING	MARKS	GUIDANCE
8	malware · bot · botnet · web server · website	B5	

Total: 5 marks

0478/11/O/N/25 Q4 ↗ Paper 1 · Computer systems **6 marks** ⤢ Full size

4 A computer game development company are reviewing their current security solutions.

The company wants employees to be aware of how they can identify phishing.

(a) Describe the process of phishing.

..... [4]

(b) Give **two** ways an employee could identify phishing.

[2]

Swipe sideways to read the whole question

How to start (a) four steps. (b) two checks a user can make.

▼ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

(a) A legitimate-looking email is sent to the user. The user clicks a link in the email and is directed to a fake website. The user enters their personal data, which is then stolen and used by a third party.

(b) Check the email address it was sent from; check the URL attached to the link (also: check the spelling and tone).

PART	ANSWER / WORKING	MARKS	GUIDANCE
4(a)	legitimate-looking email · clicks link / replies · fake website · enters personal data · stolen / used by third party	B4	
4(b)	Any two: check sender's email address · check tone / spelling · check the URL of the link	B2	

Total: 6 marks

11 Common mistakes

✗ "Phishing is a virus"	✓ "Phishing is a trick using a fake email; it is not malware"
✗ "A DDoS hacks the server"	✓ "A DDoS floods the server with requests so it crashes"
✗ "Spyware deletes files"	✓ "Spyware records key presses and sends them to a third party"
✗ Mixing up phishing and pharming	✓ phishing = email link; pharming = redirected from a typed URL

12 Practice

Practice: easy, medium, hard

1. Which threat makes a botnet?
2. Which malware is disguised as genuine software?
1. Describe what is meant by social engineering, with an example. [3]
2. State the aim of pharming.
1. Explain why pharming is harder for a user to spot than phishing. [2]

13 Can I do this?

0 / 4 ticked

- [ ] I can describe brute force, hacking and data interception, with aims.
- [ ] I can describe and draw a DDoS attack.
- [ ] I can describe the six types of malware.
- [ ] I can describe phishing, pharming and social engineering.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

ANSWER Ransomware

2.

ANSWER Worm

3.

ANSWER Brute-force attack

4.

ANSWER No

Practice: easy, medium, hard

Easy 1.

ANSWER DDoS (distributed denial of service)

Easy 2.

ANSWER Trojan horse

Medium 1.

ANSWER

Manipulating / deceiving people to give away data or make an error; e.g. a call pretending to be the bank asking for a PIN

Medium 2.

ANSWER To obtain personal data

Hard 1.

ANSWER

The user types the genuine URL themselves, but is redirected; there is no suspicious email or link to notice

NOTE 5.5

Keeping data safe

1 In this note

SYLLABUS 5.3 CYBER SECURITY

- 5.3.2 Explain how a range of solutions help keep data safe: **access levels**, **anti-malware**, **authentication** (username and password, biometrics, two-step verification), **automating software updates**, **checking spelling and tone**, **checking the URL**, **firewalls**, **privacy settings**, **proxy-servers**, **SSL**.

Before this: Cyber security threats.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

The threats

Brute force, hacking, interception, DDoS, malware, phishing, pharming, social engineering.

Quick check: which threat does encryption defend against?

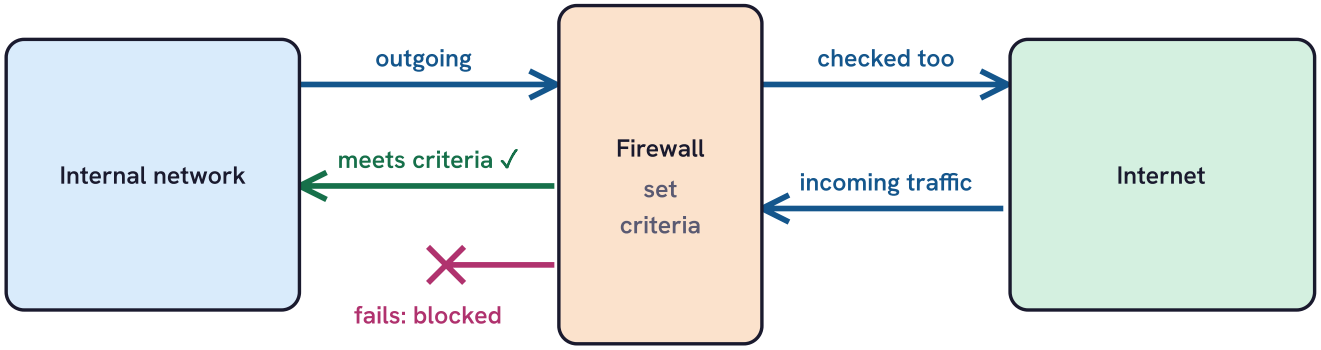
Data interception: intercepted data is meaningless.

3 Authentication and access

Authentication means proving that a user is who they claim to be.

Solution	How it keeps data safe	Helps against
Username and password	only someone who knows the password gets in. A **strong password** (mix of letters, numbers, symbols) is very hard to guess; **limiting login attempts** stops repeated guessing	brute force, hacking
Biometrics	uses a unique physical feature (fingerprint, face, iris, voice); very difficult to fake	brute force, hacking
Two-step verification	after the password, a **code is sent to the user's registered device** (or email) and must be entered: a hacker would need that device too	brute force, hacking, phishing
Access levels	give users **different permissions**: some can only **read** certain data, some can **edit or delete** it; linked to the username	limits the damage any one account can do
Privacy settings	control **who can see** a user's personal information (e.g. on social media)	social engineering, identity theft

4 Software and network defences



Traffic in BOTH directions is compared with the criteria.

How a firewall works.

Solution	How it keeps data safe
Firewall (hardware or software)	sits between a network / computer and the internet; **examines all incoming and outgoing traffic**, **compares it with set criteria** (rules) and **blocks** any that does not meet them; can block certain IP addresses or websites
Proxy-server	sits between users and the internet / a web server: **examines each request**; can **limit the rate of requests** (stopping a DDoS reaching the web server); **hides the server's / user's IP address**; **caches** web pages to answer requests itself
Anti-malware (anti-virus, anti-spyware)	**scans** files and downloads, compares them with a database of known malware, and **quarantines or deletes** malware it finds; anti-spyware stops keyloggers sending passwords
Automating software updates	updates are installed automatically, so **security weaknesses are fixed** as soon as possible and anti-malware always knows the latest malware
SSL (secure socket layer)	**encrypts** data sent between browser and web server; checks the server's **digital certificate**; intercepted data is **meaningless**

5 What the user can check

Solution	How it keeps data safe
Checking the spelling and tone of communications	phishing emails often have spelling mistakes or an urgent, threatening tone ("your account will be closed today")
Checking the URL attached to a link	hover over a link before clicking: a fake site's address is often slightly different (examp1e-bank.com) or not HTTPS

Threat	Best solutions
brute-force attack	strong password · limit login attempts · two-step verification · biometrics
data interception	encryption / SSL (HTTPS)
DDoS	proxy-server · firewall · anti-malware on users' computers
hacking	firewall · strong passwords · two-step verification · access levels
malware	anti-malware · firewall · automatic updates · only download from trusted sources
phishing / pharming	check the URL · check spelling and tone · anti-malware (pharming) · never give personal details
social engineering	staff training · privacy settings · never give data to unverified callers

TRY IT YOURSELF

1. Which solution sends a code to your phone after you enter your password?
2. Which solution makes intercepted data meaningless?
3. Which solution can limit the number of requests reaching a web server?

