

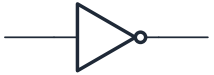
Exercise walk-through

3.2

Logic Gates and Logic Circuits

A-Level Computer Science

Logic gates



NOT



AND



OR



NAND



NOR



XOR

A **logic gate** does one **Boolean** operation; inputs/outputs are 0 or 1. Know the symbol, function and **truth table** of each.

Truth tables

A	B	AND	OR	NAND	NOR	XOR
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

NOT: $0 \rightarrow 1, 1 \rightarrow 0$. **AND:** all 1. **OR:** any 1. **XOR:** inputs differ.

NAND, NOR and XOR: three quick rules

- **NAND**: work out AND, then **flip** every bit. The output is 0 only when both inputs are 1.
- **NOR**: work out OR, then **flip** every bit. The output is 1 only when both inputs are 0.
- **XOR**: the output is 1 when the two inputs are **different**. OR allows “both”; XOR does not.

NAND



NOR



XOR



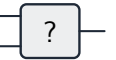
A truth table for n inputs has 2^n rows, written by **counting up in binary**.

Exercise 2.1

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.

(a)	(b)	(c)	(d)	
				

Exercise 2.1

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.



2.1

- (a) 1 only when both are 1 → **AND**
- (b) 0 only when both are 0 (so 1 when at least one input is 1) → **OR**
- (c) one input, inverted → **NOT**
- (d) 1 only when both are 0: the OR output flipped → **NOR**

Exercise 2.2 (a)

2.2 Draw the symbol for each gate.

[2]

(a) an AND gate

Exercise 2.2 (a)

2.2 Draw the symbol for each gate.

[2]

(a) an AND gate

(a) a flat back and a rounded (D-shaped) front, with two inputs and one output

Exercise 2.2 (b)

2.2 Draw the symbol for each gate.

[2]

(b) a NOR gate

Exercise 2.2 (b)

2.2 Draw the symbol for each gate.

[2]

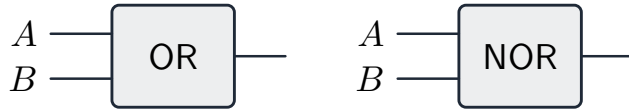
(b) a NOR gate

(b) the OR shape (curved back, pointed front) with a **small circle** on the output

Exercise 2.3

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

[2]

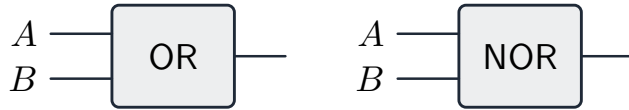


A	B	A OR B	A NOR B
0	0		
0	1		
1	0		
1	1		

Exercise 2.3

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		

2.3

- OR is 1 when at least one input is 1: **0, 1, 1, 1**
- NOR is the OR column flipped: **1, 0, 0, 0**

Exercise 2.4

2.4 Complete the truth table for a **NAND** gate.

[2]



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

Exercise 2.4

2.4 Complete the truth table for a **NAND** gate.

[2]



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

2.4

- NAND is the inverse of AND: output 0 only when both inputs are 1

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

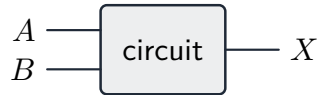
- outputs (top to bottom): 1, 1, 1, 0

Exercises 2.5-2.6

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]



Exercises 2.5-2.6

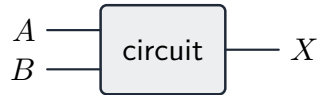
2.5 Name the gate that outputs 1 only when its two inputs are **different**. [1]



2.5

- output 1 when the two inputs are **different** → **XOR**

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



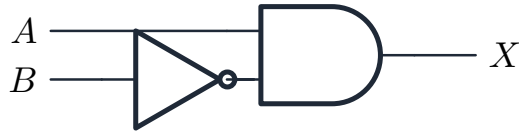
2.6

- *X* is 1 when *A* is 1 **or** *B* is 0
- $X = A \text{ OR } (\text{NOT } B)$

Exercise 2.7

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

[2]

