CSCI 141

Lecture 5:
Code Execution
Order of Operations
Binary representation

Announcements

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- WWU has a Society of Women Engineers (SWE) club

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    - CS students are eligible to join. They have cool events and career networking opportunities, among other things

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- WWU has a Society of Women Engineers (SWE) club
    - CS students are eligible to join. They have cool events and career networking opportunities, among other things
    - Not just for women: men are also welcome to join
    - Their first meeting is at 6:00pm next Wednesday in ET 321

Announcements

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- A1 is due Monday!

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    - Start soon if you haven't yet...

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Announcements

- A1 is due Monday!
  - Start soon if you haven't yet...
- Lab 1 is due tonight!
  - Make sure you've submitted your file on Canvas

QOTD

What will the following line print?

```
print(int(str("43")))
```

QOTD

What will the following program print?

```
day = "12"
year = "Saturday"
print("mon", year, sep="day", end=day)
```

QOTD

What will the following program print?

```
a = 4 // 2
b = 3 // 2
c = 3 % 2
print(a + b + c)
```

Goals

- Understand how the + and `*` operators behave with string operands.

- Know how to apply operator precedence rules to determine the order in which pieces of an expression are evaluated.

- Know how to convert a decimal number to binary and vice versa.

- Understand the basic idea behind how strings and floating-point numbers are represented on computers.

Code execution: Putting it all together

```
a = 4
b = float(2 + a)
```

Code execution: Putting it all together

- Consider this program:

```
a = 4
b = float(2 + a)
```

- What happens when we execute it?

Code execution: Putting it all together

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```
a = 4
b = float(2 + a)
```

- What happens when we execute it?
  - the value `4` gets stored in `a`

Code execution: Putting it all together

- Consider this program:

```
a = 4
b = float(2 + a)
```

- What happens when we execute it?
    - the value `4` gets stored in `a`
    - the expression `2+a` is evaluated, resulting in the value `6`

Code execution: Putting it all together

- Consider this program:

```
a = 4
b = float(6)
```

- What happens when we execute it?
  - the value `4` gets stored in `a`
  - the expression `2+a` is evaluated, resulting in the value `6`

Code execution:
Putting it all together

- Consider this program:

```
a = 4
b = float(6)
```

- What happens when we execute it?
  - the value `4` gets stored in `a`
  - the expression `2+a` is evaluated, resulting in the value 6
  - `6` is passed into the `float` function

Code execution: Putting it all together

- Consider this program:

```
a = 4
b = 6.0
```

- What happens when we execute it?
  - the value `4` gets stored in `a`
  - the expression `2+a` is evaluated, resulting in the value 6
  - `6` is passed into the `float` function
  - the `float` function converts 6 to a `float` and returns `6.0`

Code execution: Putting it all together

- Consider this program:

```
a = 4
b = 6.0
```

- What happens when we execute it?
    - the value `4` gets stored in `a`
    - the expression `2+a` is evaluated, resulting in the value 6
    - `6` is passed into the `float` function
    - the `float` function converts 6 to a `float` and returns `6.0`
    - the value `6.0` gets stored in variable `b`

Code execution: Putting it all together

In what order do things get evaluated?

A function’s arguments are always evaluated left-to-right before it is called:

Code execution: Putting it all together

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```
print(2+2, 4+6, int(10.4))
```

Code execution:
Putting it all together

In what order do things get evaluated?

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```
print(2+2, 4+6, int(10.4))

print(4, 4+6, int(10.4))
```

Code execution: Putting it all together

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```
print(2+2, 4+6, int(10.4))

print(4, 4+6, int(10.4))

print(4, 10, int(10.4))
```

Code execution: Putting it all together

In what order do things get evaluated?

A function's arguments are always evaluated left-to-right before it is called:

```
print(2+2, 4+6, int(10.4))

print(4, 4+6, int(10.4))

print(4, 10, int(10.4))

print(4, 10, 10)
```

Code execution: Putting it all together

In what order do things get evaluated?

A function's arguments are always evaluated left-to-right before it is called:

```
print(2+2, 4+6, int(10.4))
print(4, 4+6, int(10.4))
print(4, 10, int(10.4))
print(4, 10, 10)
```

`4 10 10` is printed to the console

Code execution: Putting it all together

- In what order do things get evaluated?
- A function’s arguments are always evaluated left-to-right before it is called:

```
print(2+2, 4+6, int(10.4))
```

- Parenthesized expressions are evaluated inside-out:

Code execution: Putting it all together

- In what order do things get evaluated?

- A function’s arguments are always evaluated left-to-right before it is called:

```
print(2+2, 4+6, int(10.4))
```

- Parenthesized expressions are evaluated inside-out: `20 // (6 + 3)`

Code execution: Putting it all together

- In what order do things get evaluated?
- A function’s arguments are always evaluated left-to-right before it is called:

```
print(2+2, 4+6, int(10.4))
```

- Parenthesized expressions are evaluated inside-out:

```
20 // (6 + 3)

20 // 9
```

Code execution: Putting it all together

- In what order do things get evaluated?
- A function's arguments are always evaluated left-to-right before it is called:

```
print(2+2, 4+6, int(10.4))
```

- Parenthesized expressions are evaluated inside-out:

```
   20 // (6 + 3)

   20 // 9

=> 2
```

Code execution: Putting it all together

- In what order do things get evaluated?

- A function's arguments are always evaluated left-to-right before it is called

```
print(2+2, 4+6, int(10.4))
```

- Parenthesized expressions are evaluated inside-out: `20 // (6 + 3)`

- What about `20 // 6 + 3` ?

Code execution: Putting it all together

- In what order do things get evaluated?
- A function's arguments are always evaluated left-to-right before it is called

```
print(2+2, 4+6, int(10.4))
```

- Parenthesized expressions are evaluated inside-out: `20 // (6 + 3)`
- What about `20 // 6 + 3` ?

More later on *operator precedence*.

A Note on Operators

- Operators only work if their operands have the correct types.

- Some operators can work on more than one type or combination of types:

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Not too surprising:

```
int + int => int
int + float => float
float + int => float
float + float => float
```

A Note on Operators

- Operators only work if their operands have the correct types.

- Some operators can work on more than one type or combination of types:

Not too surprising:

```
int + int => int
int + float => float
float + int => float
float + float => float
```

Maybe a little surprising:

```
str + str => str
str * int => str
```

A Note on Operators

- Operators only work if their operands have the correct types.

```
float * str => error
```

- Some operators can work on more than one type or combination of types:

Not too surprising:

```
int + int => int
int + float => float
float + int => float
float + float => float
```

Maybe a little surprising:

```
str + str => str
str * int => str
```

Demo

Demo

- operator behaviors:

```
4 + 5 => 9
4.0 + 5 => 9.0
4.0 + 5.0 => 9.0
“a” + “b” => “ab”
“a” + 1 => error
“a” + “b” => “ab”
“a” * 16 => “aaaaaaaaaaaaaaaa”
```

Practice Problem: Operators

Suppose we run the following program, and the user types `6` and presses enter.

What value gets stored in `result`?

```
user_num = input("Enter a number: ")
result = 5 % (3 ** (user_num // 4))
```

Practice Problem: Operators

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What value gets stored in `result`?

```
user_num = input("Enter a number: ")
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```

A: 1

B: 2

C: 3

D: None of the above

Practice Problem: Operators

Suppose we run the following program, and the user types `6` and presses enter.

What value gets stored in `result`?

```
user_num = input("Enter a number: ")
result = 5 % (3 ** (user_num // 4))
```

Let's try it out…

Practice Problem: Operators

Suppose we run the following program, and the user types `6` and presses enter.

What value gets stored in `result`?

