A-LEVEL COMPUTER SCIENCE • EXERCISE SHEET

3.2 Logic Gates and Logic Circuits

Name: _____ Class: _____ Date: _____ **Total: 20 marks**

Objective

Build the skills to answer exam questions on **logic gates** 逻辑门 and **logic circuits** 逻辑电路—the six gates and their truth tables, and converting between a problem, a logic expression, a circuit and a truth table.

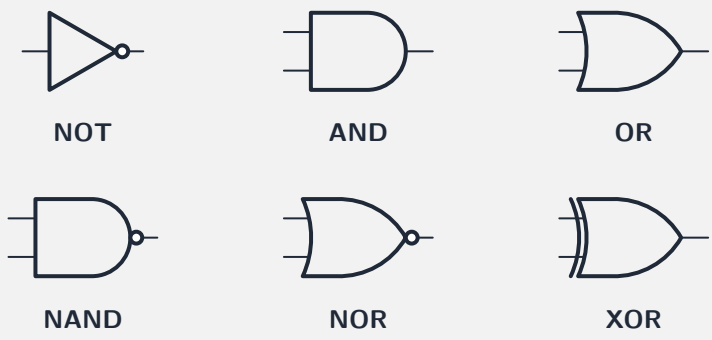
You must be able to:

- recognise and define **NOT, AND, OR, NAND, NOR** and **XOR**
- construct the **truth table** 真值表 for any gate or circuit
- build a **logic expression** and a **logic circuit** from a problem statement, and convert between expression, circuit and truth table

1 Worked examples

Study these first. Each one shows the method for a question type used later —follow the steps and you can do the Practice and Exam-style questions yourself.

The six gates



- **NOT** —output is the opposite of the input.
- **AND** —output 1 only if **all** inputs are 1. **OR** —output 1 if **at least one** input is 1.
- **NAND** = NOT AND; **NOR** = NOT OR (so their outputs are the AND/OR output flipped).
- **XOR** —output 1 only when the inputs are **different**.

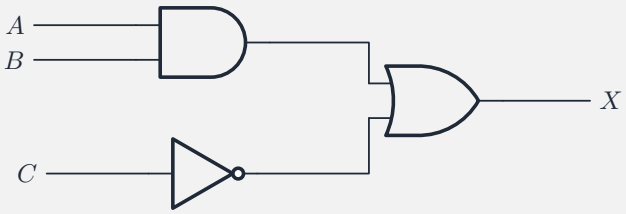
■ Building a truth table

List **every** input combination (2 inputs → $2^2 = 4$ rows; 3 inputs → $2^3 = 8$ rows), then work out the output for each. For example, AND and XOR:

A	B	A AND B	A XOR B
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

■ Circuit, expression and truth table

These three describe the same logic. From this circuit you can read the expression $X = (A \text{ AND } B) \text{ OR } (\text{NOT } C)$, then build the truth table by filling each gate's output column.



A	B	C	A AND B	NOT C	X
0	0	0	0	1	1
0	0	1	0	0	0
0	1	0	0	1	1
0	1	1	0	0	0
1	0	0	0	1	1
1	0	1	0	0	0
1	1	0	1	1	1
1	1	1	1	0	1

2 Practice

Now apply the methods above.

2.1 Complete the truth table for a **NAND** gate. [2]

A	B	A NAND B
0	0	
0	1	
1	0	
1	1	

2.2 Name the gate that outputs 1 only when its two inputs are **different**. [1]

2.3 Write the logic expression for: *"X is 1 when A is 1 OR B is 0."* [2]

2.4 Complete the truth table for $X = A$ AND (NOT B). [2]

A	B	X
0	0	
0	1	
1	0	
1	1	

3 Exam-style questions

3.1 A circuit has the expression $X = (A$ OR $B)$ AND (NOT $C)$.

(a) Draw the logic circuit for X. [3]

(b) Complete the truth table for X. [3]

A	B	C	X
0	0	0	
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	

3.2 A pump X turns on when the tank is **not full** $(A = 0)$ **or** the manual switch B is on. Write the logic expression for X. [2]

3.3 Construct the truth table for A XOR B, and give one use of an XOR gate. [3]

3.4 Write the Boolean expression for the logic described by this truth table. [2]

A	B	X
0	0	1
0	1	1
1	0	0
1	1	1

4 Go further

You are now ready for the real exam questions on this subtopic. Open the **3.2 Logic Gates** past-paper sheet in the Library, or try these in **Practice mode**:

- 9618/11 N25 —Q3 (write the Boolean expression for a truth table)
- 9618/11 J25 —Q1 (logic circuit and truth table)
- 9618/11 N24 —Q5 (logic gates and expressions)
- 9618/13 N24 —Q1 (complete a truth table)

Solutions

2.1 NAND outputs: $1, 1, 1, 0$ (top to bottom).

2.2 XOR.

2.3 $X = A$ OR (NOT B).

2.4 X outputs: $0, 0, 1, 0$ —X is 1 only when $A = 1$ and $B = 0$.

3.1 (a) A and B into an **OR** gate; C into a **NOT** gate; the OR output and the NOT output into an **AND** gate → X.
(b) X outputs (top to bottom): $0, 0, 1, 0, 1, 0, 1, 0$ —i.e. X = 1 only when (A or B) is 1 **and** C = 0.

3.2 $X =$ (NOT A) OR B.

3.3 A XOR B: $0, 1, 1, 0$. Use: e.g. compare two bits (equal → 0), or add two bits in a half-adder.

3.4 $X =$ (NOT A) OR B —X is 0 only on the row $A = 1, B = 0$.