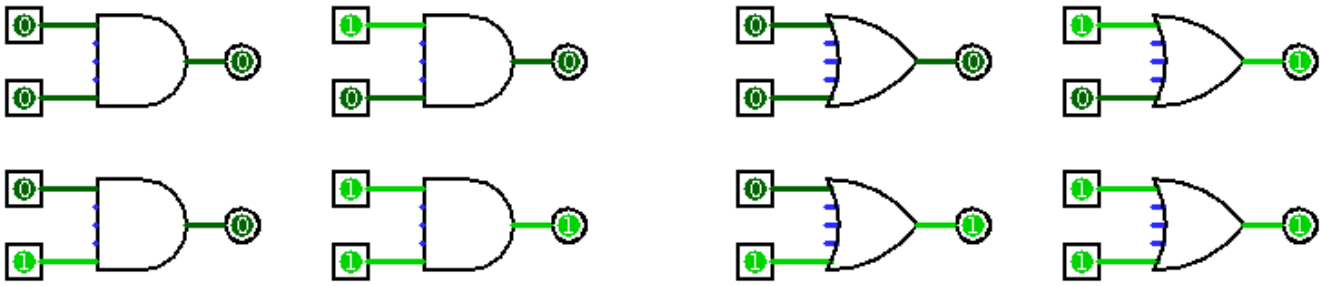
# Activity 2: Bits and Bytes

Computer hardware is made up of billions of tiny electronic circuits that use low and high voltages to represent the values 0 and 1. These binary digits, or "bits" for short, are the building blocks of all digital technology.

## Model 1 Logic Gates

*Complete the following tables based on the diagrams.*

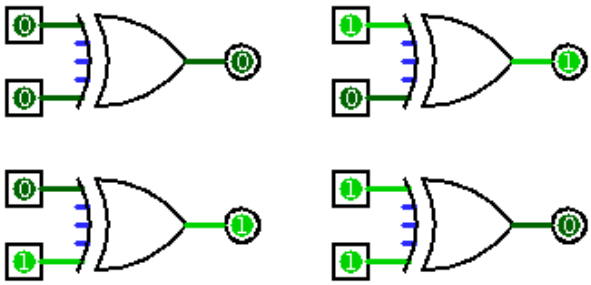


AND

| Inputs | Output |
|---|---|
| 0 0 | 0 |
| 0 1 | 0 |
| 1 0 | 0 |
| 1 1 | 1 |

OR

| Inputs | Output |
|---|---|
| 0 0 | 0 |
| 0 1 | 1 |
| 1 0 | 1 |
| 1 1 | 1 |



XOR

| Inputs | Output |
|---|---|
| 0 0 | 0 |
| 0 1 | 1 |
| 1 0 | 1 |
| 1 1 | 0 |

NOT

| Input | Output |
|---|---|
| 0 | 1 |
| 1 | 0 |

**Questions (10 min)** **Start time:** _____

**1**. In the circuit diagrams, what does the color (brightness) of the the lines represent?

Dark green represents the value 0, and light green represents the value 1.

**2**. For each type of gate, describe the circumstances when it will output the value 1.

AND: when both inputs are 1

OR: when either input is 1

XOR: when only one input is 1

NOT: when the input is 0

**3**. As a team, define the following words as they are used in everyday English.

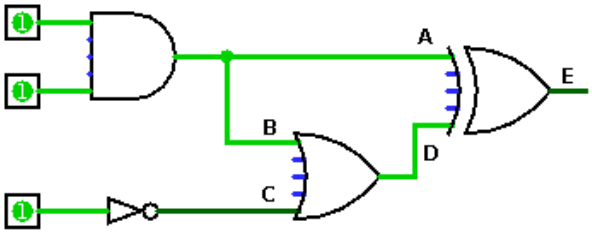
logic: making conclusions based on fundamental principles

gate: opening in a fence or wall that you can walk through

**4**. Based on your definitions, what do you think a "logic gate" represents?

A digital circuit that electricity flows through to compute a simple truth value. Composing gates together into a larger circuit makes it possible to compute more complex logic.