6 Summary

- Authentication: password (strong, limited attempts), biometrics, two-step verification.
- Access levels: read / edit permissions. Privacy settings: who sees your data.
- Firewall: compares traffic both ways with criteria, blocks what fails.
- Proxy: examines and rate-limits requests, hides IP, caches. Anti-malware: scans, quarantines, deletes.
- Auto-updates fix weaknesses. SSL encrypts. Users: check spelling / tone and the URL.

IF YOU SEE …

"explain how the firewall operates" [5]	→ monitors traffic in and out · set criteria / rules · compares · blocks / allows · can block IP addresses / sites
"identify two solutions and explain how each helps" [6]	→ name (1) + two points of how it stops the attacker

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

7 Ways they test it

TYPE 1 Solution + explanation

> *"Identify two security solutions … explain how each helps prevent hackers" [6]*

Spot it "explain how".

1 mark the name, 2 marks how it stops the attack.

TYPE 2 Firewall diagram

> *"Draw and annotate a diagram to demonstrate how a firewall works" [4]*

Spot it "firewall".

Traffic both ways, criteria set, compared, rejected / accepted.

TYPE 3 Proxy vs firewall

> *"Identify two similarities and one difference" [3]; "tasks a proxy performs that a firewall does not" [2]*

Spot it "proxy".

Both filter traffic / can block IPs. Proxy only: hides the IP, caches pages.

TYPE 4 Match to a threat

> *"Give two solutions that could prevent a brute-force / DDoS attack" [2]*

Spot it a named threat.

Use the threat → solution table.

8 What the examiner looks for

"Draw and annotate a diagram to demonstrate how a firewall works" [4]

Marking points (one mark each, up to the marks shown)

- Traffic passing both ways through the firewall
- An indication that criteria are set for the firewall
- Traffic is compared to the criteria
- Traffic being rejected if it does not meet the criteria
- Traffic being accepted if it meets the criteria

KEYWORDS **both ways** **criteria** **compared** **rejected** **accepted**

9 Past-paper questions, solved

2210/13/O/N/25 Q4 ↗ Paper 1 · Computer systems **6 marks** ⤢ Full size

4 A cyber security company specialises in security solutions that help prevent hackers being successful.

(a) Identify **two** security solutions that can be provided to help prevent hackers being successful.

Explain how each solution helps prevent hackers being successful.

Solution 1 .....

Explanation .....

Solution 2 .....

Explanation .....

[6]

Swipe sideways to read the whole question

How to start Choose solutions you can explain in two steps each.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

Solution 1: two-step verification. After the password, a code is sent to the user's registered device, so a hacker who has guessed the password would also need that device.

Solution 2: firewall. It examines incoming traffic and blocks any data that does not meet the set criteria, so the hacker's attempts to connect can be stopped.

PART	ANSWER / WORKING	MARKS	GUIDANCE
4(a)	Per solution: name (1) + two matching points (2), e.g. strong password · limit attempts · biometrics · two-step verification · firewall · anti-spyware	B6	

Total: 6 marks

6 A student is writing a help guide about how to recognise and avoid the cyber-security threat of pharming.

(a) Give **three** appropriate solutions he could include.

[3]

(b) The student also wants to include information in the help guide about the use of social engineering as a cyber-security threat.

Describe what is meant by social engineering.

Include **one** example of social engineering in your answer.

..... [3]

(c) The student includes information about the security solution of access levels.

Describe what is meant by access levels.

..... [3]

Swipe sideways to read the whole question

How to start (a) three different solutions. (b) two marks of description + an example. (c) three points about permissions.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a) Check the URL attached to a link; scan downloads with anti-malware; only download software from trusted sources.

(b) Social engineering is manipulating or deceiving people into giving away data or making a security mistake. For example, someone phones pretending to be from the bank and asks for a PIN.

(c) Access levels give users different permissions for the data: some users can only read certain data, while others can also edit or delete it. They are normally linked to a username.

PART	ANSWER / WORKING	MARKS	GUIDANCE
6(a)	Any three: check spelling / tone · check URL · anti-malware scan · trusted sources only · no personal details · firewall	B3	
6(b)	manipulating / deceiving people … to obtain data / make an error · any suitable example	B3	
6(c)	Any three: different permissions · limit reading / viewing · limit editing / deleting · linked to a username	B3	
			Total: 9 marks

10 Common mistakes

✗ "A firewall removes viruses"

✓ "Anti-malware removes viruses; a firewall blocks traffic that fails its criteria"

✗	✓
"Encryption stops data being intercepted"	"Encryption makes intercepted data meaningless"

It can still be intercepted.

✗	✓
"Use a password" for 3 marks	name it + how it helps + why that stops this attacker

11 Practice

Practice: easy, medium, hard

1. Give one example of biometric data.
2. Which software scans for and removes malware?
1. Explain how automating software updates helps keep data safe. [2]
2. Give two tasks a proxy-server can do that a firewall does not.
1. A school wants teachers to edit grades but students only to view them. Name and explain the solution. [3]

12 Can I do this?

0 / 3 ticked

- [ ] I can explain passwords, biometrics, two-step verification, access levels and privacy settings.
- [ ] I can explain firewalls, proxy-servers, anti-malware, automatic updates and SSL.
- [ ] I can match each threat to suitable solutions.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

ANSWER Two-step verification

2.

ANSWER Encryption (SSL)

3.

ANSWER Proxy-server

Practice: easy, medium, hard

Easy 1.

ANSWER e.g. fingerprint

Easy 2.

ANSWER Anti-malware (anti-virus)

Medium 1.

ANSWER

Updates are installed as soon as released, fixing security weaknesses before attackers can exploit them

Medium 2.

ANSWER Hide the IP address; cache web pages

Hard 1.

ANSWER

Access levels: teachers' accounts get edit permission, students' accounts read-only, linked to each username

6

Automated and Emerging Technologies

1 Automated systems

2 Robotics

3 Artificial intelligence

NOTE 6.1

Automated systems

1 In this note

SYLLABUS 6.1 AUTOMATED SYSTEMS

- 6.1.1 Describe how **sensors**, **microprocessors** and **actuators** can be used in collaboration to create **automated systems**.
- 6.1.2 Describe the **advantages and disadvantages** of an automated system used for a given purpose: industry, transport, agriculture, weather, gaming, lighting, science.

Before this: Sensors (chapter 3). Next: Robotics.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

Sensors

A sensor is an input device that measures a physical property (temperature, light, distance…) and sends the reading as data, after an ADC turns it into digital form.

Quick check: does a sensor make decisions?

No: the microprocessor does.

Microprocessor

An integrated circuit that processes data: here it runs the control program.

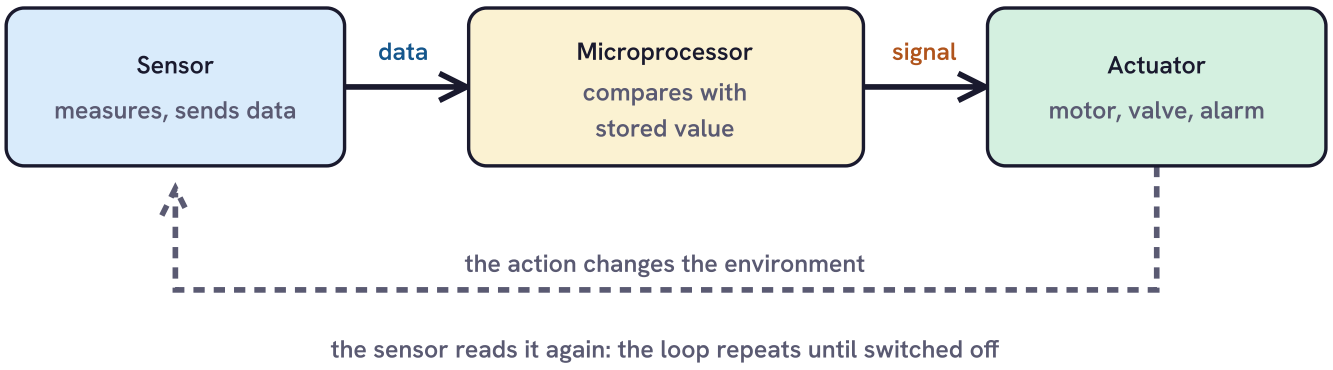
Quick check: where is the control program kept?