```
user_num = input("Enter a number: ")
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```

A: 1

B: 2

C: 3

D: None of the above

Bugs

- We had a bug in our code!
- Why are they called bugs? An anecdote from the history of computing:

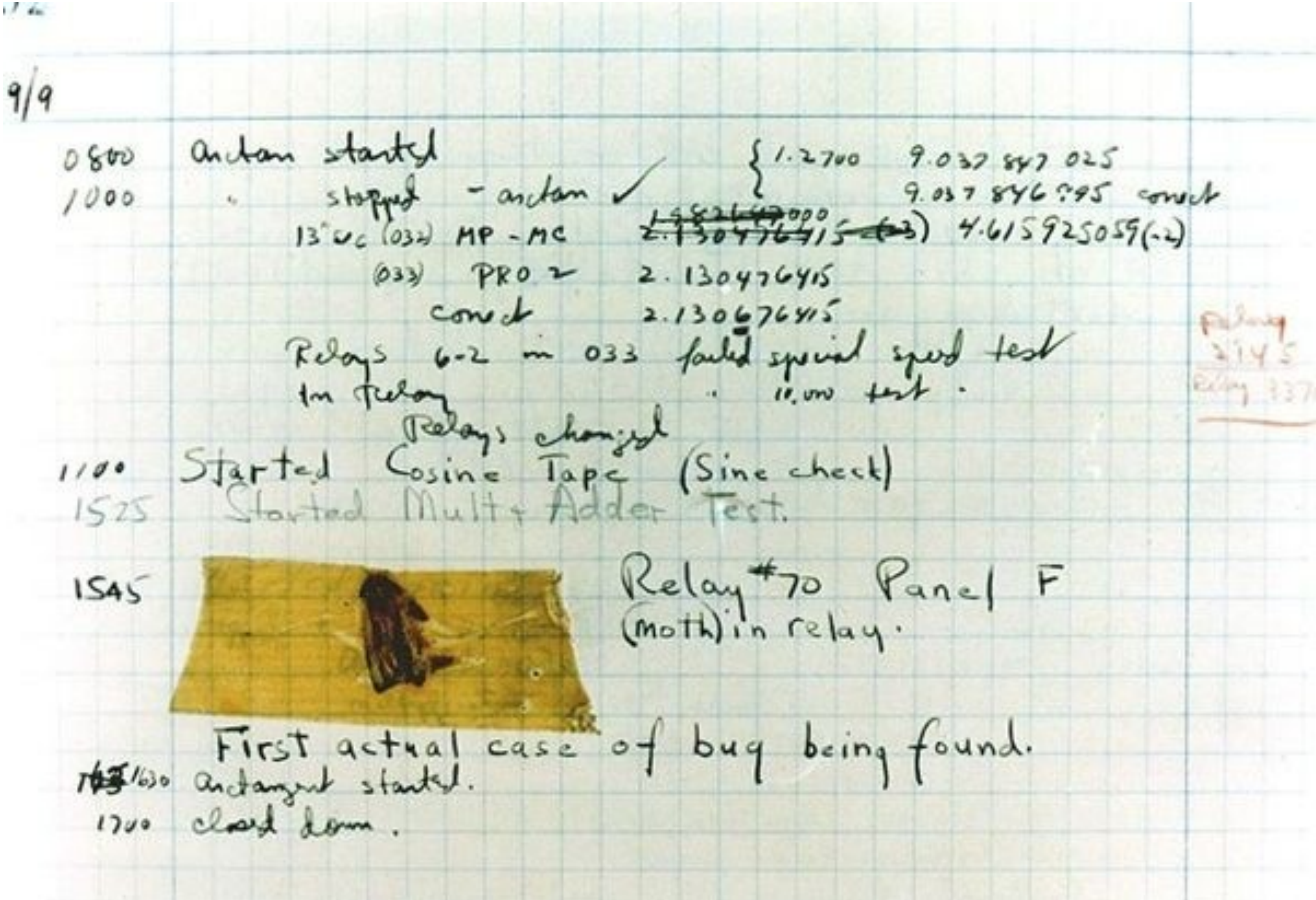
September 9th, 1945(!)

Grace Hopper

At 3:45 p.m., Grace Murray Hopper records 'the first computer bug' in the Harvard Mark II computer's log book. The problem was traced to a moth stuck between relay contacts in the computer, which Hopper duly taped into the Mark II's log book with the explanation: “First actual case of bug being found.” The bug was actually found by others but Hopper made the logbook entry.

Source: https://www.computerhistory.org/tdih/september/9/

“First actual case of a bug being found”



9/9

0800 arctan started

1000 " stopped - arctan ✓ {1.2700 9.037 847 025
{ 9.037 846 995 correct

13" uc (032) MP - MC ~~1.982147000~~ ~~2.130476415~~ ~~(-3)~~) 4.615925059(-2)

(033) PRO 2 2.130476415

correct 2.130676415

Relays 6-2 in 033 failed special speed test
in relay " 11.000 test ".

Relays changed

1100 Started Cosine Tape (Sine check)

1525 Started Mult + Adder Test.

1545 Relay #70 Panel F
(moth) in relay.

First actual case of bug being found.

1630 Antangent started.

1700 closed down.

Relay 2145
Relay 3370

Practice Problem: Operators

Suppose we run the following program, and the user types `6` and presses enter.

What value gets stored in `result`?

```
user_num = int(input("Enter a number: "))
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A: 1

B: 2

C: 3

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Suppose we run the following program, and the user types `6` and presses enter.

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user_num = int(input("Enter a number: "))
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```

Practice Problem: Operators

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user_num = int(input("Enter a number: "))
result = 5 % (3 ** (user_num // 4))
result = 5 % (3 ** (    6    // 4))
```

Practice Problem: Operators

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user_num = int(input("Enter a number: "))
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user_num = int(input("Enter a number: "))
result = 5 % (3 ** (user_num // 4))
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user_num = int(input("Enter a number: "))
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result = 5 % (3 **         1      )
result = 5 % (          3         )
```

Practice Problem: Operators

```
user_num = int(input("Enter a number: "))
result = 5 % (3 ** (user_num // 4))
result = 5 % (3 ** (    6    // 4))
result = 5 % (3 **         1      )
result = 5 % (          3         )
result =           2
```

Order of Operations

We know parenthesized expressions get evaluated from inside to out. Are there any other rules?

What if we took the parentheses out?

```
result = 5 % (3 ** (6 // 4))

