Solutions

Each answer shows the steps, then the **result**.

2.1

(a) both conditions are needed → **AND**

(b) the condition must be false → **NOT**

(c) one is enough, and both is also allowed → **OR**

(d) exactly one → **XOR**

2.2

- the expression has three operators: OR, AND and NOT, so the circuit has **three** gates
- an **OR** gate, a **NOT** gate and an **AND** gate

2.3

- a NOR gate with A and B as its inputs, drawn on the left because it is in the brackets
- the NOR output and C go into an AND gate, whose output is labelled X

2.4

- "dark and the switch is on" is D AND S
- "or the test button" adds OR T: $X = (D \text{ AND } S) \text{ OR } T$

2.5

(a) row 01 gives NOT A AND B; row 10 gives A AND NOT B

- $X = (\text{NOT } A \text{ AND } B) \text{ OR } (A \text{ AND NOT } B)$

(b) the output is 1 when the inputs are different → **XOR**

2.6

- the wire from B **branches**, and a **junction dot** is drawn where it branches; B is still one input

3.1

(a) "A reads 1 and B reads 0" is A AND NOT B

- "or C reads 1" adds OR C: $X = (A \text{ AND NOT } B) \text{ OR } C$

(b) a NOT gate with B as its input

- an AND gate that takes A and the output of the NOT gate
- an OR gate that takes the AND output and C, and gives X
- C goes straight into the OR gate: nothing in the sentence acts on it first

3.2

- row 000: NOT A AND NOT B AND NOT C

- row 011: NOT A AND B AND C
- row 110: A AND B AND NOT C, and the three terms joined with OR

$$X = (\text{NOT } A \text{ AND NOT } B \text{ AND NOT } C) \text{ OR } (\text{NOT } A \text{ AND } B \text{ AND } C) \text{ OR } (A \text{ AND } B \text{ AND NOT}$$

3.3

- an XOR gate with A and B as its inputs
- a NOT gate with C as its input
- both outputs go into an AND gate, whose output is X
- the XOR symbol is the OR shape with a **second curved line** at its back; a plain OR shape loses the first mark

3.4

- the brackets decide which gate comes first: in A AND (B OR C) the OR is worked out first and A must be 1 for X to be 1
- in (A AND B) OR C, the input C reaches the output on its own, so $C = 1$ gives $X = 1$ whatever A is
- any row with $A = 0$ and $C = 1$ shows the difference, for example $A = 0$, $B = 0$, $C = 1$: the correct circuit gives $X = 0$ and the student's circuit gives $X = 1$

3.5

(a) "the window is closed" is $W = 0$, so write NOT W

- "either the window is closed or the override is on" is (NOT W) OR V
- $H = C$ AND ((NOT W) OR V)

(b) a NOT gate with W as its input

- an OR gate that takes the NOT output and V
- an AND gate that takes C and the OR output
- the output of the AND gate is labelled H, and all three inputs are labelled

(c) working column NOT W: 1, 1, 0, 0, 1, 1, 0, 0

- working column (NOT W) OR V: 1, 1, 0, 1, 1, 1, 0, 1
- AND this column with C, which is 1 only on the last four rows
- $H =$ **0, 0, 0, 0, 1, 1, 0, 1**

(d) the row is $C = 1$, $W = 1$, $V = 0$, and it gives $H = 0$: the heater is **off**

- this is sensible because the heat would escape through the open window, so heating would waste energy