

# Logic gates and truth tables

Name: \_\_\_\_\_ Class: \_\_\_\_\_ Date: \_\_\_\_\_

In logic, **1** means on, true or yes, and **0** means off, false or no.

**NOT** flips its input · **AND** gives 1 if both inputs are 1 · **OR** gives 1 if either input is 1 (or both) · **XOR** gives 1 if the inputs are different

## Part A · Gates

**A1** Name each gate.

[4]



(a)

\_\_\_\_\_



(b)

\_\_\_\_\_



(c)

\_\_\_\_\_



(d)

\_\_\_\_\_

**A2** Complete the truth tables.

[4]

**AND**

| A | B | Q |
|---|---|---|
| 0 | 0 |   |
| 0 | 1 |   |
| 1 | 0 |   |
| 1 | 1 |   |

**OR**

| A | B | Q |
|---|---|---|
| 0 | 0 |   |
| 0 | 1 |   |
| 1 | 0 |   |
| 1 | 1 |   |

**XOR**

| A | B | Q |
|---|---|---|
| 0 | 0 |   |
| 0 | 1 |   |
| 1 | 0 |   |
| 1 | 1 |   |

**NOT**

| A | Q |
|---|---|
| 0 |   |
| 1 |   |

**A3** In **Ring the Bell**, the bell rings when the front button OR the back button is pressed. Explain why an AND gate would be the wrong choice.

[2]

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

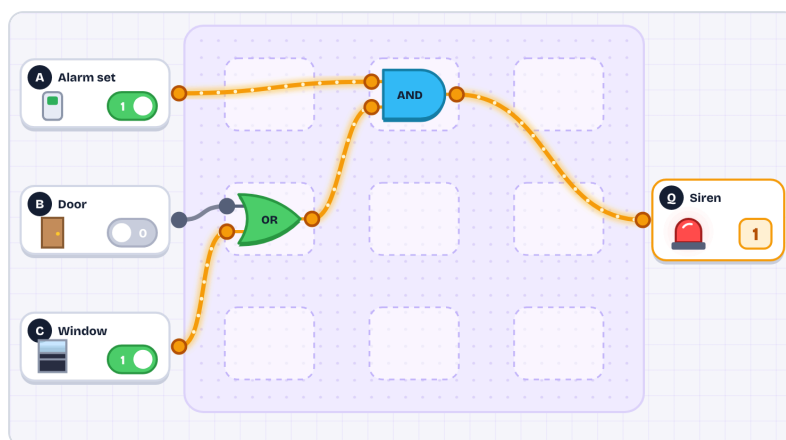
## Part B · Play levels 1 to 5

Before you build, fill in the "Want" column in your head: which rows should give 1? Record your best circuit for each level.

| Level | Gates I used | Stars | What went wrong, and how I fixed it |
|-------|--------------|-------|-------------------------------------|
| 1     |              |       |                                     |
| 2     |              |       |                                     |
| 3     |              |       |                                     |
| 4     |              |       |                                     |
| 5     |              |       |                                     |

## Part C · The burglar alarm

The siren (Q) should sound when the alarm is set (A) AND the door (B) OR the window (C) is open. Here is the circuit, with A = 1, B = 0 and C = 1.



**C1** Complete the truth table.

[3] **C2** Write the Boolean expression for Q.

[1]

| A | B | C | B OR C | Q |
|---|---|---|--------|---|
| 0 | 0 | 0 |        |   |
| 0 | 0 | 1 |        |   |
| 0 | 1 | 0 |        |   |
| 0 | 1 | 1 |        |   |
| 1 | 0 | 0 |        |   |
| 1 | 0 | 1 |        |   |
| 1 | 1 | 0 |        |   |
| 1 | 1 | 1 |        |   |

**C3** Why does the truth table have 8 rows?

[1]

**C4** The owner adds a panic button, P. The siren should also sound whenever P is pressed, even if the alarm isn't set. Write the new expression.

[2]

## Part D · Design a circuit

**D1** A car's seatbelt warning light (Q) comes on when the engine is running (E = 1) AND the driver's seatbelt is NOT fastened (S = 0).

a) Complete the truth table.

[2] b) Draw the logic circuit, using two gates.

[2]

| E | S | Q |
|---|---|---|
| 0 | 0 |   |
| 0 | 1 |   |
| 1 | 0 |   |
| 1 | 1 |   |

c) Write the Boolean expression for Q.