In ROM, as firmware.

3 What is an automated system?

Automated system: a system that can **perform actions without human intervention**. It is made of **sensors**, a **microprocessor** and **actuators** working together.

Part	Its job
Sensor	**measures** something in the environment and **sends the reading (data) to the microprocessor**
Microprocessor	**receives** the data, **compares it with a stored / preset value or range**, **decides** what to do and **sends a signal** to the actuator
Actuator	a component that **makes something move or happen** when it gets a signal: a motor, a valve, a pump, a heater, a light, a buzzer



Sensor, microprocessor and actuator working together in a loop.

✗ COMMON MISTAKE

The **sensor does not decide anything** and does not "tell the actuator". Marks are for the **microprocessor** comparing and sending the signal.

4 How it works, step by step

GENERAL METHOD **Describe how an automated system works (any scenario)**

1. Name the **sensor** that fits (e.g. temperature, proximity / infra-red, light, moisture, pressure).
2. The sensor **continuously** sends **digitised data** (readings) to the **microprocessor**.
3. The microprocessor **compares the data with the stored value** (give the number from the question, e.g. 40 °C, 10 cm).
4. **If** the reading is outside the range / past the value, the microprocessor **sends a signal to the actuator** to act (name the action).
5. **If** it is within the range, **no action** is taken (or the current action carries on).
6. The process **repeats continuously** until the system is switched off.

EXAMPLE: SMART HEATING **A room is kept at 21 °C. Describe how the heating system works. [5]**

Follow the method: sensor → microprocessor compares → actuator → repeat.

A **temperature sensor** continuously sends digitised readings to the **microprocessor**.

The microprocessor compares each reading with the stored value of 21 °C.

If the reading is below 21 °C, it sends a signal to an **actuator** to switch the heater on.

If the reading is 21 °C or above, it sends a signal to switch the heater off.

This repeats until the system is switched off.

ANSWER

Sensor → microprocessor compares with stored value → signal to actuator → repeat.

TRY IT YOURSELF

1. Which part compares a reading with a stored value?
2. Name the component that makes something move, e.g. a motor.

3 An automated street light turns on when it gets dark. Which sensor does it use?

5 Where automated systems are used

The syllabus names seven settings. In the exam you get a scenario and must give advantages and disadvantages **for that scenario** and **for the person named** (the employees, the owner, the farmer, the customer).

Setting	Example	Sensors → actuator
Industry	a bottling line fills and caps bottles	level / proximity → valve, motor
Transport	a driverless train stops at the platform; car parking sensors	proximity / infra-red → brakes, buzzer
Agriculture	automatic irrigation; a self-driving plough or tractor	moisture, proximity → pump, motor
Weather	a weather station records and alerts	temperature, humidity, pressure, light → stored data, alert
Gaming	a motion controller or VR headset reacts to movement	accelerometer, gyroscope → screen, vibration motor
Lighting	street lights or room lights switch themselves on	light, infra-red (motion) → lights
Science	a lab experiment logs readings overnight	temperature, pH, gas → stored readings, heater

6 Advantages and disadvantages

Advantages	Disadvantages
faster and more **accurate / consistent** than a person	**expensive to set up** (buy, install)
works 24/7, no breaks, no tiredness	**ongoing maintenance / repair costs**; needs skilled people to fix
safer: people don't go into **dangerous** places or handle heavy loads	can **malfunction**: production stops, or it fails to act (e.g. doesn't stop)
takes over **boring, repetitive** tasks; staff can do **more skilled** work	**deskilling** and **job losses**; staff need **training**
saves labour costs over time	**can't adapt** to an unexpected event it wasn't programmed for
creates new **maintenance** jobs	can be **hacked** if it is connected to a network

> Write the advantage **for the person the question names** and **explain** it: "employees don't need to go into dangerous areas to take readings, **so they are safer**" earns 2; "it is safer" earns at most 1.

7 Summary

- Automated system: performs actions without human intervention.
- Sensor sends data → microprocessor compares with stored value → signal to actuator → repeats.
- Settings: industry, transport, agriculture, weather, gaming, lighting, science.
- Advantages: 24/7, accurate, safer, no repetitive work. Disadvantages: cost, maintenance, malfunction, deskilling, job loss.

IF YOU SEE …

"explain how the sensor and the microprocessor are used to automate this" [5-7]	→ name sensor · continuously sends data · microprocessor compares with stored value · if… signal to actuator · if not… · repeats
"give two advantages to the employees" [2]	→ safety · no repetitive tasks · no heavy lifting · no night work · new maintenance jobs

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

8 Ways they test it

TYPE 1 **Explain the process**

> *"Explain how the sensor, microprocessor and actuator are used to stop the tractor" [5-7]*

Spot it a scenario with a number (3 m, 40 °C, 10 cm).

1. Follow the method; repeat the number from the question.

TYPE 2 **Role of a part**

> *"Describe the role of the microprocessor in this process" [3]*

Spot it "role".

1 receives data · compares / checks the range · sends signals to trigger actions

TYPE 3 **Advantages / disadvantages**

> *"Give two advantages to the employees..." [2]; "Explain one disadvantage to the owner" [2]*

Spot it who it is for.

1 Point for that person + its matching explanation.

TYPE 4 **Definition / components**

> *"State what is meant by an automated system" [1]; "give one other component" [1]*

Spot it "what is meant by".

1 without human intervention; microprocessor · actuator · storage

9 What the examiner looks for

"Explain how the sensor and microprocessor are used to automate the system" [5-7]

Marking points (one mark each, up to the marks shown)

- Names a suitable sensor (e.g. infra-red / proximity)
- Sensor continuously sends the digitised value to the microprocessor
- Microprocessor compares the data with the stored value (the number given)
- If past the value, a signal is sent to the actuator to act
- If not, no action / carries on
- The process repeats until switched off

KEYWORDS **continuously** **digitised** **compares** **stored value** **signal** **actuator** **repeats**

TOO VAGUE "the sensor decides"; "the sensor tells the motor"

10 Past-paper questions, solved

2210/13/O/N/24 Q5 ↗ Paper 1 · Computer systems **6 marks** ⤢ Full size

5 A farmer has a plough that is an automated system. The plough is used to dig the ground in a field to prepare it for planting seeds.

The plough uses sensors and a microprocessor to maintain a straight line when digging the ground.

(a) State what is meant by an automated system.

..... [1]

(b) Describe the role of the microprocessor in this process.

..... [3]

(c) Give **two** benefits to the farmer of using an automated system for this purpose.

[2]

Swipe sideways to read the whole question

How to start (a) a definition [1]; (b) three things the microprocessor does [3]; (c) two benefits for the farmer [2]. Part (d), on AI, is solved on the AI page.

▼ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

(a) A system that can perform actions without human intervention.

(b) It receives data from the sensors. It checks whether the data is within the range for a straight line. If it is out of range, it sends signals to trigger an action to steer the plough back.

(c) The farmer doesn't have to handle heavy equipment; it can work 24/7 without breaks.

PART	ANSWER / WORKING	MARKS	GUIDANCE
5(a)	Performs actions without human intervention	B1	
5(b)	receives data from sensor · analyses / checks if within range · sends signals to trigger actions	B3	
5(c)	Any two: no heavy equipment · frees farmer for other jobs · 24/7 · repetitive tasks · saves labour · more accurate / efficient	B2	

Total: 6 marks

6 A weather station uses automated systems to collect and analyse data about the weather.

The automated system uses sensors.

