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Number Bases

CS 1.3 - Core Data Structures

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Welcome to CS 1.3!

Self Paced Course Structure

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- 1 hour: Optional lecture/activities
- 15 min: Break
- 1.5 hours: Required Lab Time (working on modules)

Modules

- Self assessments
- Only Mastery portion required
- Base and Stretch are for your own learning if you choose to complete them
- Videos, links, reading, exercises

Check In Activity

- Break into groups and write/discuss
- One thing you are most excited to learn
- One thing you are most nervous about
- One question you have for me

Students, write your response!

Learning Outcomes

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- Be able to explain the concept of representing numbers in different formats
- Be able to understand the differences between base 10, base 2, and base 16 number systems
- Be able to explain how to convert between various number bases at a high level

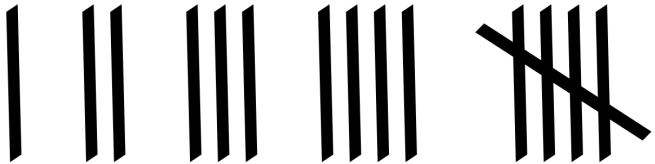
Number Bases: There are many ways to represent numbers

Back in the day: Unary Numbers

Basically there's one symbol which represents 1 and it's repeated

5: 11111

3: 🙃🙃🙃

15: 

Eventually number systems evolved to use more than one symbol

Roman: I, II, III, IV, V, X, L, M etc.

Only gave unique symbols to 5, 10, 50, 100, 1000, etc.

Egyptian Numerals

You can even make your own!

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Troll counting system from Terry Pratchett's Discworld series

one, two, three, many, many-one, many-two, many-three, many many,
many-many-one, many-many-two, many-many-three, many many many,
many-many-many-one, many-many-many-two, many-many-three, LOTS.

Activity: 10 mins, make your own number system

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Think about how would design your own number system

If you want to use emojis: ctrl + cmd + spacebar brings up the emoji palette

Students, draw anywhere on this slide!

What if we gave each number their own symbol?

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The Hindu-Arabic Numeral System

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Use the position of the numeral as well

“We always add and never subtract. And each position is 10 more than the one before it.

So, 35 means “add 3*10 to 5*1″ and 456 means 4*100 + 5*10 + 6*1. This “positional decimal” setup is the Hindu-Arabic number system we use today.

Source: https://betterexplained.com/articles/numbers-and-bases/

Base 10 (decimal)

Most modern day cultures use base-10, a.k.a. “decimal.”

We have 10 digits in base-10. (0 through 9)

9 rolls over to 10.

99 rolls over to 100.

https://www.youtube.com/watch?v=DKavhec9fGE

Base 2 (binary)

Computers use base-2, a.k.a. “binary.”

There are 2 digits in base-2. (0 and 1) 1

1 rolls over to 10.

11 rolls over to 100.

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“There are 10 kinds of people in the world. Those who understand binary, and those who don’t.”

–Old Programming Proverb

Counting in Binary

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0, 1, 10, 11, 100, 101, 110, 111,

1000, 1001, 1010, 1011, 1100, 1101, 1110, 1111,

10000, 10001, 10010, 10011, 10100, 10101, 10110, 10111,
11000, 11001, 11010, 11011, 11100, 11101, 11110, 11111,

100000, 100001, 100010, 100011, 100100, 100101, 100110, 100111,
101000, 101001, 101010, 101011, 101100, 101101, 101110, 101111,
110000, 110001, 110010, 110011, 110100, 110101, 110110, 110111,
111000, 111001, 111010, 111011, 111100, 111101, 111110, 111111,
…

Binary to Decimal

Let’s Practice Binary to Decimal!

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1 0 0 1 0

Students, draw anywhere on this slide!

Flippy Do!