result = 5 % 3 ** 6 // 4
```

Order of Operations

We know parenthesized expressions get evaluated from inside to out. Are there any other rules? Yes: operator precedence.

Order of Operations

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Remember PEMDAS? BIDMAS? BODMAS?

Order of Operations

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Remember PEMDAS? BIDMAS? BODMAS?

Parentheses

Exponentiation

Multiplication and Division

Addition and Subtraction

Order of Operations

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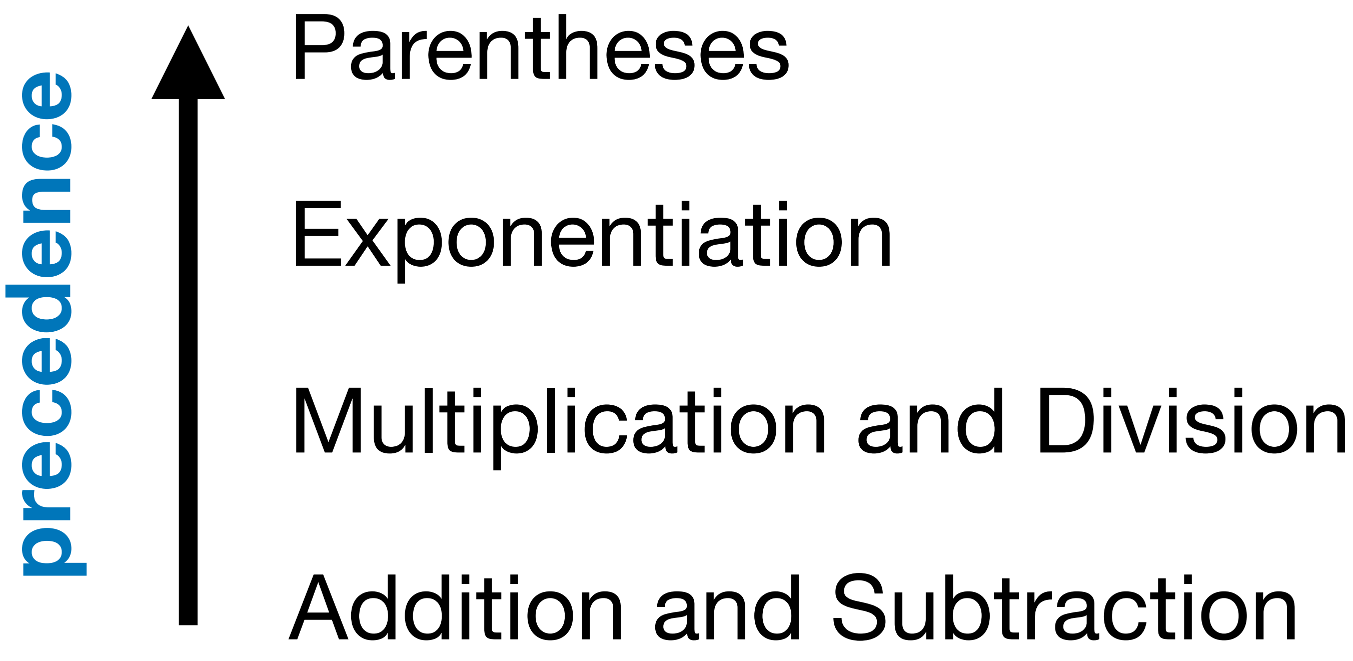

precedence

Parentheses

Exponentiation

Multiplication and Division

Addition and Subtraction

Order of Operations

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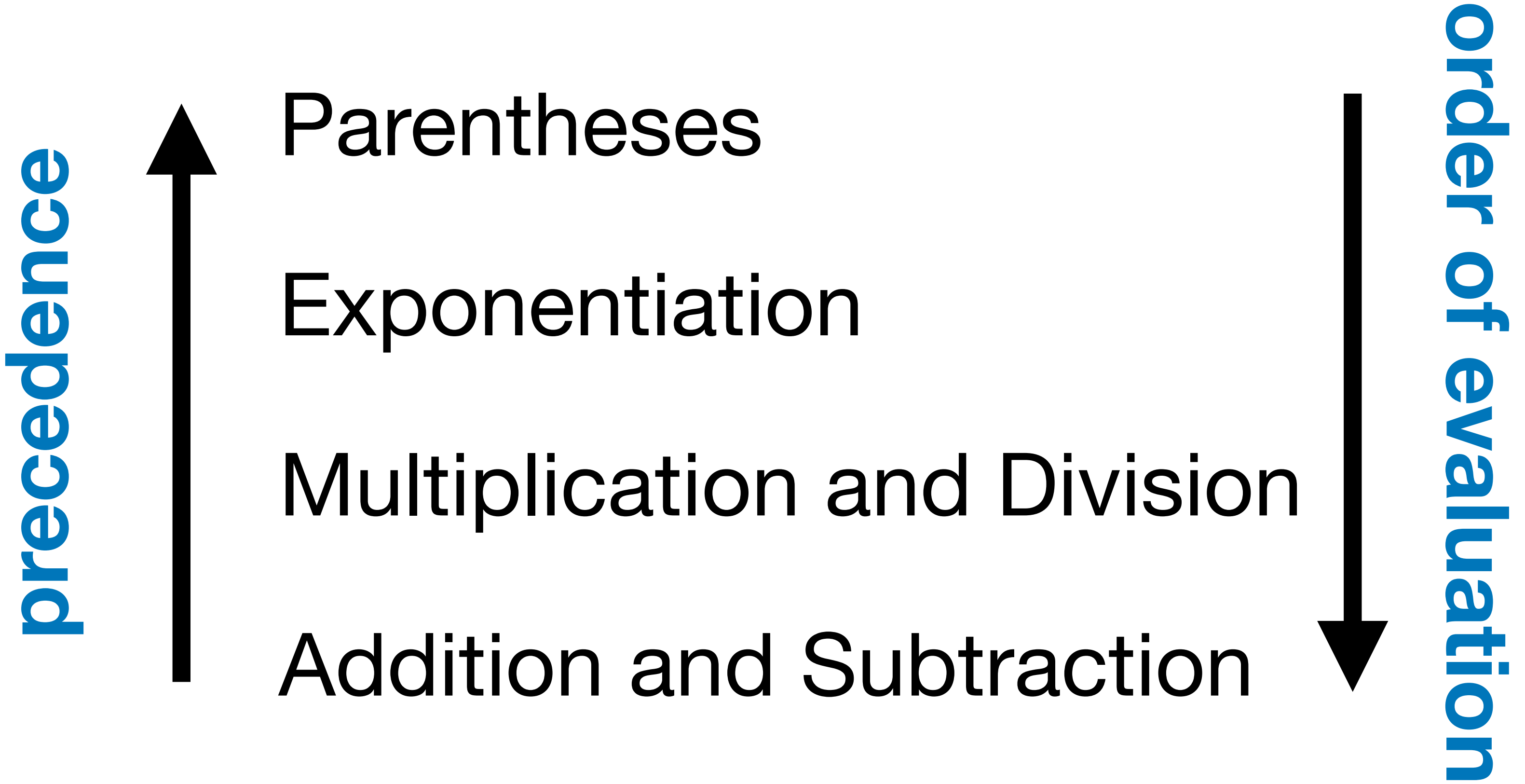

precedence

Parentheses

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Multiplication and Division

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order of evaluation

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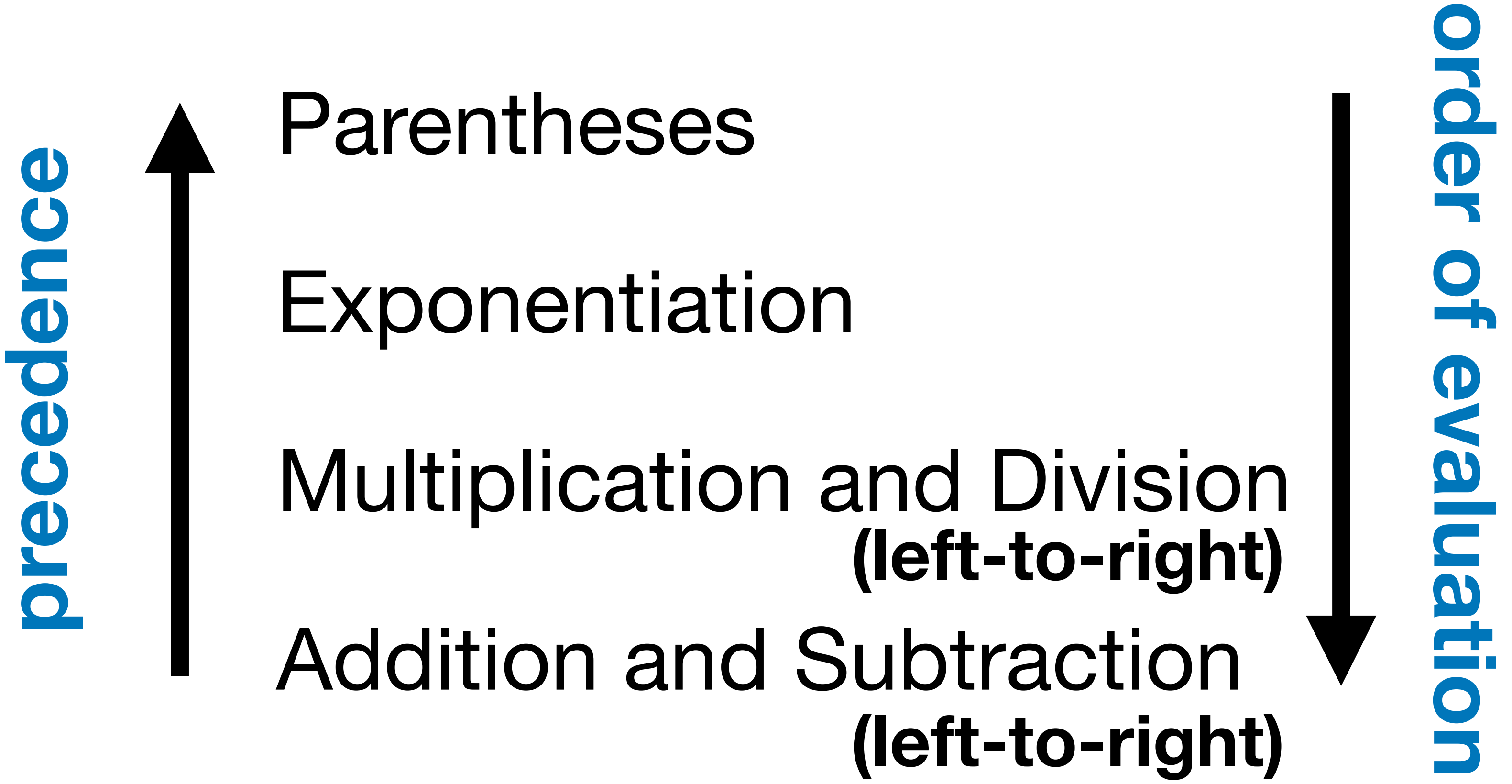

precedence

Parentheses

Exponentiation

Multiplication and Division
(left-to-right)

Addition and Subtraction
(left-to-right)

order of evaluation

Order of Operations

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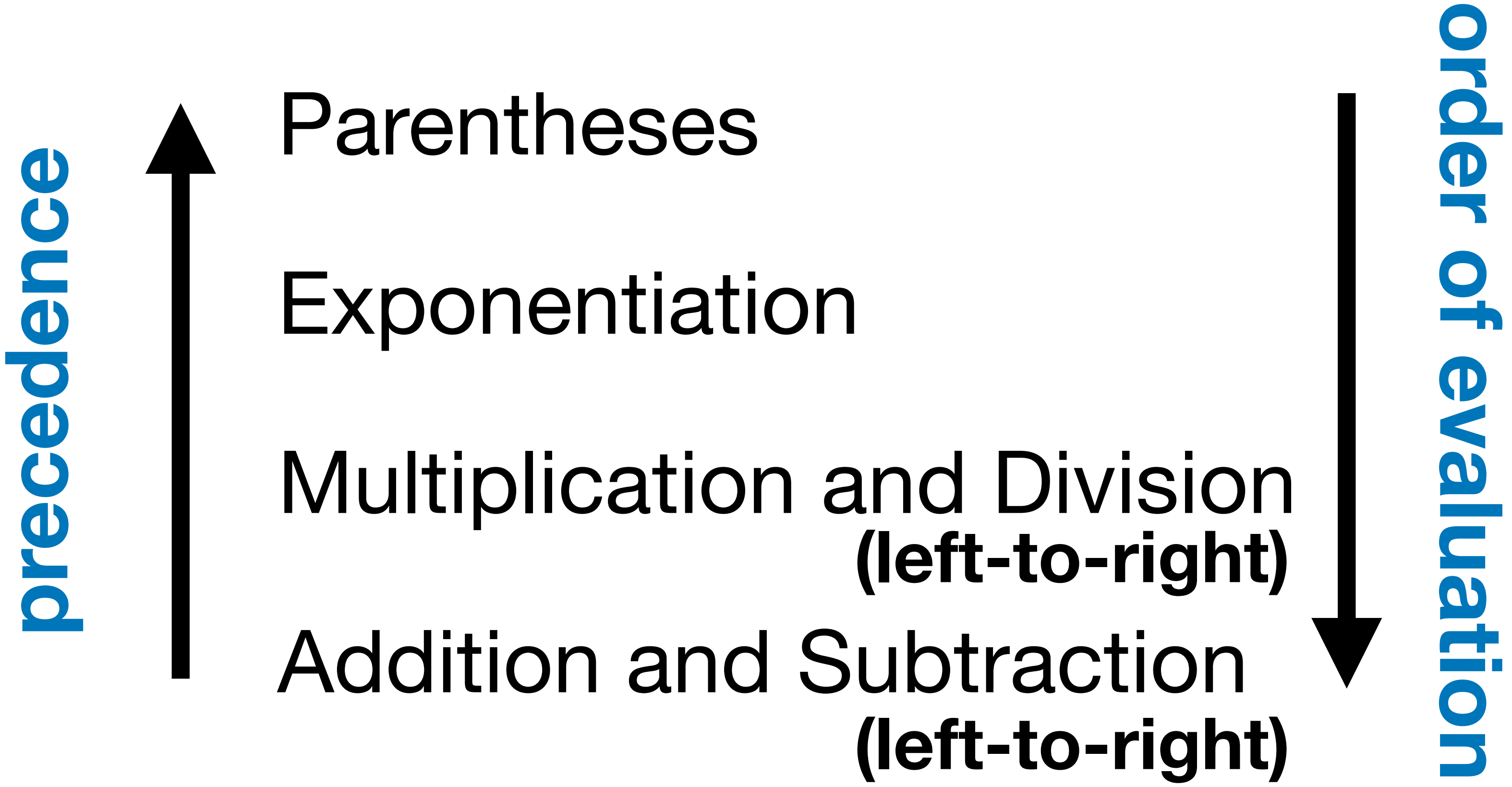

precedence

Parentheses

Exponentiation

Multiplication and Division **(left-to-right)**

Addition and Subtraction **(left-to-right)**

order of evaluation

Example (whiteboard):