**5**. In the example circuit below, what are the values of *A*, *B*, *C*, *D*, and *E*?



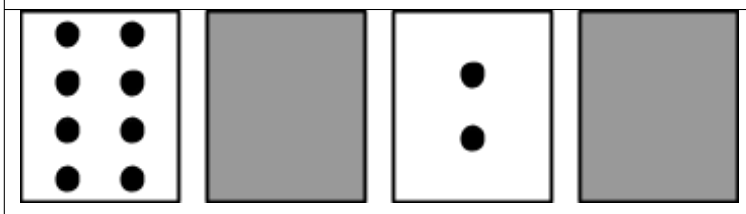
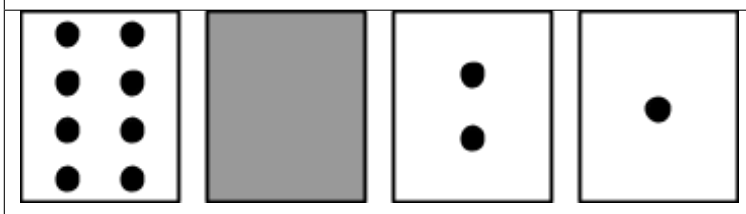
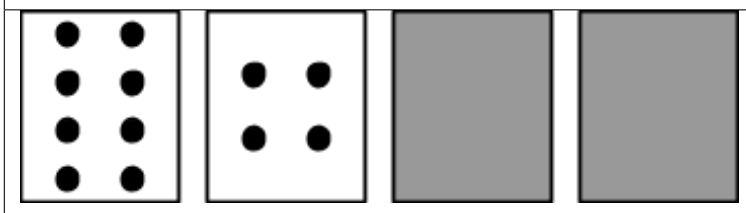
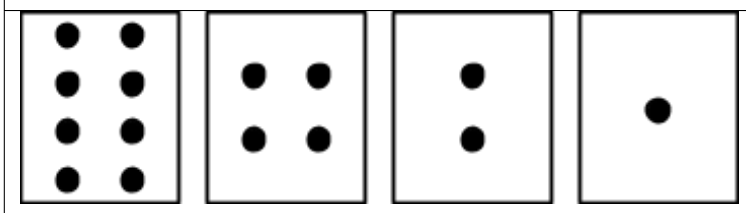

$A = 1$ $B = 1$ $C = 0$ $D = 1$ $F = 0$

**6**. How would *A*, *B*, *C*, *D*, and/or *E* change if the top input were zero?

All five values would be zero.

## Model 2 Binary Numbers

Each team has four cards that are ordered from the card with the most dots (8) to the card with the least dots (1). The cards represent four binary digits, or in other words, a 4-bit number.

| Binary | Decimal |
|---|---|
|  1 0 1 0 | 10 |
|  1 0 1 1 | 11 |
|  1 1 0 0 | 12 |
|  1 1 1 1 | 15 |

**Questions (15 min)** **Start time:** _____

**7.** In the table above, write the decimal value for each row by counting the number of dots.

a) What is the largest decimal number that can be represented by four bits? 15

b) What is the smallest decimal number that can be represented by four bits? 0

c) How many possible decimal numbers can be represented by four bits? 16

**8**. Examine the binary notation below the cards. Explain in a full sentence what a 0 means about the card's dots and what a 1 means.

0 means the card is turned over and the dots don't count, and 1 means the dots count in that binary number.

**9**. Complete the following table by writing the binary representation of the decimal numbers 0 to 15 using four bits. (And check your answers for #7.)

| Decimal | Binary | Hex |
|---|---|---|
| 0 | 0000 | 0 |
| 1 | 0001 | 1 |
| 2 | 0010 | 2 |
| 3 | 0011 | 3 |
| 4 | 0100 | 4 |
| 5 | 0101 | 5 |
| 6 | 0110 | 6 |
| 7 | 0111 | 7 |
| 8 | 1000 | 8 |
| 9 | 1001 | 9 |
| 10 | 1010 | A |
| 11 | 1011 | B |
| 12 | 1100 | C |
| 13 | 1101 | D |
| 14 | 1110 | E |
| 15 | 1111 | F |

**10**. ***Hexadecimal*** is shorthand for binary. For example, 0xD5 in hex is 1101 0101.

a) What is 0x2E in binary? 0010 1110

b) What is 0x74 in binary? 0111 0100

c) What is 0xB00 in binary? 1011 0000 0000

d) What is 0xFAD in binary? 1111 1010 1101

**11**. Based on the table in #9, explain why binary is sometimes referred to as base-2, decimal as base-10, and hexadecimal as base-16.

In base-2, there are two possible digits: 0 and 1. In base-10, there are ten possible digits: 0–9. In base-16, there are sixteen possible digits: 0–9 and A–F.

**12**. Explain the humor: "There are only 10 types of people in the world: those who understand binary, and those who don't."

The number 10 in binary is 2 in decimal. So there are only two types of people in the world.

**13**. Typically computers group 8 bits together at a time (8 bits are also called 1 ***byte***). Fill in the number of dots for the four new cards: 128 64 32 16


**14**. What is the largest number that can be represented by:

a) five bits? 31

b) six bits? 63

c) seven bits? 127

d) eight bits? 255

e) $n$ bits? $2^n - 1$

**15**. Most computers built since the year 2000 have 64-bit processors. Before then, 32-bit processors were the norm. What is the advantage of having more bits?

All data on a computer (text, images, sounds) are represented with numbers. With more bits, the processor can represent larger values and thus support more complex information.

**16**. In terms of logic gates and digital circuits, what is the disadvantage of having more bits?

Since bits are implemented with logic gates, they take up physical space. The more bits, the larger the processor (and other hardware) needs to be and the more power it will consume.