[1]

# Boolean algebra, NAND and adders

Name: \_\_\_\_\_ Class: \_\_\_\_\_ Date: \_\_\_\_\_

$A \cdot B$  means A AND B ·  $A + B$  means A OR B ·  $\overline{A}$  means NOT A ·  $A \oplus B$  means A XOR B  
De Morgan's laws:  $\overline{A \cdot B} = \overline{A} + \overline{B}$  and  $\overline{A + B} = \overline{A} \cdot \overline{B}$  · Binary:  $0 + 1 = 1$ ,  $1 + 1 = 10$ ,  $1 + 1 + 1 = 11$

**1 Majority Vote.** Three guards press buttons A, B and C. The lift door (Q) opens when at least two of them press.

a) Complete the Q column of the table. [2]

| A | B | C | Q | $A \cdot B$ | $A + B$ | $C \cdot (A + B)$ | $A \cdot B + C \cdot (A + B)$ |
|---|---|---|---|-------------|---------|-------------------|-------------------------------|
| 0 | 0 | 0 |   |             |         |                   |                               |
| 0 | 0 | 1 |   |             |         |                   |                               |
| 0 | 1 | 0 |   |             |         |                   |                               |
| 0 | 1 | 1 |   |             |         |                   |                               |
| 1 | 0 | 0 |   |             |         |                   |                               |
| 1 | 0 | 1 |   |             |         |                   |                               |
| 1 | 1 | 0 |   |             |         |                   |                               |
| 1 | 1 | 1 |   |             |         |                   |                               |

b) Write Q as three AND terms joined by OR. [1]

c) Complete the other columns to show that  $Q = A \cdot B + C \cdot (A + B)$  gives the same output. [2]

d) How many 2-input gates does each expression need? [1]

## 2 Only NAND.

a) Write down the NAND gate's output for the inputs 00, 01, 10 and 11. [1]

b) Show that a NAND gate with both of its inputs joined to A acts as a NOT gate. [1]

c) Use De Morgan's law to show that  $\overline{A} \text{ NAND } \overline{B} = A + B$ . [2]

d) Suggest why chip makers often build circuits entirely from NAND gates. [1]

**3 Half adder.** It adds two bits, A and B.

a) Complete the table.

| A | B | Carry | Sum |
|---|---|-------|-----|
| 0 | 0 |       |     |
| 0 | 1 |       |     |
| 1 | 0 |       |     |
| 1 | 1 |       |     |

b) Write Boolean expressions for the sum and the carry. [2]

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**4 Full adder.** It adds A, B and a carry in ( $C_{in}$ ).

a) Complete the table. [1]

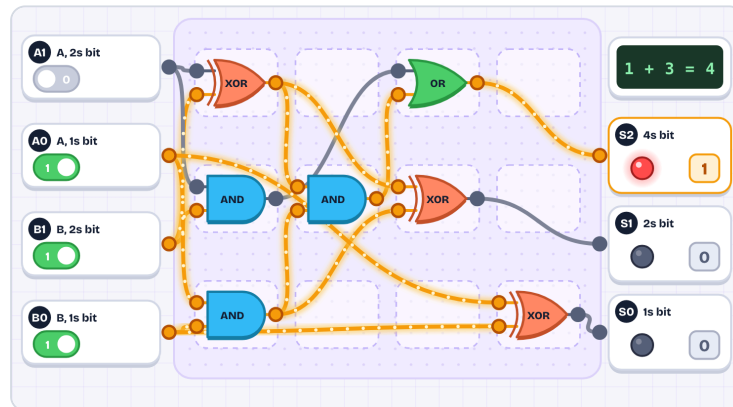
[2]

| A | B | $C_{in}$ | $C_{out}$ | Sum |
|---|---|----------|-----------|-----|
| 0 | 0 | 0        |           |     |
| 0 | 0 | 1        |           |     |
| 0 | 1 | 0        |           |     |
| 0 | 1 | 1        |           |     |
| 1 | 0 | 0        |           |     |
| 1 | 0 | 1        |           |     |
| 1 | 1 | 0        |           |     |
| 1 | 1 | 1        |           |     |

4b) A full adder uses  $Sum = A \oplus B \oplus C_{in}$  and  $C_{out} = A \cdot B + C_{in} \cdot (A \oplus B)$ . Check both for  $A = 1, B = 0, C_{in} = 1$ . [2]

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**5 The Calculator** adds two 2-bit numbers, A ( $A_1 A_0$ ) and B ( $B_1 B_0$ ). The 1s column is a half adder; the 2s column is a full adder. Here it is adding  $1 + 3$ .



a) Write 1, 3 and the answer in binary, and check the outputs S2 S1 S0 in the figure. [1]

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b) In the 1s column,  $A_0 = 1$  and  $B_0 = 1$ . What are S0 and the carry? [1]

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c) The 2s column adds  $A_1 = 0, B_1 = 1$  and the carry. What are S1 and S2? [1]

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d) A half adder takes 2 gates and a full adder 5. How many gates would a 4-bit adder need? An 8-bit adder? [2]

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[6]

| Idea                        | What happens, with evidence from Logic Lab |
|-----------------------------|--------------------------------------------|
| Adding one column           |                                            |
| Carrying to the next column |                                            |
| Adding bigger numbers       |                                            |
| Building from one gate type |                                            |