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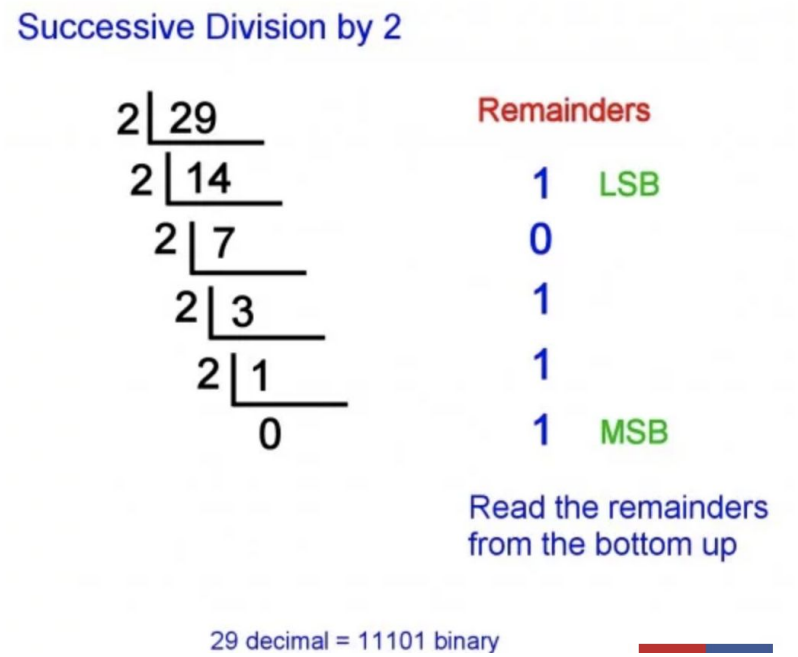
- Paper: https://curriculum.code.org/csp-18/unit1/5/
- Digital: https://docs.google.com/spreadsheets/d/1v4_WCGzdvi6_X5fj_vGu3xt3D3TWGTET5q9yTRJljr0/copy

Decimal to Binary

Remainder Method, keep dividing by 2:

https://owlcation.com/stem/How-to-Convert-Decimal-to-Binary-and-Binary-to-Decimal



Let’s Practice Decimal to Binary!

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25 / 2 --->

Students, draw anywhere on this slide!

Base 16

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Computers sometimes also use base-16, a.k.a. “hexadecimal” or simply “hex.”

There are 16 digits in base-16. (0-9 and A-F)

9 continues to A. F rolls over to 10.

99 continues to 9A. FF rolls over to 100.

Base 16

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There are 16 digits in base-16. (**0–9** and **A–F**)

$A_{16} = 10_{10}$ $D_{16} = 13_{10}$

$B_{16} = 11_{10}$ $E_{16} = 14_{10}$

$C_{16} = 12_{10}$ $F_{16} = 15_{10}$

Base 16

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Hex is often prefixed with 0x

0xAF32010016 == AF32010016

Counting in Hex

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0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F,

10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 1A, 1B, 1C, 1D, 1E, 1F,

20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 2A, 2B, 2C, 2D, 2E, 2F,

…

90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 9A, 9B, 9C, 9D, 9E, 9F,

A0, A1, A2, A3, A4, A5, A6, A7, A8, A9, AA, AB, AC, AD, AE, AF,

B0, B1, B2, B3, B4, B5, B6, B7, B8, B9, BA, BB, BC, BD, BE, …

Hex to Decimal

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Check out this article: https://owlcation.com/stem/Convert-Hex-to-Decimal

Post more resources you find on piazza!

Let's Practice Hex to Decimal!

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0x D 3 F 2

$$(13 \times 16^3) + (3 \times 16^2) + (15 \times 16^1) + (2 \times 16^0)$$

0

Students, draw anywhere on this slide!

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How would we go from Decimal to Hex?

Students, write your response!

Let's Practice Decimal to Hex!

84 / 16 ---> 5 remainder of 4

5 / 16 r5

54

Students, draw anywhere on this slide!

Hex to Binary

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Every hex digit is 4 binary digits (bits)

$5_{16} \leftrightarrow 0101_2$

$8_{16} \leftrightarrow 1000_2$

$B_{16} \leftrightarrow 1011_2$

$F_{16} \leftrightarrow 1111_2$

$10_{16} \leftrightarrow 0001\ 0000_2$

$72_{16} \leftrightarrow 0111\ 0010_2$

$A6_{16} \leftrightarrow 1010\ 0110_2$

$FF_{16} \leftrightarrow 1111\ 1111_2$

Let’s Practice Hex to Binary!

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0x D 3 F 2

Students, draw anywhere on this slide!

Think about this...

Based on what we've learned how would we convert from decimal to base 4?

Base 4 to decimal?

What about any arbitrary base n?

Students, write your response!

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Module 1: Number Bases