“There are 10 types of people in the world... those that understand binary and those that don’t.”
What is binary?

• You and I write numbers like this: twelve is 12, sixty eight is 68, and one hundred is 100

• Binary is a number system that computers use. That is, binary is the way that computers express numbers.

• It’s good to know binary because it helps us understand how computers think
Our number system is made up of ten digits (0, 1, 2...,9)....that’s why it’s called base-10.

We use those ten digits to express any number we want!

But how do we do this when there are only 10 of them?
Base-10 Example

6 8 3 4

1000’s place
6 x 10^3

100’s place
8 x 10^2

10’s place
3 x 10^1

1’s place
4 x 10^0

So the number 6834 is made up of six 1000s, eight 100s, three 10s, and four 1s. In other words...

6834 = (6 x 1000) + (8 x 100) + (3 x 10) + (4 x 1)
What are the first few places in our number system?

– Ones, tens, hundreds, thousands, ten thousands, hundred thousands, millions, etc...

Do you notice any patterns here?

Each one is ten times bigger than the one before it!
What is binary?

- Binary is just like our number system....
- Except it only uses two digits!
- The only digits in binary are 0 and 1
- In base-10 (the normal number system), any number bigger than 9 needs more than one digit.
- In binary, any number bigger than 1 needs more than one digit.
Exponents in Binary

- There are ten possible digits in the Base-10 number system (0 to 9).
- Powers of 10 are used to decide the places values.
- If binary only has two possible digits, what do you think is used to decide the values of its places?
- Powers of 2!
Binary Example System

What is 1010 equal to in the base-10 number system?

So the number 1010 in BINARY is made up of one 8, zero 4s, one 2, and zero 1s.

1010 is binary for \((1 \times 8) + (0 \times 4) + (1 \times 2) + (0 \times 1)\)
Let’s Count!

<table>
<thead>
<tr>
<th>...in Base-10</th>
<th>...in Binary</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
</tr>
<tr>
<td>5</td>
<td>101</td>
</tr>
<tr>
<td>6</td>
<td>110</td>
</tr>
<tr>
<td>7</td>
<td>111</td>
</tr>
<tr>
<td>8</td>
<td>1000</td>
</tr>
<tr>
<td>9</td>
<td>1001</td>
</tr>
<tr>
<td>10</td>
<td>1010</td>
</tr>
</tbody>
</table>

Are there any patterns that you notice?
Converting Base-10 to Binary!

• Let’s convert the number 25 to binary!
• First we need to find the **largest** binary digit that has a value **less** than 25.
  – In this case it is $2^4$: **16**
  – $2^5$ wouldn’t work because it is 32, which is bigger than 25.
• So now we know that the largest binary digit for this number will be the **16’s place**.
Converting Base-10 to Binary!

- We chose the 16’s place to be our first digit because 16 is the largest number that can fit inside 25.
- So we put a 1 in the 16’s place, indicating that 16 is part of our number.
Converting Base-10 to Binary!

- So, now 16 out of our total 25 is accounted for. Let’s take care of the remainder.
- \(25 - 16 = 9\)
- Now we go to the next digit, the 8’s place. Does an 8 fit inside 9 – our remainder?
- Yes it does!!
Converting Base-10 to Binary!

16’s place | 8’s place | 4’s place | 2’s place | 1’s place

- Now 8 out of the remainder 9 is taken care of.
- \(9 - 8 = 1\)
- Does the next digit – the 4’s place – fit inside this remainder?
- Nope! So, we have to put a 0 at the 4’s place because 1 is smaller than 4.
Converting Base-10 to Binary!

• Let’s see if the next digit can take care of our remainder (which is still 1).
• The next digit is the 2’s place. Can this digit fit inside our remainder?
• No, it can’t either, because 1 is smaller than 2. We have to put a 0 here too.
Converting Base-10 to Binary!

• One last try to get rid of our remainder (still 1)!
• The last thing we have is the 1’s place. Can a 1 fit inside our remainder?
• Yes! 1 is equal to 1!
• We have no remainder left now, because $1 - 1 = 0$!
• We’re done!
Converting Binary into Base-10!

Now let’s convert our number back!

All we have to do is take each binary digit, and figure out how much it is worth in base-10.

0 means that the digit doesn’t add anything to our number

1 means it adds the value of the place it’s in

This way is easier!
Converting Binary into Base-10!

1 1 0 0 1

16’s place 8’s place 4’s place 2’s place 1’s place

• 1 in the 16’s place. Add 16.  16
• 1 in the 8’s place. Add 8.  8
• 0 in the 4’s place. Nothing added  0
• 0 in the 2’s place. Nothing added  0
• 1 in the 1’s place. Add 1.  +1

TOTAL:  25
1. Is the following number written in binary form? 121011
   – No! Binary only has 1s and 0s.
2. What is this binary number in the base-10 system? 111
   – It is \((4 \times 1) + (2 \times 1) + (1 \times 1)\), which is 7!
3. *What is this base-10 number in binary?* 14

- 14 has 1 eight, 1 four, 1 two, and 0 ones. So it’s 1110!
3. What is this base-10 number in binary? 11
   – 11 has 1 eight, 0 fours, 1 two, and 1 one. So it’s 1011!
Why does binary matter?

A computer has many switches inside it that tell it what to do. The computer will do different things, depending on which ones are switched ON and which are OFF.

To a computer, an ON switch is represented by 1 and an OFF switch is represented by 0.
Why does anyone use binary?

Because computers only understand things in terms of ON and OFF, a system with only two options for digit values makes a lot sense (OFF = 0, ON = 1).

This makes it very easy for computers to express everything happening inside them as a bunch of 0s and 1s.
Why does anyone use binary?

There is a particular assortment of ON and OFF switches for everything you do on a computer. **ANYTHING** you do on computer can be represented as a very long string of binary.

It sounds crazy until you realize there are a huge amount of switches in your computer – and so many ways the whole system can be arranged. Actually, it still sounds pretty amazing!
So remember... there are 10 types of people in this world: those that understand binary, and those that don’t! 😊

Any questions?