(a) Give **one** other component that would be part of the automated system.

..... [1]

(b) One sensor that is part of the automated system is a temperature sensor.

Give **one** other sensor that could be part of the automated system.

..... [1]

(c) An alert is sent to an employee in the weather office if a temperature above 40 °C is detected.

(i) Explain how a temperature above 40 °C is detected for the alert.

..... [3]

(d) Give **two** advantages to the weather station employees of using an automated weather system.

[2]

(e) Give **one** disadvantage to the weather station employees of using an automated weather system.

..... [1]

Swipe sideways to read the whole question

How to start (a) a part other than sensors; (b) another sensor; (c)(i) the process with 40; (d) and (e) for the employees. (c)(ii) is data transmission (chapter 2).

▼ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

(a) A microprocessor (or an actuator).

(b) Humidity sensor.

(c)(i) The microprocessor receives data from the temperature sensor. It compares the data with the preset value of 40. If the data is greater than 40, it sends a signal to trigger the alert.

(d) Employees don't need to work outside in bad weather; they don't need to work overnight.

(e) It may replace employees and take their jobs.

PART	ANSWER / WORKING	MARKS	GUIDANCE
6(a)	Any one: microprocessor · actuator · storage	B1	
6(b)	Any one: humidity · light · level · infra-red	B1	
6(c)(i)	microprocessor used · receives data from sensor · compares with 40 · greater than 40 → signal to trigger alert	B3	
6(d)	Any two: no repetitive task · no overnight work · not outside in bad weather · maintenance jobs	B2	
6(e)	Any one: deskilling · replaces employees	B1	

Total: 8 marks

2210/12/O/N/23 Q11 ↗ Paper 1 · Computer systems **5 marks** ⤢ Full size

11 A manufacturing company uses an automated system in its manufacturing process.

(a) The automated system uses a flow sensor.

Identify what a flow sensor measures.

.....

..... [1]

(b) Explain **one** advantage to employees of using an automated system in manufacturing.

.....

.....

.....

..... [2]

(c) Explain **one** disadvantage to the company owner of using an automated system in manufacturing.

.....

.....

.....

..... [2]

Swipe sideways to read the whole question

How to start (b) and (c) say **explain one** : a point + its matching explanation, 2 marks each.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a) The amount of liquid or gas flowing through a pipe.

(b) It increases safety, because workers don't need to go into dangerous areas to take readings or make checks.

(c) High set-up cost, so the owner must find a lot of money up front to pay for the equipment and train employees.

PART	ANSWER / WORKING	MARKS	GUIDANCE
11(a)	Amount of liquid / gas / steam flowing	**B1**	
11(b)	Benefit + matching explanation, e.g. safety → no need to enter dangerous areas; no repetitive tasks → more skilled work	**B2**	
11(c)	Drawback + matching explanation, e.g. high set-up cost → money up front; maintenance cost → skilled staff needed	**B2**	
		Total: 5 marks	

11 Common mistakes

✗ "The sensor checks if it is too hot"

✓ "The microprocessor compares the reading with the stored value"

Sensors only measure.

✗ "The sensor sends a signal to the motor"

✓ "The microprocessor sends a signal to the actuator"

✗ "It is cheaper" (one-word answers)

✓ "It saves labour costs because no workers need to be paid to ..."

Explain = point + reason.

✗ Forgetting the loop

✓ "This repeats until the system is switched off"

It is a mark on most schemes.

12 Practice

Practice: easy, medium, hard

1. State what is meant by an automated system. [1]
2. Give one example of an actuator.
1. An automatic door opens when a person is within 2 m. Explain how it works. [5]
2. Give two disadvantages to a factory owner of an automated system. [2]
1. A science lab keeps a reaction between 60 °C and 65 °C overnight. Explain how an automated system does this and give one advantage to the scientists. [6]

13 Can I do this?

0 / 3 ticked

- [ ] I can say what each of the sensor, microprocessor and actuator does.
- [ ] I can explain step by step how an automated system works in a scenario.
- [ ] I can give advantages and disadvantages for the person named.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

ANSWER The microprocessor

2.

ANSWER Actuator

3.

ANSWER Light sensor

Practice: easy, medium, hard

Easy 1.

ANSWER A system that performs actions without human intervention

Easy 2.

ANSWER e.g. motor · valve · pump · heater · buzzer

Medium 1.

ANSWER

Infra-red / proximity sensor continuously sends data to the microprocessor · compares with stored 2 m · if within 2 m, signal to actuator (motor) to open · if not, door stays shut / closes · repeats

Medium 2.

ANSWER e.g. high set-up cost · maintenance cost · production stops if it malfunctions

Hard 1.

ANSWER

Temperature sensor sends data continuously · microprocessor compares with 60 and 65 · below 60 → signal to heater on · above 65 → heater off · repeats · advantage: scientists needn't stay overnight to check readings, and readings are taken more accurately

NOTE 6.2

Robotics

1 In this note

SYLLABUS 6.2 ROBOTICS

- 6.2.1 Understand what is meant by **robotics**: a branch of computer science that incorporates the **design, construction and operation** of robots, e.g. factory equipment, domestic robots, drones.
- 6.2.2 Describe the **characteristics of a robot**: a mechanical structure or framework, electrical components, programmable.
- 6.2.3 Understand the **roles** that robots can perform and describe the **advantages and disadvantages** of their use in industry, transport, agriculture, medicine, domestic and entertainment.

Before this: Automated systems. Next: Artificial intelligence.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

Automated systems

Sensor → microprocessor compares with a stored value → signal to an actuator → repeats.

Quick check: which part decides?

The microprocessor.

Firmware

Permanent instructions stored in ROM that control the hardware.

Quick check: where is a robot's program kept?

In ROM, as firmware.

3 What is robotics?

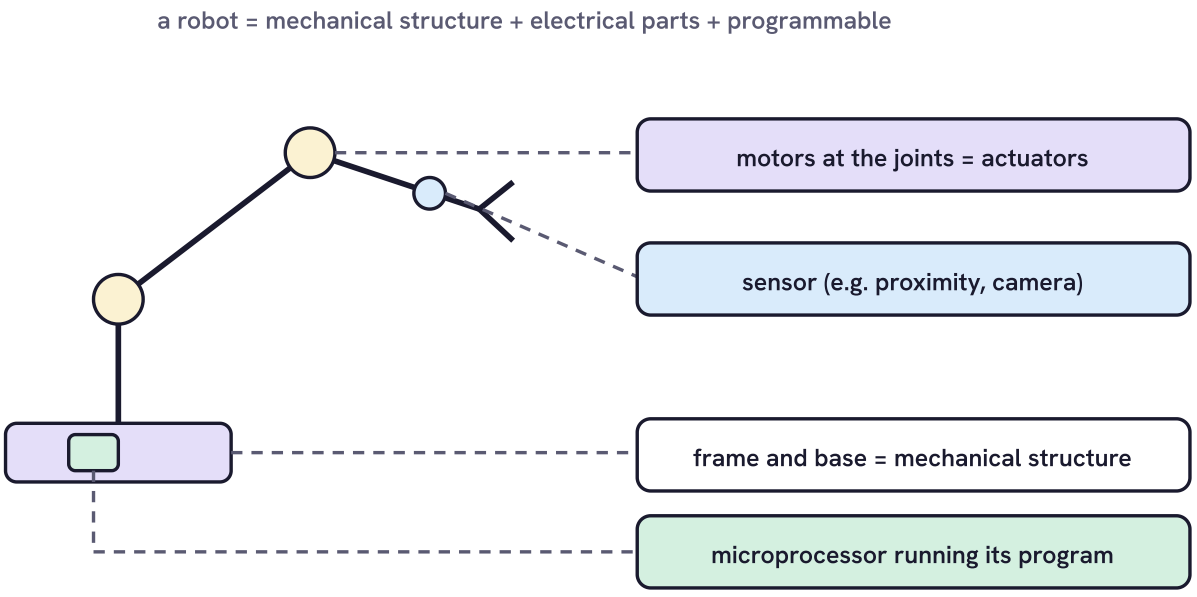
> **Robotics**: a branch of computer science that covers the **design**, **construction** and **operation** of **robots**.

