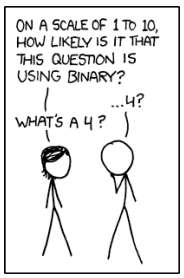
## Representations of numbers in different bases

There are only 10 kinds of people. Those who understand binary and those that don't.

## Binary Digits → Bits

Base 2 numbers




## Decimal Numbers

- Base 10
- 0, 1, 2, 3, 4, 5, 6, 7, 8, 9
- What happens when we get to 10?
  → add a digit
- 10, 11, … 20, 21, … 30, … 40, … 99
  → add another digit to get 100
- Notice that each **digit** represents a power of **10**

## Decimal Numbers

- How can 2531 be represented in terms of powers of 10?
- → $2*10^3 + 5*10^2 + 3*10^1 + 1*10^0$

## Converting Decimal to Binary

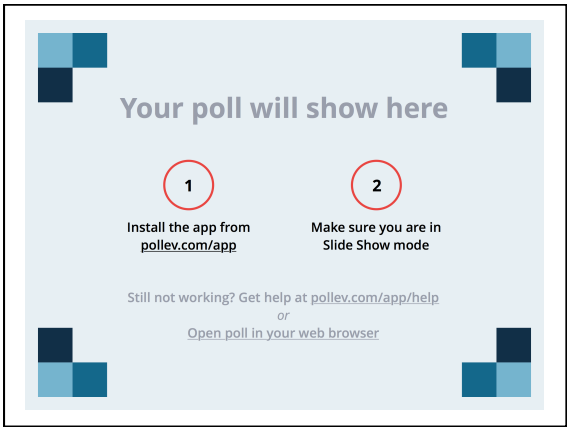
- How will this work with base 2?
- Digits will be either 0 or 1
- How do we represent 2 in terms of base 2?
- $1*2^1 + 0*2^0$ → 10 is 2 in binary
- What about 6?
- $1*2^2 + 1*2^1 + 0*2^0$ → 110

## Converting Decimal to Binary

- What about 2531?

1. Find closest power of 2 → $2^{11}$
2. $2531 - 2^{11}$ → 483
3. Repeat 1 and 2

- $1*2^{11} + 0*2^{10} + 0*2^9 + 1*2^8 + 1*2^7 + 1*2^6 + 1*2^5 + 1*2^4 + 1*2^3 + 0*2^2 + 1*2^1 + 1*20$
  → 100111111011

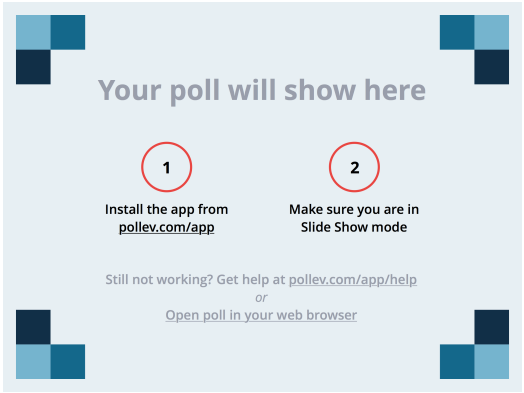



## Binary Numbers

- What's the largest number you can count up to using 2 hands?
- 10 fingers → $2^{10}$ possible numbers
- 0 to 1023
- Denoted in Java with prefix "0b"
- 2531 → 0b100111111011

## Converting Binary to Decimal

- What is 0b110101 in decimal?
- $1*2^5 + 1*2^4 + 0*2^3 + 1*2^2 + 0*2^1 + 1*2^0$
- → 32 + 16 + 0 + 4 + 0 + 1
- =53




## Byte

- 8 bits
- Historically, a byte was the number of bits used to encode a single character of text
- 0 through 255
- Two hexadecimal digits

## Storing Numbers in Java

- Java uses 4 bytes for int (32 bits)
- int stores integers from $-2^{31}$ to $2^{31}-1$
- double has 8 bytes, float has 4 bytes
- float = single-precision, double = double-precision
- Uses scientific notation
- → $sign*mantissa*2^{exponent}$
- double has 11 bits for exponent, 52 bits for mantissa
- Floating point numbers converted into decimal →leads to round-off error

## Nibble

- 4 bits
- Half of a byte (nibble is a small bite)
- 0 through 15
- One hexadecimal digit

## Hexadecimal → base 16

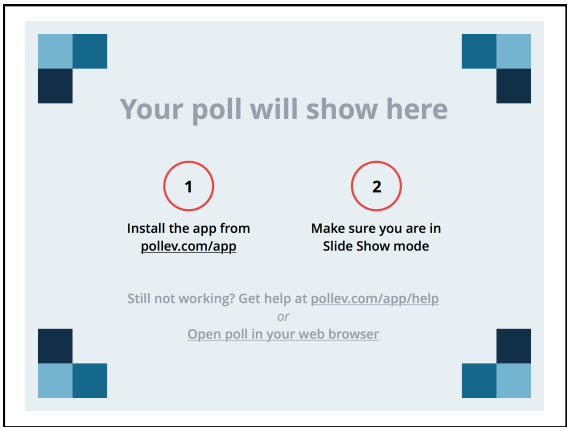
Hexa- → 6
Dec- → 10
6+10 → 16

## Hexadecimal

- Each **digit** represents a power of **16**
- How can we represent 16 different numbers using only one digit?
- 0, 1, 2, 3, 4, 5, 6, 7, 8, 9…
- A, B, C, D, E, F
- 0 to F
- Denoted in Java with prefix "0x"

## Convert Hexadecimal to Decimal

- What is 0x2C4 in decimal?
- $2*16^2 + C*16^1 + 4*16^0$
- $2*256 + 12*16 + 4*1$
- =708




## Convert Decimal to Hexadecimal

- What is 500 in hexadecimal?

1. Find closest multiple of power of 16 → $1*16^2$
2. $500 - 1*16^2$ → 244
3. Repeat 1 and 2

- $1*16^2 + F*16^1 + 4*16^0$

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Picture Element → Pict El → Pixel

**1 bit per pixel**

Pixel is either 0 or 1

Black or white

**3 byte per pixel**

24 bits per pixel

R- 8 bits (1 byte)

G- 8 bits (1 byte)

B- 8 bits (1 byte)

Resulting color is a combination of Red, Green, and Blue

## Hex code

- 24 bits per pixel → 8 bits per R, G, B
- $2^8$ → 256 possible shades each of R, G, B
- 4 bits (nibble) → $2^4$ → 16
- Hexadecimal is base 16
- 4 bits → one hexadecimal digit
- 8 bits → two hexadecimal digits
- 24 bits → six hexadecimal digits

## Hex code

- Web color codes
  - 000000 → black
  - FFFFFF → white
  - FF0000 → red
  - 00FF00 → green
  - 0000FF → blue
  - FFFF00 → yellow

Octal → base 8

## Octal

- Why do computer scientists mistake Halloween for Christmas?
- Oct 31 → Dec 25
- $3*8^1 + 1*8^0 \rightarrow 2*10^1 + 5*10^0$
- Octal digits go from 0 to 7

## Convert Octal to Hex

- What is 0x19 in octal?
- 0x19 → $1*16^1 + 9*16^0$ → 25
- Dec 25 → Oct 31