Logic gates, diagrams and truth tables

2.4.1 · Algorithms and programming (Paper 2) · revision notes

Logic gates (AND, OR and NOT) combine binary inputs (1 = True, 0 = False) to give an output. You need to draw and read simple logic diagrams, complete truth tables and write logic expressions, for diagrams with up to three inputs. Expect 'complete the truth table', 'write the expression' and 'draw the diagram' questions.

Key facts

- AND: output 1 only when both inputs are 1 (D-shaped symbol)
- NOT: output is the opposite of the input (triangle with a circle)
- n inputs give 2^n rows: 2 inputs = 4 rows, 3 inputs = 8 rows
- Add a column for each gate's output before the final output
- OR: output 1 when at least one input is 1 (curved back, pointed front)
- 1 = True, 0 = False (T/F and other valid notation are accepted)
- Fill input columns by counting in binary: 000, 001, 010 …
- Brackets show which gate is worked out first

Notes

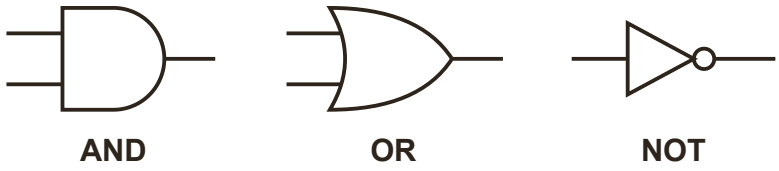
The three gates

- **AND** (conjunction): the output is 1 only when **both** inputs are 1. Symbol: a D shape (flat back, rounded front).
- **OR** (disjunction): the output is 1 when **at least one** input is 1. Symbol: a curved back and a pointed front.
- **NOT** (negation): one input; the output is the **opposite** of the input. Symbol: a triangle with a small circle at its tip.
- Truth tables for the three gates:

A	B	A AND B	A OR B
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	1

A	NOT A
0	1
1	0

- The three symbols:



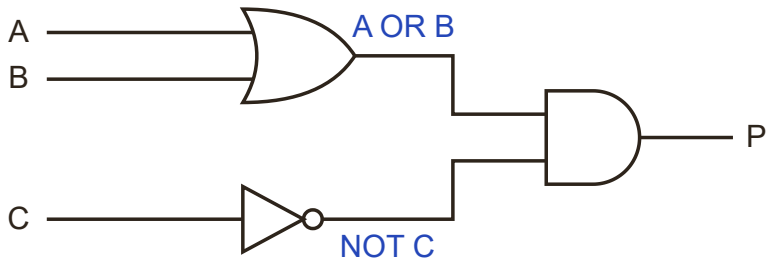
Truth tables for combined gates

- A truth table lists every combination of inputs. 2 inputs give 4 rows and 3 inputs give 8 rows (2^n rows for n inputs).
- Fill in the input columns by counting up in binary: 000, 001, 010, 011, 100, 101, 110, 111.
- Add a column for each gate before the final one, then use those columns to work out the output.
- Example: P = (A OR B) AND NOT C

A	B	C	A OR B	NOT C	P
0	0	0	0	1	0
0	0	1	0	0	0
0	1	0	1	1	1
0	1	1	1	0	0
1	0	0	1	1	1
1	0	1	1	0	0
1	1	0	1	1	1
1	1	1	1	0	0

Diagrams and expressions

- To write an expression from a diagram, start at the inputs and follow each gate to the output. Put brackets round each gate that feeds into another gate.



The example P = (A OR B) AND NOT C as a logic diagram

- To draw a diagram from an expression, draw the gates inside the brackets first, then feed their outputs into the next gate.
- In a scenario, 'and' usually means AND, 'or' means OR, and 'not' means NOT: for example, a light comes on if it is dark AND someone moves.

How to answer each type of question

Complete a truth table

2 to 4 marks | **Grade 5**

1. Fill in the input columns in binary order if they are not given.
2. Work out any middle columns (the inner gates) first.
3. Then work out the final output for each row.

Example. Complete the truth table for P = NOT (A AND B).

A	B	A AND B	P
0	0		
0	1		
1	0		
1	1		

[4]

Model answer.