Examples you can quote: **factory equipment** (welding and painting arms on a car production line), **domestic robots** (robot vacuum cleaners, lawn mowers) and **drones** (delivery, filming, crop spraying).

4 The characteristics of a robot

A machine is only a **robot** if it has all three of these:

Characteristic	What it means	Example
Mechanical structure / framework	a physical body, often with wheels, arms, joints or grippers, so it **can move** and do a physical task	the arm and base of a welding robot
Electrical components	**sensors** (to collect data), a **microprocessor** (to process it) and **actuators** (motors to move)	a proximity sensor, a microprocessor, joint motors
Programmable	it is controlled by a **program** that can be written or changed, so it can be given a new task	reprogrammed to weld a new car model



A factory robot arm and its three characteristics.

Is it a robot? A **smart speaker** is **not**: it has no mechanical structure and no actuators, so it cannot move itself. A **self-driving tractor** is: it has a framework, electrical components and is programmable.

TRY IT YOURSELF

1. One characteristic of a robot is that it is programmable. Name another.
2. Robotics covers the design, construction and … of robots.
3. Give two electrical components a robot has.

5 How a robot reacts to its surroundings

A robot is an automated system, so the **same method** earns the marks when a question asks how it avoids an obstacle, stops for a person or turns at a fence.

GENERAL METHOD **Explain how a robot uses its sensor and microprocessor**

1. A **proximity / infra-red** sensor (or the sensor that fits) is used.
2. The sensor **continuously sends digitised data** to the **microprocessor**.
3. The microprocessor **compares the data with the stored value** (e.g. 10 cm, 3 m).
4. **If** the object is at or within the value, it **sends a signal to an actuator** to stop / turn / brake.
5. **Otherwise** it sends a signal to carry on (move forward) or takes no action.
6. This **repeats** until the robot is turned off.

6 Roles robots perform

Area	Roles	Advantages	Disadvantages
Industry	welding, painting, assembling, moving heavy parts, packing	works 24/7; consistent quality; workers do no heavy lifting or dangerous work	expensive to buy and maintain; job losses; stops production if it breaks
Transport	driverless cars, trains and delivery vehicles; warehouse robots	fewer accidents from human error; works without breaks	can fail to recognise a hazard; can be hacked; job losses for drivers
Agriculture	planting seeds, ploughing, harvesting, weeding, crop-spraying drones	more accurate planting; 24/7; farmer is free for other jobs	expensive; needs maintenance; can't adapt to an unexpected event; farmer needs training
Medicine	surgery controlled by a doctor (even from far away); dispensing medicine	more precise, so smaller cuts and faster recovery; a specialist anywhere can operate without travelling	connection can be lost or delayed; can be hacked; very expensive
Domestic	robot vacuum cleaners, lawn mowers, pool cleaners	saves people time on repetitive chores	expensive; can get stuck; may not clean as thoroughly
Entertainment	theme-park rides, animatronics, camera robots and drones for filming	repeats a show exactly; films shots a person can't	expensive; can malfunction mid-show; less of a human touch

✗ COMMON MISTAKE

Read **whose** advantage it is. "Advantages to the **workers**": no heavy lifting, safer, no repetitive tasks, new maintenance jobs. "To the **company**": no wages, 24/7, consistent. They are different mark lists.

7 Summary

- Robotics: the design, construction and operation of robots (factory equipment, domestic robots, drones).
- A robot: mechanical structure / framework + electrical components (sensors, microprocessor, actuators) + programmable.
- It reacts using the automated-system loop: sensor → microprocessor compares → actuator → repeat.
- Roles in industry, transport, agriculture, medicine, domestic, entertainment, each with advantages and disadvantages.

IF YOU SEE …

"give three characteristics of a robot" [3]	→ mechanical structure / framework · electrical components · programmable · (can move)
"explain why X is not a robot" [3]	→ no mechanical structure · no actuators · so it cannot move itself

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

8 Ways they test it

TYPE 1 **Characteristics**

> *"One characteristic is that it is programmable. State two other characteristics" [2]*

Spot it a characteristic already given.

1. Don't repeat the one in the question.

TYPE 2 **Robot or not?**

> *"Explain why the smart speaker is not a robot" [3]*

Spot it "not a robot".

1. Say which characteristic is missing and what it means.

TYPE 3 **Sensor process**

> *"Explain how the robot uses sensors and a microprocessor to know it has reached a fence" [6-7]*

Spot it a distance or event.

1. The method above, with the value from the question.

TYPE 4 **Advantages / disadvantages**

> *"Give two advantages to the farmer..." [2]; "explain the advantages of using the robot to perform surgery" [4]*

Spot it whose and how many.

1. For "explain", each point + its "so...".

9 What the examiner looks for

"Describe the characteristics of a robot" [3]

Marking points (one mark each, up to the marks shown)

- A mechanical structure / framework
- Electrical components
- ... such as sensors / microprocessor / actuators
- Programmable
- Has the ability to move

KEYWORDS **mechanical structure** **framework** **electrical components** **programmable**

TOO VAGUE "it is intelligent" (that is AI, not a characteristic of a robot); "it is automatic"

10 Past-paper questions, solved

2210/11/M/J/24 Q8 ↗ Paper 1 · Computer systems **16 marks** ⤢ Full size

8 A farmer uses an automated robot to plant seeds in the field.

(a) State what is meant by the robot being automated.

..... [1]

(b) Give **three** characteristics of a robot.

[3]

(c) The robot plants seeds and stops when it reaches a fence. It then turns and continues planting seeds. The robot uses sensors and a microprocessor to know when it reaches a fence.

Explain how the robot uses sensors and a microprocessor to know it has reached a fence.

..... [6]

(d) Give **two** advantages of the farmer using an automated robot to plant seeds.

[2]

(e) Give **two** disadvantages of the farmer using an automated robot to plant seeds.

[2]

(f) The robot is adapted to have machine learning capabilities.

Explain how this will improve the robot.

..... [2]

Swipe sideways to read the whole question

How to start Six parts: (a) automated [1], (b) characteristics [3], (c) the sensor process [6], (d)/(e) for the farmer [2+2], (f) machine learning (next note) [2].

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a) The robot can perform actions without human intervention.

(b) It has a mechanical structure / framework; it has electrical components; it is programmable.

(c) A proximity sensor is used. It continuously sends digitised data to the microprocessor. The microprocessor compares the data with a stored range of values. If the value is within the range, the robot carries on planting. If it is outside the range (the fence is reached), the microprocessor sends a signal to an actuator to stop and turn the robot. This repeats until the robot is turned off.

(d) It is more accurate when planting seeds; it does not need breaks, so it can work 24/7.

(e) It is expensive to buy; it needs maintenance, which may be costly.

(f) It can change its own rules and data, so it remembers where the fence and obstacles are and makes fewer errors.

