

3.2 Logic Gates and Logic Circuits

Name: _____ Class: _____ Date: _____

Total: 35 marks

KEY WORDS logic circuit • truth table • logic gate • boolean
• rom

Objective

Learn the six **logic gates** : their symbols, what each one does, and the **truth table** of each. You also meet your first short **logic expressions** and one small **logic circuit** . This is the first sheet of 3.2: sheet 3.2.1 then reads larger circuits, and sheet 3.2.2 builds them.

You must be able to:

- recognise and define **NOT**, **AND**, **OR**, **NAND**, **NOR** and **XOR**
- construct the **truth table** 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



AND



OR



NAND



NOR



XOR

- **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

A truth table lists **every** input combination in binary counting order (2 inputs $\rightarrow 2^2 = 4$ rows; 3 inputs $\rightarrow 2^3 = 8$ rows), with the output for each row. The five two-input gates:

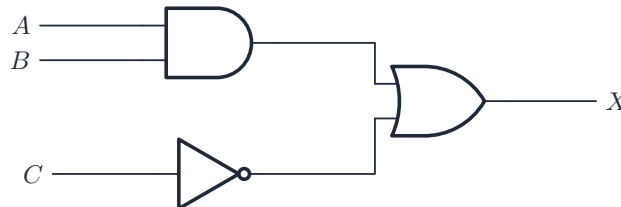
A	B	A AND B	A OR B	A NAND B	A NOR B	A XOR B
0	0	0	0	1	1	0
0	1	0	1	1	0	1
1	0	0	1	1	0	1
1	1	1	1	0	0	0

A **NOT** gate has one input: input 0 gives output 1, and input 1 gives output 0.

- To find a NAND column, write the AND column and **flip** every bit. NOR is the OR column flipped.
- **OR** is 1 when one input is 1 **or both** are. **XOR** is 1 when **exactly one** input is 1.

■ Circuit, expression and truth table

All three describe the **same logic**. This circuit reads as $X = (A \text{ AND } B) \text{ OR } (\text{NOT } C)$; its truth table is filled one gate column at a time.



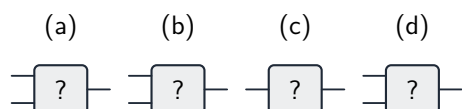
A	B	C	A AND B	NOT C	X
0	0	0	0	1	1
0	0	1	0	0	0
0	1	0	0	1	1
0	1	1	0	0	0
1	0	0	0	1	1
1	0	1	0	0	0
1	1	0	1	1	1
1	1	1	1	0	1

2 Practice

Now apply the methods above. The first questions need one idea each.

2.1 Name the logic gate that fits each description. [4]

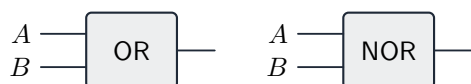
- (a) The output is 1 only when **both** inputs are 1.
- (b) The output is 0 only when **both** inputs are 0.
- (c) The output is always the opposite of its one input.
- (d) The output is 1 only when **both** inputs are 0.



2.2 Draw the symbol for each gate. [2]

- (a) an AND gate
- (b) a NOR gate

2.3 Complete the truth tables for an **OR** gate and a **NOR** gate. [2]



A	B	A OR B	A NOR B
0	0		
0	1		
1	0		
1	1		

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



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

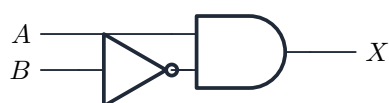
2.5 Name the gate that outputs 1 only when its two inputs are **different**. [1]



2.6 Write the logic expression for: “*X is 1 when A is 1 OR B is 0.*” [2]



2.7 Complete the truth table for $X = A \text{ AND } (\text{NOT } B)$. [2]

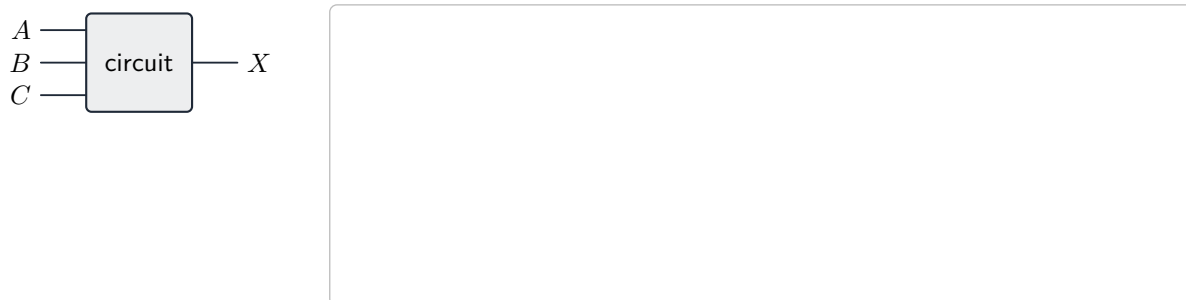


A	B	X
0	0	
0	1	
1	0	
1	1	

3 Exam-style questions

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

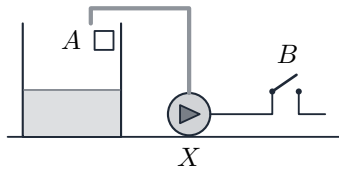
(a) Draw the logic circuit for X . [3]



(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]

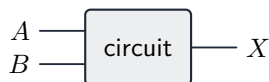


3.3 Construct the truth table for $A \text{ XOR } B$, and give one use of an XOR gate. [3]



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



3.5 A gate has two inputs, A and B , and one output, X .

(a) The table shows the output of the gate. Identify the gate.

[1]

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



(b) The same output can be made with **two** gates instead of one. Name the two gates, and state the order in which they are connected.

[2]

(c) State the difference between the output of an **OR** gate and the output of an **XOR** gate.

[2]

(d) A student says: “A *truth table for three inputs has six rows.*” State the correct number of rows, and show how you worked it out.

[2]