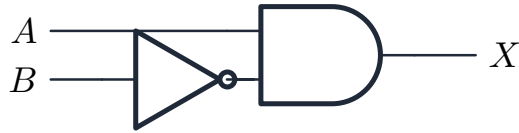


A	B	X
0	0	
0	1	
1	0	
1	1	

Exercise 2.7

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	

2.7

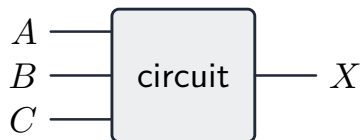
- AND of A with NOT B : $X = 1$ only when $A = 1$ and $B = 0$
- outputs (top to bottom): 0, 0, 1, 0

Exercise 3.1 (a)

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]

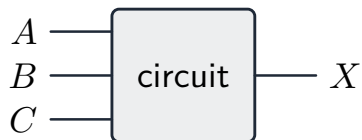


Exercise 3.1 (a)

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]



(a) A and B into an **OR** gate; C into a **NOT** gate

- the OR output and the NOT output into an **AND** gate $\rightarrow X$

Exercise 3.1 (b)

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

(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	

Exercise 3.1 (b)

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

(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	

Full solution 3.1 (b)

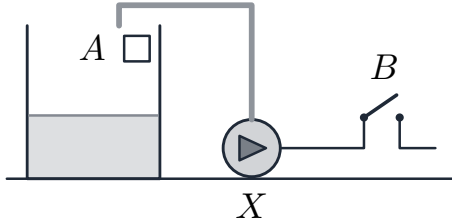
(b) $X = 1$ only when $(A \text{ or } B)$ is 1 **and** $C = 0$

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

- outputs (top to bottom): 0, 0, 1, 0, 1, 0, 1, 0

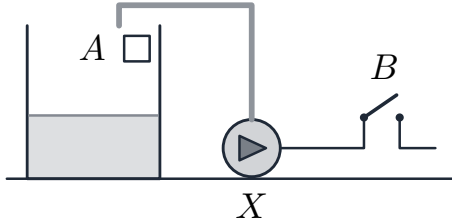
Exercise 3.2

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]



Exercise 3.2

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]



3.2

- tank not full $\rightarrow$ NOT A ; OR the manual switch B
- $X = (\text{NOT } A) \text{ OR } B$

Exercise 3.3

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



A	B	X
0	0	
0	1	
1	0	
1	1	

Exercise 3.3

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



3.3

- XOR is 1 when the inputs differ

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

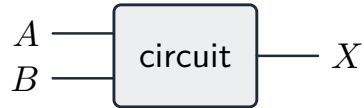
- outputs: 0, 1, 1, 0
- use: e.g. compare two bits (equal $\rightarrow$ 0), or add two bits in a half-adder

Exercise 3.4

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

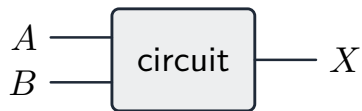


Exercise 3.4

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



3.4

- X is 0 only on the row $A = 1, B = 0$
- $X = (\text{NOT } A) \text{ OR } B$

Exercise 3.5 (a)

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



Exercise 3.5 (a)

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(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



(a) the output is 0 only when both inputs are 1: the AND column flipped $\rightarrow$ **NAND**

Exercise 3.5 (b)

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

(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]

Exercise 3.5 (b)

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

(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]

(b) an **AND** gate and a **NOT** gate

- A and B go into the AND gate, and the output of the AND gate goes into the NOT gate

Exercise 3.5 (c)

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

(c) State the difference between the output of an **OR** gate and the output of an **XOR** gate. [2]

Exercise 3.5 (c)

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

(c) State the difference between the output of an **OR** gate and the output of an **XOR** gate. [2]

(c) the two gates differ only when **both** inputs are 1

- OR gives 1 there, and XOR gives 0: XOR is 1 only when exactly one input is 1

Exercise 3.5 (d)

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

(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]

Exercise 3.5 (d)

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

(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]

(d) each input can be 0 or 1, so the number of rows is $2 \times 2 \times 2 = 2^3$

- 8 rows