PART	ANSWER / WORKING	MARKS	GUIDANCE
8(a)	Performs actions without human intervention	**B1**	
8(b)	Any three: mechanical structure / framework · electrical components · programmable · can move	**B3**	
8(c)	proximity sensor · sends digitised data continuously · compares with stored value / range · within range → continues · outside → signal to turn / stop · using an actuator · repeats	**B6**	
8(d)	Any two: more accurate · 24/7 · not bored · farmer does other tasks · faster · safer · no wages	**B2**	
8(e)	Any two: expensive · maintenance cost · job losses · deskilling · training · manual if it breaks · damage if faulty · can't adapt	**B2**	
8(f)	adapts its own rules / data / processes · more efficient · … e.g. remembers where the fence / obstacles are · fewer errors	**B2**	
			Total: 16 marks

6 A self-driving tractor sows seeds and harvests crops for a farmer. The self-driving tractor moves automatically through the field, turning at each end and stopping when it has finished.

(a) One reason the self-driving tractor is a robot is because it has a mechanical structure that includes wheels, an engine, and a framework.

Give **one** other reason why the self-driving tractor is an example of a robot.

..... [1]

(b) If a person is detected within 3 metres whilst the tractor is moving, the self-driving tractor must stop.

(i) Explain how an infra-red sensor, microprocessor and actuator can be used to stop the self-driving tractor if a person is detected within 3 metres.

..... [5]

(ii) Identify **one** other sensor that the self-driving tractor might use and how it will use the sensor.

Sensor .....

Use .....

[2]

(c) Explain the drawbacks of a farmer using a self-driving tractor to sow seeds and harvest crops.

..... [3]

Swipe sideways to read the whole question

How to start (b)(i) needs all three named parts; (c) says **explain the drawbacks** : points with reasons. (d) and (e) are expert systems and error checking.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a) It is programmable (or: it has electrical components).

(b)(i) The infra-red sensor continuously sends the digitised readings to the microprocessor. The microprocessor compares the data with the stored data for a person and the distance of 3 m. If a person is within 3 m, it sends a signal to the actuator to apply the brakes and stop the tractor. If not, no action is taken. The process repeats until the tractor is turned off.

(b)(ii) A proximity sensor, to detect when it is near the end of the field so it can turn.

(c) The set-up cost may be high. Maintenance needs skilled experts, which is costly. It can malfunction and fail to recognise a person, so it does not stop.

PART	ANSWER / WORKING	MARKS	GUIDANCE
6(a)	Any one: electrical components · programmable	**B1**	
6(b)(i)	Any five: sensor sends data continuously · microprocessor compares with stored data / 3 m · if person within 3 m · signal to actuator to stop / brake · if more than 3 m no action · restart when clear · repeats	**B5**	
6(b)(ii)	Sensor + matching use, e.g. accelerometer → uneven ground / crash; proximity → end of field; light → headlights	**B2**	
6(c)	Any three: set-up cost · maintenance cost · needs experts · retraining · deskilling · fewer employees · malfunction → fails to stop	**B3**	
		Total: 11 marks	

5 A hospital has computers and technology that it uses when caring for its patients.

(b) The hospital has a robot that is used to perform surgery. A doctor controls the robot from a different location to perform surgery on a patient.

(i) One feature of the robot is that it has electrical components.

Give **two** examples of the electrical components of a robot.

[2]

(ii) Explain the advantages of using the robot to perform surgery.

..... [4]

(iii) Explain **one** disadvantage of using the robot to perform surgery.

..... [2]

Swipe sideways to read the whole question

How to start (ii) **explain the advantages** [4]: two advantages, each with its "so...". (iii) one disadvantage + its consequence [2].

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(b)(i) Sensors; actuators (or a microprocessor).

(ii) The doctor does not need to travel to the hospital, so any specialist in the world can do the surgery and it can be done immediately. The robot is more precise, so a smaller incision can be made and the recovery time is shorter.

(iii) The internet connection could be lost or delayed, so the surgery may not be able to continue.

PART	ANSWER / WORKING	MARKS	GUIDANCE
5(b)(i)	Any two: sensors · microprocessors · actuators	B2	
5(b)(ii)	no travel · … any specialist · … done immediately · … not tired · precision · … smaller incision · … shorter recovery · safer	B4	
5(b)(iii)	Point + expansion, e.g. connection lost → surgery stops; hacked → endangers patient; malfunction → cannot continue	B2	

Total: 8 marks

2210/12/O/N/25 Q7 ↗ Paper 1 · Computer systems — **3 marks** — ⤢ Full size

7 A house has a smart speaker that can take voice commands as input. A person in the house can tell the smart speaker to play music or audio books.

(a) The smart speaker cannot be described as a robot.

Explain why the smart speaker is **not** a robot.

..... [3]

Swipe sideways to read the whole question

How to start Use the three characteristics: which ones are missing?

▾ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

It does not have a mechanical structure. It does not have any actuators, so it cannot move itself.

PART	ANSWER / WORKING	MARKS	GUIDANCE
7(a)	no mechanical structure · no actuators · so it cannot move itself	B3	

Total: 3 marks

11 Common mistakes

✗ "A robot is intelligent"

✓ "A robot has a mechanical structure, electrical components and is programmable"

AI is a separate idea; not every robot has it.

✗ "It has a sensor" as the characteristic

✓ "It has electrical components, such as sensors"

Name the characteristic first.

✗ Repeating the characteristic given in the question

✓ Give the other ones

No mark for the one they gave you.

✗ "The robot is cheaper"

✓ "The company does not need to pay wages to workers"

Explain the point.

12 Practice

Practice: easy, medium, hard

1. Give three characteristics of a robot. [3]
2. Give one example of a domestic robot.
1. A drone delivers parcels. Give two advantages to the delivery company. [2]
2. Explain why a robot vacuum cleaner is a robot. [3]
1. A robot moves forward until an object is 15 cm in front, then turns left. Explain how it uses its sensor and microprocessor. [6]

13 Can I do this?

0 / 4 ticked

- [ ] I can say what robotics is, with examples.
- [ ] I can give the three characteristics of a robot and say why something is not a robot.
- [ ] I can explain how a robot reacts using its sensor, microprocessor and actuator.
- [ ] I can give roles, advantages and disadvantages in the six areas.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

ANSWER A mechanical structure / framework (or electrical components)

2.

ANSWER Operation

3.

ANSWER Sensors and actuators (or a microprocessor)

Practice: easy, medium, hard

Easy 1.

ANSWER Mechanical structure / framework · electrical components · programmable

Easy 2.

ANSWER e.g. robot vacuum cleaner · robot lawn mower

Medium 1.

ANSWER e.g. no driver wages · faster deliveries (not stuck in traffic) · works 24/7

Medium 2.

ANSWER

It has a mechanical structure (body, wheels, brushes) so it can move · it has electrical components (sensors, microprocessor, motors) · it is programmable

Hard 1.

ANSWER

Proximity / infra-red sensor · continuously sends digitised data to the microprocessor · compares with 15 cm · if greater than 15 cm, signal to actuator to move forward · if 15 cm or less, signal to actuator to turn left · repeats until turned off

NOTE 6.3

Artificial intelligence

1 In this note

SYLLABUS 6.3 ARTIFICIAL INTELLIGENCE

- 6.3.1 Understand what is meant by **artificial intelligence (AI)**: a branch of computer science dealing with the **simulation of intelligent behaviours** by computers.
- 6.3.2 Describe the **main characteristics** of AI: the collection of data and the rules for using that data; the ability to reason; it can include the ability to learn and adapt.
- 6.3.3 Explain the basic operation and components of AI systems: **expert systems** (knowledge base, rule base, inference engine, interface) and **machine learning** (a program that can automatically adapt its own processes and/or data).

Before this: Robotics. This is the last note of Paper 1 theory.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

Robots

Mechanical structure + electrical components + programmable. A robot does not have to be intelligent.