A	B	A AND B	P
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

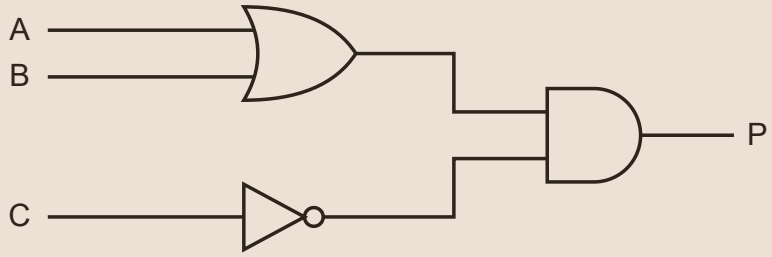
1 mark for each correct value of P.

Write the expression for a logic diagram

2 to 3 marks | **Grade 6**

1. Find the gates that the inputs go into first.
2. Write each one in brackets, such as (A OR B).
3. Join them with the gate that produces the output.

Example. In a logic diagram, inputs A and B go into an OR gate. Input C goes into a NOT gate. The outputs of the OR gate and the NOT gate go into an AND gate, whose output is P.



Write the logic expression for P. [3]

Model answer.

P = (A OR B) AND (NOT C)

(A OR B) (1); NOT C (1); the two joined by AND, with correct brackets (1).

Draw a logic diagram from an expression

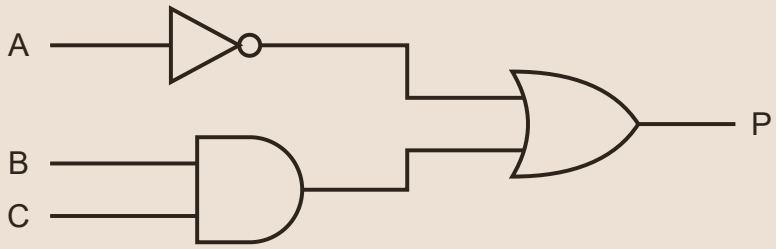
3 marks | **Grade 6**

1. Draw each input on the left.
2. Draw the gates inside the brackets first.
3. Feed their outputs into the final gate, and label the output.
4. Use the correct symbol for every gate.

Example. Draw a logic diagram for P = (NOT A) OR (B AND C). [3]

Model answer.

Input A goes into a NOT gate (1). Inputs B and C go into an AND gate (1). The outputs of the NOT gate and the AND gate go into an OR gate, whose output is P (1).



Write logic for a scenario

2 to 4 marks | Grade 8

1. Give each input a letter as the question does, with 1 meaning the condition is true.
2. Turn the words into AND, OR and NOT, keeping the grouping the sentence describes.
3. Use brackets, and check with one or two rows.

Example. An alarm (P) sounds if the door is open (D = 1) and the system is armed (S = 1), or if the panic button is pressed (B = 1).
(a) Write a logic expression for P. [2]
(b) State the value of P when D = 0, S = 1 and B = 1. [1]

Model answer.

(a) P = (D AND S) OR B: (D AND S) (1); OR B (1).

(b) 1 (1), because the panic button is pressed.

Don’t lose marks

- Drawing the OR symbol when AND is needed, or leaving the circle off a NOT gate.
- Missing input combinations or repeating a row: 3 inputs need exactly 8 rows.
- Forgetting brackets, so the order of the gates is unclear.
- Applying NOT to the wrong part: NOT (A AND B) is different from NOT A AND B.
- Giving a NOT gate two inputs.

More tips

Memory tricks

- AND is like two switches in a line (series): both must be on. OR is like two switches side by side (parallel): either one works.
- AND gives 1 in only one row of a 2-input table; OR gives 0 in only one row.
- Binary counting order for inputs: the right-hand column alternates 0, 1, 0, 1; the next column pairs 0, 0, 1, 1; and so on.

Exam technique

- Always fill in any middle columns: they help you and can earn credit.
- Label every input and the output on diagrams you draw.
- Check one or two rows of your truth table against the words in the question.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3 — **Recall the truth tables for AND, OR, NOT**
AND needs both inputs 1; OR needs at least one; NOT reverses the input.

Grade 4 — **Recognise the symbols for the three gates**
AND is D-shaped, OR has a curved back and a point, NOT is a triangle with a circle.

Grade 5

Complete a truth table for two gates

Add a column for the first gate, then work out the final output.

Grade 6

Write the expression for a logic diagram

Work from the inputs to the output, using brackets to show which gate comes first.

Grade 6

Draw a logic diagram from an expression

Draw the gates in brackets first, then join their outputs to the final gate.

Grade 7

Complete a three-input truth table

List all 8 input combinations in order and work out each output.

Grade 8

Turn a written problem into logic

Write an expression and truth table for a scenario, such as an alarm system.

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