Quick check: does every robot have AI?

No: AI is something extra some robots have.

3 What is AI?

Artificial intelligence (AI): a branch of computer science dealing with the **simulation of intelligent behaviours** by computers, so a computer can do things that would need

intelligence if a person did them.

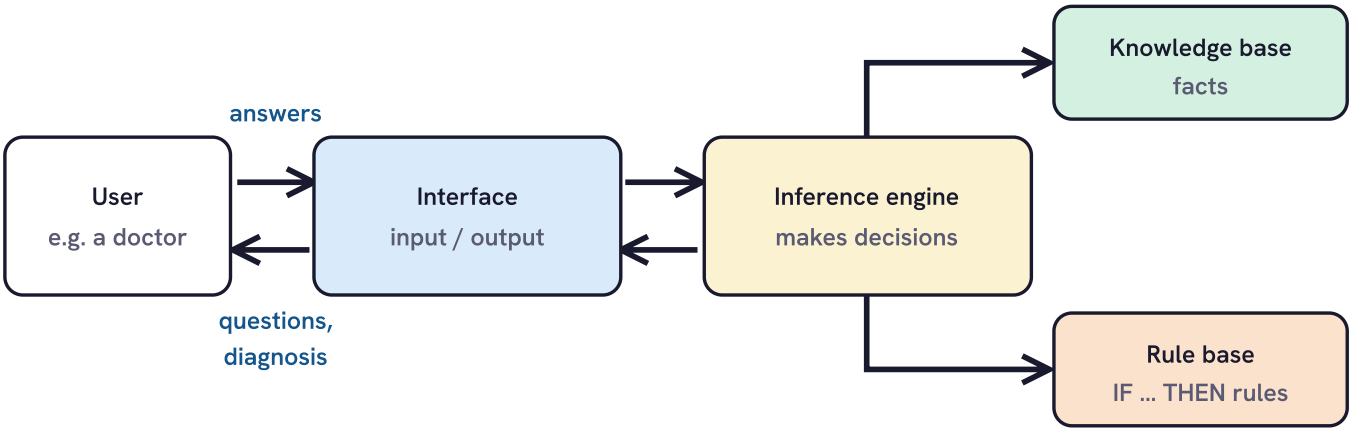
Characteristic	What it means	Example
Collection of data and **the rules for using that data**	it holds facts and rules that say what to do with them	a medical system stores symptoms and IF … THEN rules
Ability to reason	it can work out a conclusion or **make a decision** from the data	decides the most likely illness
Ability to learn and adapt (can be included)	it can **change its own processes / data** from experience, so it improves	a game character learns how a player moves

The syllabus covers two kinds of AI system: **expert systems** and **machine learning**.

4 Expert systems

An **expert system** copies the knowledge of a human expert (a doctor, a mechanic, a geologist) so that someone else can get an expert answer: a **diagnosis**, a fault, a decision. It has four components:

Component	Its job
Knowledge base	a database of **facts** about the subject (collected from experts)
Rule base	the **rules** (IF … THEN) for using the facts; **links the facts** in the knowledge base so the inference engine can use them
Inference engine	the part that **makes decisions**: it **applies the rule base to the knowledge base** and the user's answers to reach a **diagnosis**; it also **decides which question to ask next** based on the previous answers
Interface	how the user **inputs data** (answers questions) and **sees the output** (the questions and the diagnosis)



The four components of an expert system.

GENERAL METHOD **How an expert system works (e.g. diagnosing a car fault)**

1. The user enters data through the **interface** (or plugs the car into it), e.g. "the brakes squeak".
2. The **inference engine** **compares the data with the knowledge base** ...
3. ... and **applies the rule base** to the knowledge base.
4. It **decides which question to ask next**, **based on the previous answers**, and shows it on the interface.
5. When it has enough data it **decides the diagnosis** (the most likely one if there are several).
6. The **interface outputs the diagnosis** (often with how it was reached).

✗ COMMON MISTAKE

The **inference engine** makes the decisions. The knowledge base only stores facts and the rule base only stores rules: neither of them "decides".

5 Machine learning

Machine learning: a program that can **automatically adapt its own processes and/or data**, so it improves without being reprogrammed by a person.

GENERAL METHOD **How a system uses machine learning (any scenario)**

1. It **collects / gathers data** as it works (e.g. where obstacles are, how a user speaks, which results were clicked).
2. It **analyses the data to find patterns**.
3. It **stores successful and unsuccessful** results / actions.
4. It **adapts its own processes, rules or data** using this.
5. So **next time** it makes **fewer mistakes** / gives **more accurate** results (say what improves in the scenario).

Scenario	What it learns	So …
robot vacuum cleaner	the shape of the room, where obstacles and dirtier areas are	it takes the most efficient route
smart speaker	the user's voice, accent and different ways of asking	it understands voice commands better, ignores background noise
search engine	which results users clicked or ignored (feedback)	it changes its rules to give more relevant results
game character	patterns in the player's movements	it predicts and reacts to the player's next move
weather system	patterns in past weather data, feedback on its forecasts	it makes more accurate predictions

Training can be **supervised** (the system is given the inputs and the correct outputs) or **unsupervised** (it is given only inputs and must find the patterns itself). Either earns a mark when describing machine learning.

TRY IT YOURSELF

1. Which component of an expert system makes the decisions?
2. Which component stores the facts?
3. A program can automatically adapt its own processes and data. Name this ability.
4. Name the four components of an expert system.

6 Summary

- AI: the simulation of intelligent behaviours by computers.
- Characteristics: data + rules for using it; ability to reason; can learn and adapt.
- Expert system: knowledge base (facts) · rule base (rules) · inference engine (applies rules to facts, decides next question and diagnosis) · interface.
- Machine learning: automatically adapts its own processes / data: gathers data → patterns → stores results → adapts → fewer mistakes.

IF YOU SEE …

"explain how an expert system operates" [5-6]	→ interface input · inference engine · knowledge base · rule base · applies rules to facts · decides next question · outputs diagnosis
"explain how X can make use of machine learning" [3-4]	→ gathers data · patterns · adapts own processes · so … (scenario) · fewer mistakes

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

7 Ways they test it

TYPE 1 Define / characteristics

> *"Describe what is meant by AI" [2-3]; "identify three other characteristics of AI" [3]*

Spot it "what is meant by".

1. simulation of intelligent behaviour · data + rules · reason · learn / adapt

TYPE 2 Components

> *"Identify the three other components in an expert system" [3]; "circle three components" [3]*

Spot it one component already named.

1. From knowledge base, rule base, inference engine, interface: leave out the one given.

TYPE 3 Operation

> *"Explain how the expert system operates and how it is used to diagnose the problem" [5-6]*

Spot it "operate / diagnose".

1. Follow the method; say "inference engine" for every decision.

TYPE 4 Cloze

> *"Complete the paragraph using terms from the list" [5-7]*

Spot it a word list.

1. Facts → knowledge base; decides → inference engine; links / applies → rule base; types / output → interface.

TYPE 5 **Machine learning in a scenario**

> *"Explain how the robot vacuum cleaner can make use of machine learning" [3-4]*

Spot it a named device.

1. Method + what it learns in that device.

8 What the examiner looks for

"Explain how an expert system operates" [6]

Marking points (one mark each, up to the marks shown)

- It has an interface ...
- ... used to input data / view output
- It has a knowledge base
- It has a rule base
- It has an inference engine
- Applies the rule base to the knowledge base to provide the output / diagnosis
- Decides what to ask next based on the data input

KEYWORDS **interface** **knowledge base** **rule base** **inference engine** **applies** **diagnosis**

TOO VAGUE "the knowledge base decides"; "it thinks like a human"

9 Past-paper questions, solved

2210/12/M/J/24 Q10 ↗ Paper 1 · Computer systems **7 marks** ⤢ Full size

10 A garage uses an expert system to help diagnose any problems with cars that need repair.

(a) The expert system is an example of artificial intelligence (AI).

Describe what is meant by AI.

.....

.....

.....

..... [2]

(b) A car has a problem with its braking system, so it is brought into the garage.

Explain how the expert system operates and how it is used to help diagnose the problem.

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... [5]

Swipe sideways to read the whole question

How to start (a) two characteristics [2]. (b) the operation method, in the garage's words [5].

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a) The simulation of intelligent behaviours by computers. It has the ability to reason.

(b) The mechanic enters data about the brakes into the interface. The inference engine decides which questions to ask, using the previous answers given. It compares the answers entered with the knowledge base and the rule base. It decides on the most likely diagnosis and the interface outputs it.

PART	ANSWER / WORKING	MARKS	GUIDANCE
10(a)	Any two: simulation of intelligent behaviour · data + rules for using it · ability to reason · ability to learn / adapt	B2	
10(b)	Any five: data entered via interface · inference engine decides which questions · … using previous answers · decides diagnosis · … comparing with knowledge base and rule base · most likely option · interface outputs diagnosis · explanation system	B5	

Total: 7 marks

10 A car repair garage uses an expert system.

(a) Complete the description about the operation of the expert system.

Use the terms from the list. Some of the terms in the list will **not** be used.

inference engine interface knowledge base

machine learning mechanical engine output device

question base rule base

An expert system has a ..... that contains a list of facts. The ..... applies the ..... to the ..... to reach a diagnosis for the repair of the car. The user provides data to the system using an ..... . [5]

(b) The expert system has machine learning capabilities.

Describe what is meant by machine learning capabilities.

.....

.....

.....

.....

.....

.....

.....

..... [4]

Swipe sideways to read the whole question

How to start (a) five gaps: match each gap to a component's job. (b) four points about machine learning.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a) An expert system has a **knowledge base** that contains a list of facts. The **inference engine** applies the **rule base** to the **knowledge base** to reach a diagnosis for the repair of the car. The user provides data to the system using an **interface**.

(b) It is a form of AI that can adapt its own processes and edit its own data. It analyses patterns and stores successful and unsuccessful results, to influence future decisions. It can be trained, supervised or unsupervised.

PART	ANSWER / WORKING	MARKS	GUIDANCE
10(a)	knowledge base · inference engine · rule base // knowledge base · knowledge base // rule base · interface	B5	
10(b)	Any four: form of AI · adapts own processes · edits own data · can be trained · supervised / unsupervised · analyses patterns, stores results · to influence future decisions	B4	

Total: 9 marks

2210/12/O/N/24 Q8 ↗ Paper 1 · Computer systems **6 marks** ⤢ Full size

8 A robot vacuum cleaner uses sensors to navigate around obstacles in a room.

(b) An expert system can be used to diagnose an error with a robot vacuum cleaner.

Circle **three** components that are part of an expert system.

knowledge base operating system firewall

server printer actuator inference engine

rule base encryption

[3]

(c) Explain how the robot vacuum cleaner can make use of machine learning.

..... [3]

Swipe sideways to read the whole question

How to start (b) circle exactly three. (c) machine learning **in this device** : say what it learns.

▼ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

(b) Knowledge base, rule base, inference engine.

(c) It gathers data while vacuuming, such as where obstacles are and where the dirtier areas are. It adapts its own processes using this data, so it knows the most efficient route to vacuum the room and which areas to concentrate on.

PART	ANSWER / WORKING	MARKS	GUIDANCE
8(b)	knowledge base · rule base · inference engine	B3	
8(c)	Any three: gathers data · adapts own processes · … obstacles · dirtier areas · path / shape of room · most efficient route · areas to avoid	B3	

Total: 6 marks

6 A search engine uses artificial intelligence (AI) to identify the most relevant web pages for the user.

(a) One characteristic of AI is the ability to learn.

Identify **three** other characteristics of AI.

1 .....

.....

2 .....

.....

3 .....

.....

[3]

(b) The search engine uses machine learning.

Explain how machine learning is used by the search engine.

.....

.....

.....

.....

.....

..... [3]

Swipe sideways to read the whole question

How to start (a) the question gives "learn": give three other characteristics. (b) how the search engine changes from feedback.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a) The collection of data; rules for using the data; the ability to reason.

(b) If a result does not give a suitable response, this is recorded. The search engine changes its own data and rules according to this feedback, so next time it provides more relevant results.

PART	ANSWER / WORKING	MARKS	GUIDANCE
6(a)	Any three: collection of data · rules for data · ability to reason · ability to adapt	B3	
6(b)	Any three: changes its data / rules · according to feedback · unsuitable result recorded · result changed next time · more accurate / relevant	B3	

Total: 6 marks

2210/13/O/N/24 Q5 ↗ Paper 1 · Computer systems **4 marks** ⤢ Full size

5 A farmer has a plough that is an automated system. The plough is used to dig the ground in a field to prepare it for planting seeds.

The plough uses sensors and a microprocessor to maintain a straight line when digging the ground.

(d) The plough uses artificial intelligence (AI) to navigate its way around the field.

Explain how the plough makes use of AI for this purpose.

..... [4]

Swipe sideways to read the whole question

How to start Four marks: name machine learning, then what it gathers and what improves.

▾ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

It could use machine learning. It gathers data while ploughing, such as the dimensions of the field and where obstacles are, and uses this data to adapt its own process, creating a map of the field and the most efficient route, so it makes fewer mistakes in future.

PART	ANSWER / WORKING	MARKS	GUIDANCE
5(d)	Any four: machine learning · gathers data from ploughing · adapts own process · fewer mistakes · … dimensions / landscape / obstacles · map of field · most efficient route · knows what to avoid	B4	

Total: 4 marks

10 Common mistakes

✗ "The knowledge base makes the diagnosis"

✓ "The inference engine applies the rule base to the knowledge base to make the diagnosis"

✗ "AI is a robot"

✓ "AI is the simulation of intelligent behaviour by computers"

Robots and AI are separate topics.

✗ "Machine learning means it learns"

✓ "It automatically adapts its own processes and data"

Don't define a word with itself.

✗ Generic machine-learning answers

✓ Say what this device learns (route, voice, obstacles...)

Scenario marks need the scenario.

11 Practice

Practice: easy, medium, hard

1 Name the component of an expert system that stores facts.

2 Give two characteristics of AI. [2]

1 Describe the role of the rule base in an expert system. [2]

2 Describe the role of the inference engine. [2]

1 A chess program uses machine learning. Explain how this helps it play better. [4]

12 Can I do this?

0 / 3 ticked

- [ ] I can define AI and give its characteristics.
- [ ] I can name the four components of an expert system and explain how it reaches a diagnosis.
- [ ] I can explain machine learning in a given scenario.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

ANSWER The inference engine

2.

ANSWER The knowledge base

3.

ANSWER Machine learning

4.

ANSWER Knowledge base, rule base, inference engine, interface

Practice: easy, medium, hard

Easy 1.

ANSWER Knowledge base

Easy 2.

ANSWER

e.g. collection of data and rules for using it · ability to reason · ability to learn / adapt

Medium 1.

ANSWER

Stores the rules (IF ... THEN) · used by the inference engine · to link the facts in the knowledge base

Medium 2.

ANSWER

Makes decisions · by applying the rules to the facts / knowledge · to give a result / diagnosis

Hard 1.

ANSWER

Collects data about each game / the opponent’s moves · finds patterns · stores successful and unsuccessful moves · adapts its own processes · so it chooses better moves and makes fewer mistakes next time