```
10 * 6 ** 2 / 5 // 11
```

Order of Operations

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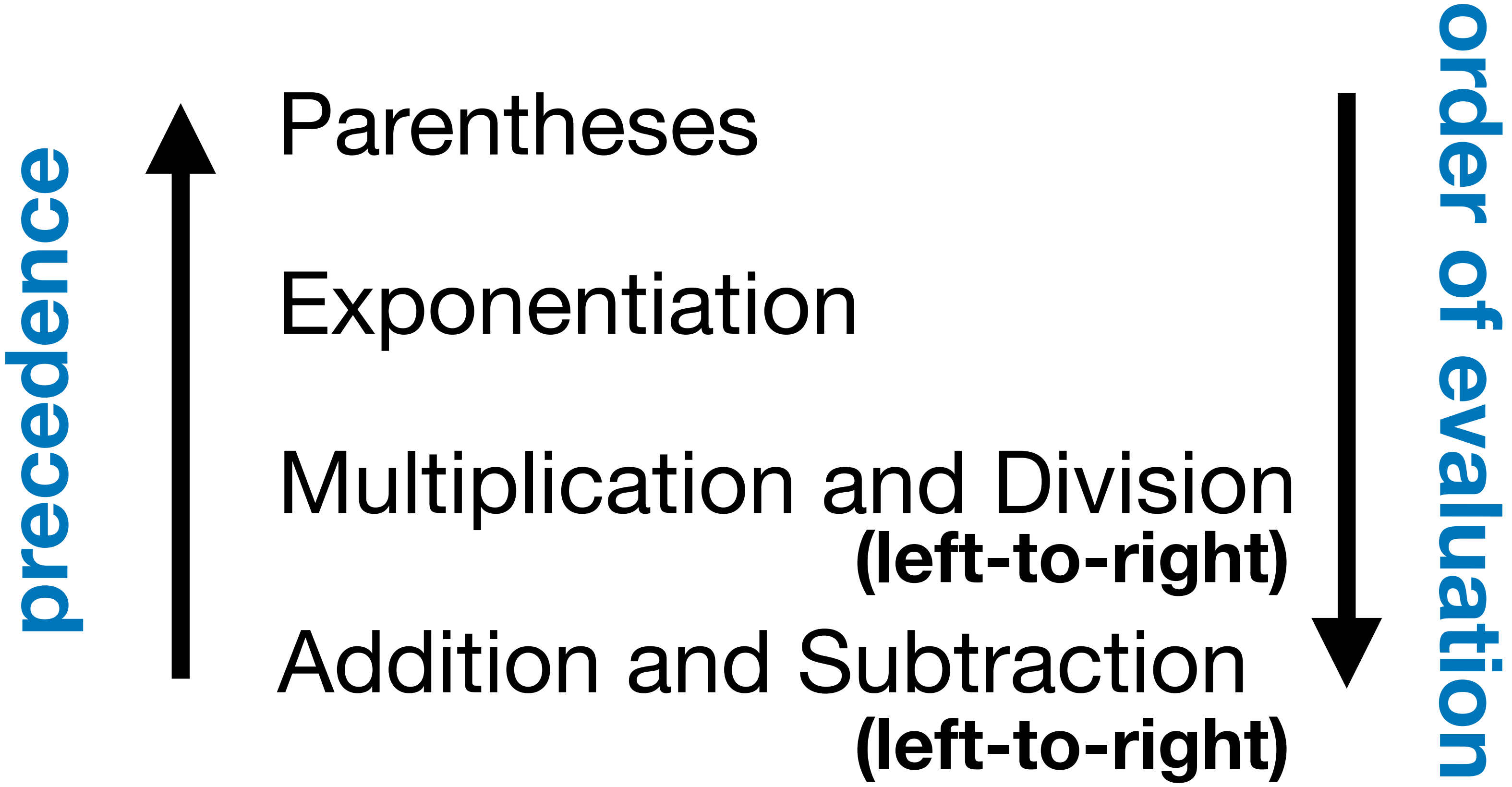

precedence

Parentheses

Exponentiation

Multiplication and Division
(left-to-right)

Addition and Subtraction
(left-to-right)

order of evaluation

Example:

```
2 ** 2 ** 3
```

Order of Operations

We know parenthesized expressions get evaluated from inside to out. Are there any other rules? Yes: operator precedence.

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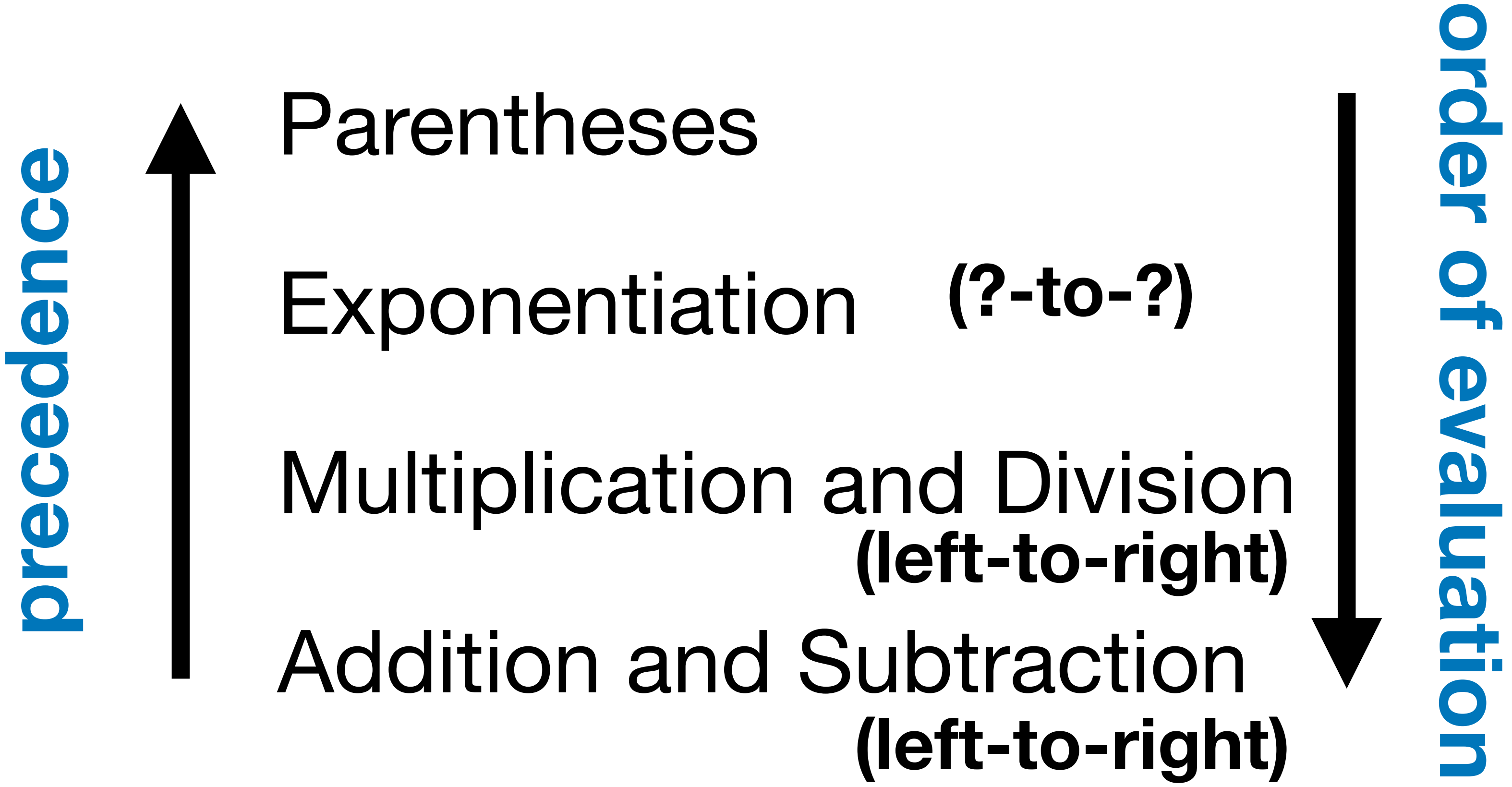

precedence

Parentheses

Exponentiation **(?-to-?)**

Multiplication and Division **(left-to-right)**

Addition and Subtraction **(left-to-right)**

order of evaluation

Example:

```
2 ** 2 ** 3
```

Order of Operations

We know parenthesized expressions get evaluated from inside to out. Are there any other rules? Yes: operator precedence.

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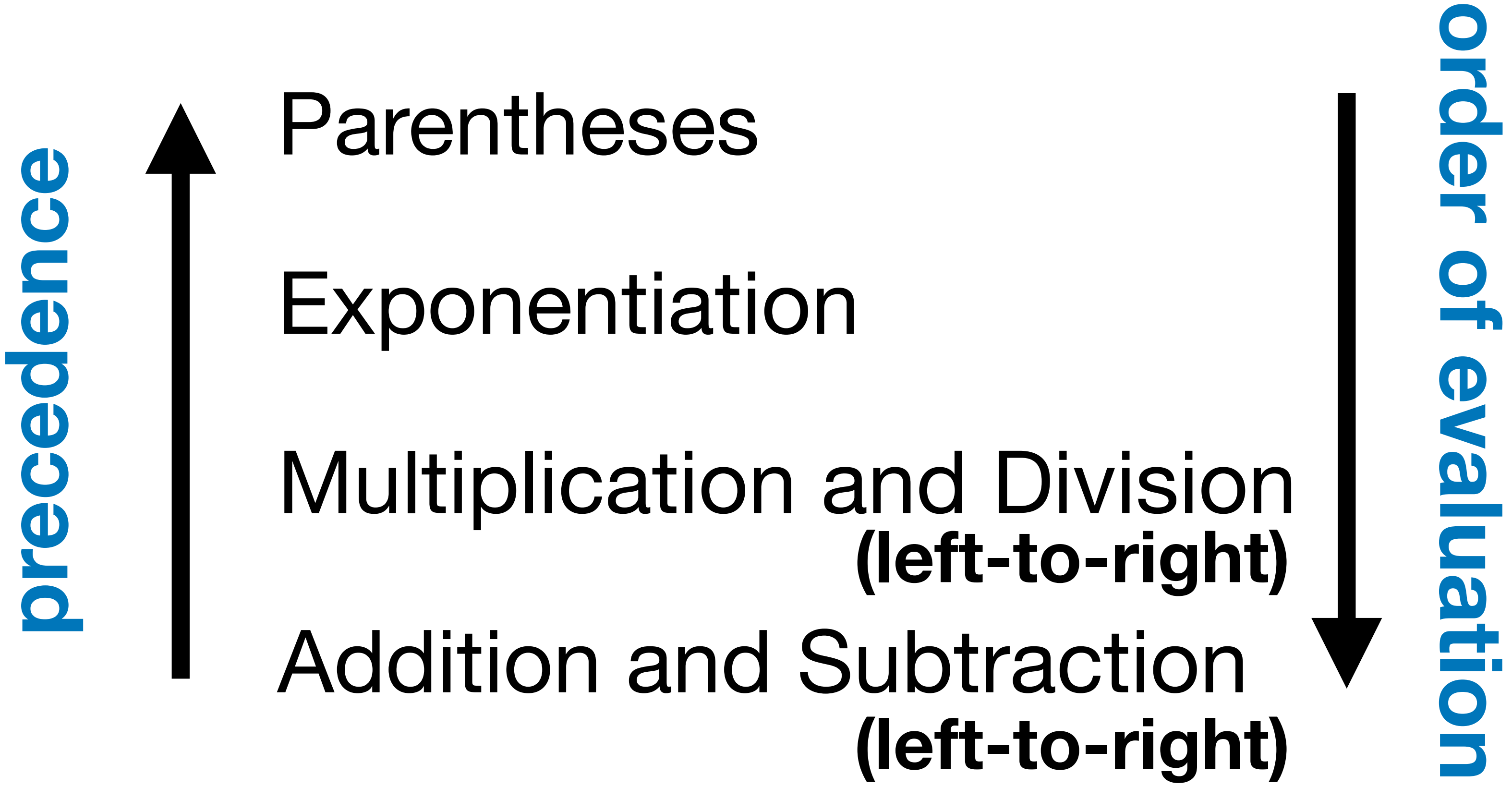

precedence

Parentheses

Exponentiation

Multiplication and Division
(left-to-right)

Addition and Subtraction
(left-to-right)

order of evaluation

Example:

```
2 ** 2 ** 3
```

Order of Operations

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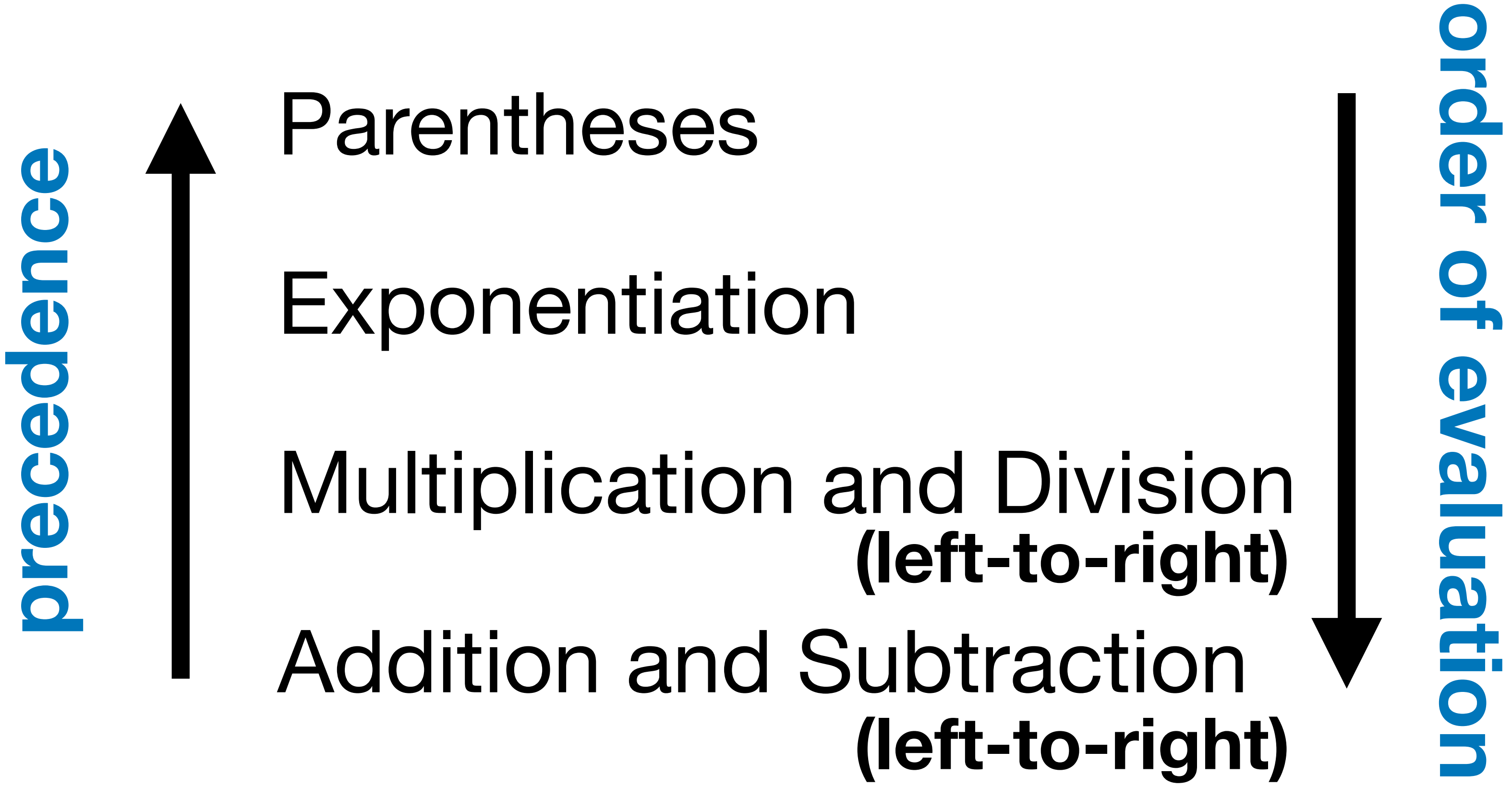


precedence

Parentheses

Exponentiation

Multiplication and Division
(left-to-right)

Addition and Subtraction
(left-to-right)

order of evaluation

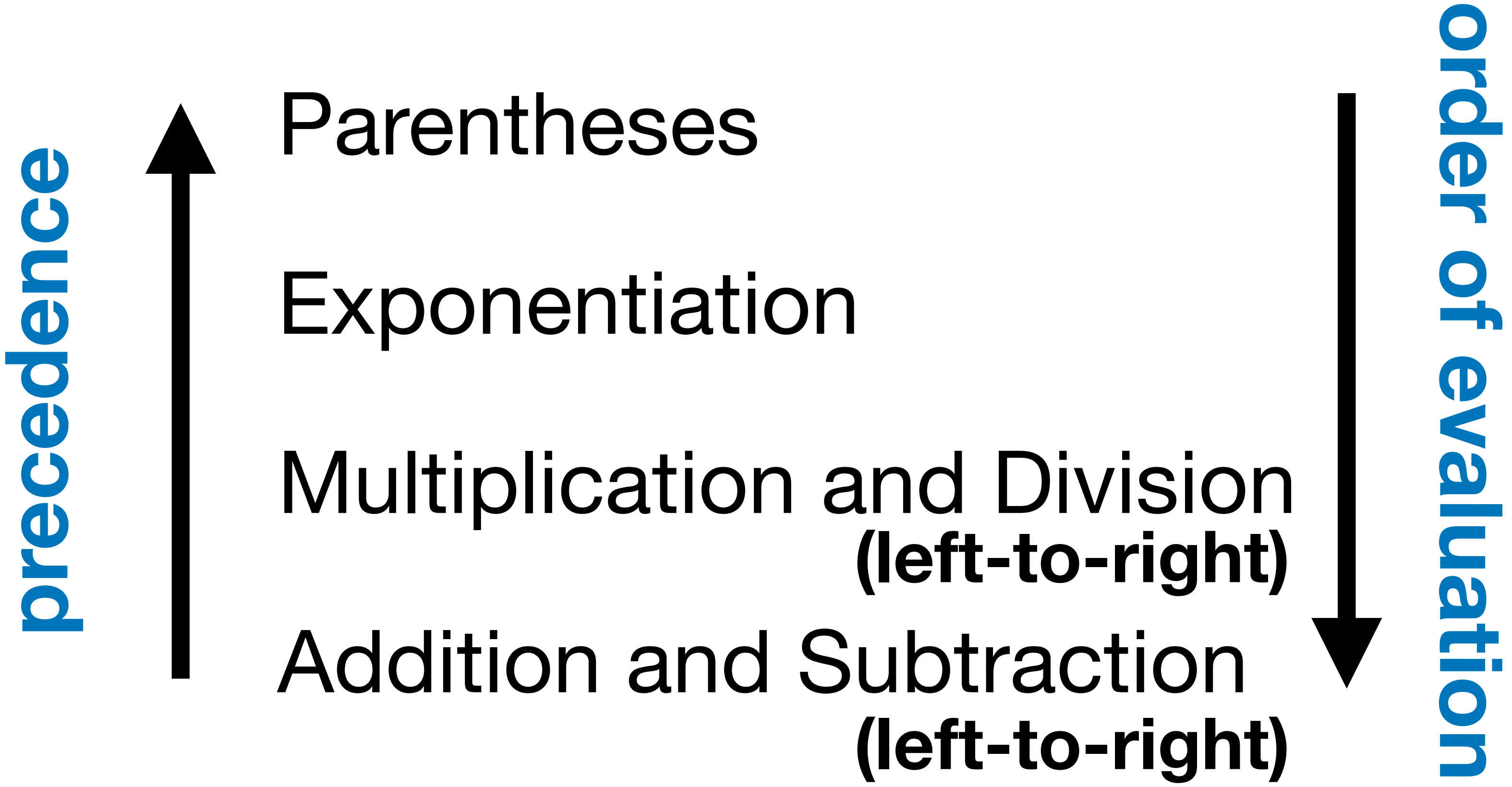
Example:

```
2 ** 2 ** 3
(2 ** 2) ** 3
```

Order of Operations

We know parenthesized expressions get evaluated from inside to out. Are there any other rules? Yes: operator precedence.

Remember PEMDAS? BIDMAS? BODMAS?



Parentheses

Exponentiation

Multiplication and Division
(left-to-right)

Addition and Subtraction
(left-to-right)

Example:

`2 ** 2 ** 3`

`(2 ** 2) ** 3`
=> 4^3 => 64

Order of Operations

We know parenthesized expressions get evaluated from inside to out. Are there any other rules? Yes: operator precedence.

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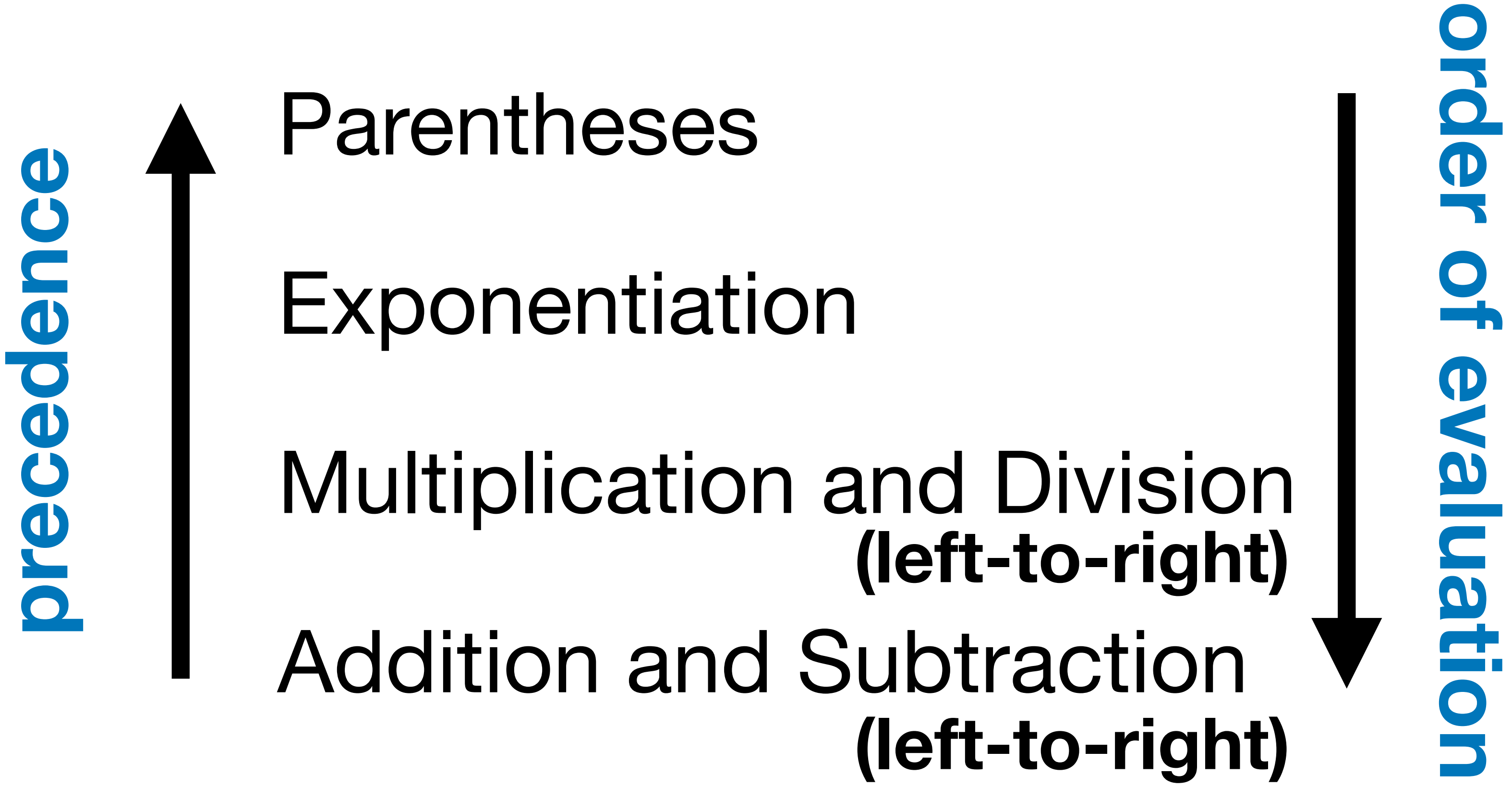

precedence

Parentheses

Exponentiation

Multiplication and Division
(left-to-right)

Addition and Subtraction
(left-to-right)

order of evaluation

Example:

```
2 ** 2 ** 3
```

```
(2 ** 2) ** 3
```

=> 4^3 => 64

```
2 ** (2 ** 3)
```

Order of Operations

We know parenthesized expressions get evaluated from inside to out. Are there any other rules? Yes: operator precedence.

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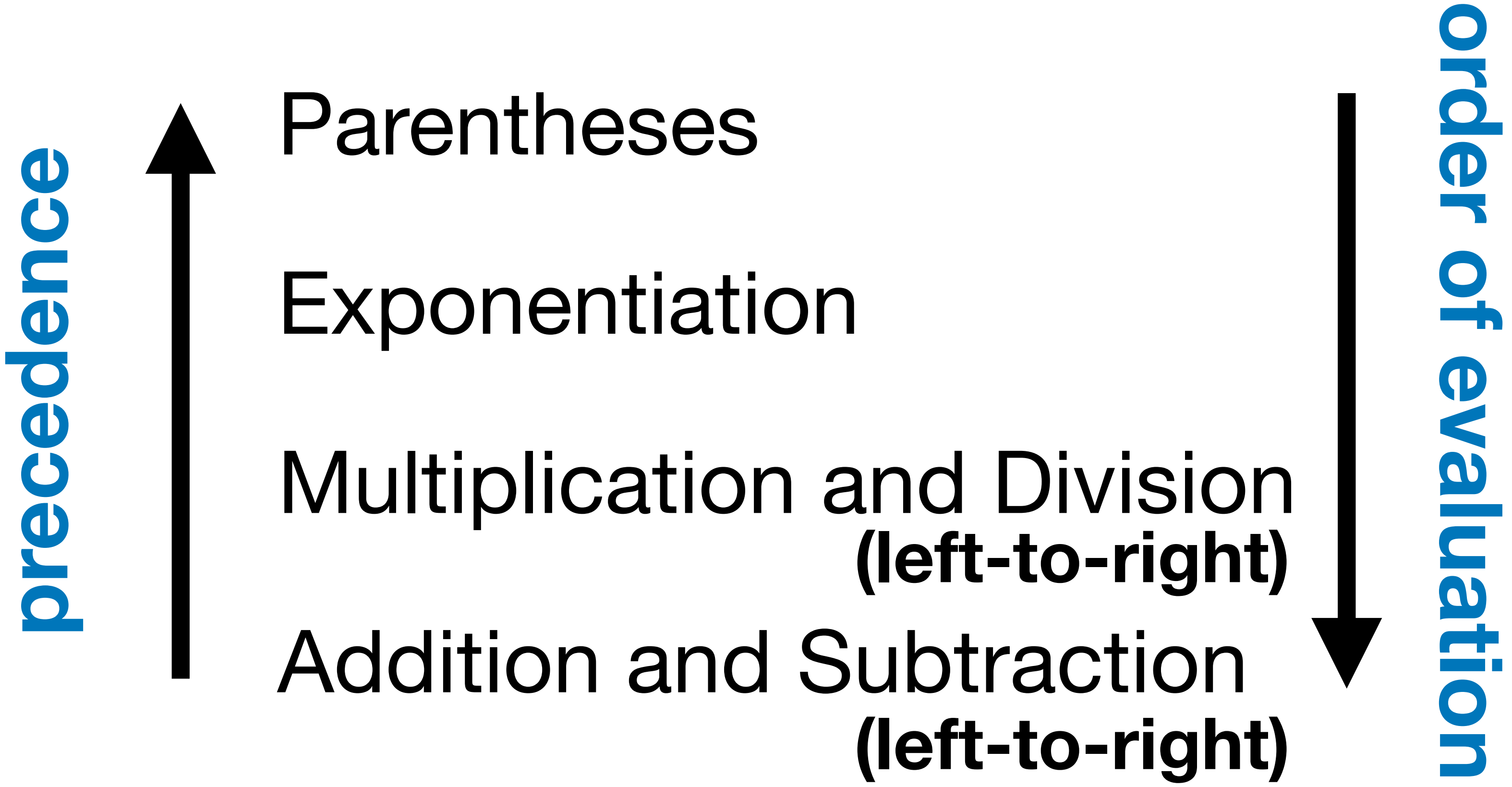

precedence

Parentheses

Exponentiation

Multiplication and Division
(left-to-right)

Addition and Subtraction
(left-to-right)

order of evaluation

Example:

`2 ** 2 ** 3`

`(2 ** 2) ** 3`
=> 4^3 => 64

`2 ** (2 ** 3)`
=> 2^8 => 256

Order of Operations

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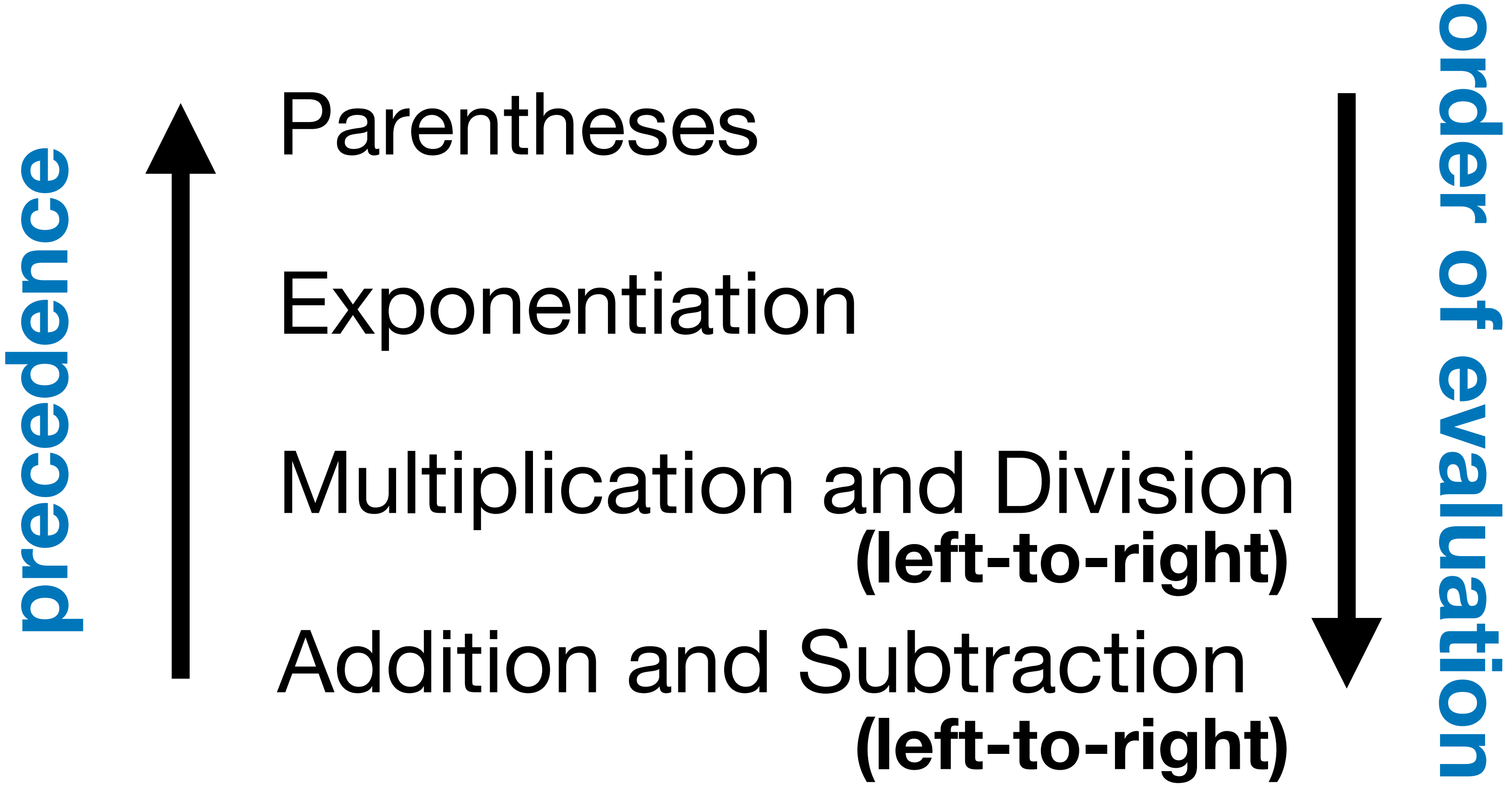


precedence

Parentheses

Exponentiation

Multiplication and Division
(left-to-right)

Addition and Subtraction
(left-to-right)

order of evaluation

Example:

`2 ** 2 ** 3`

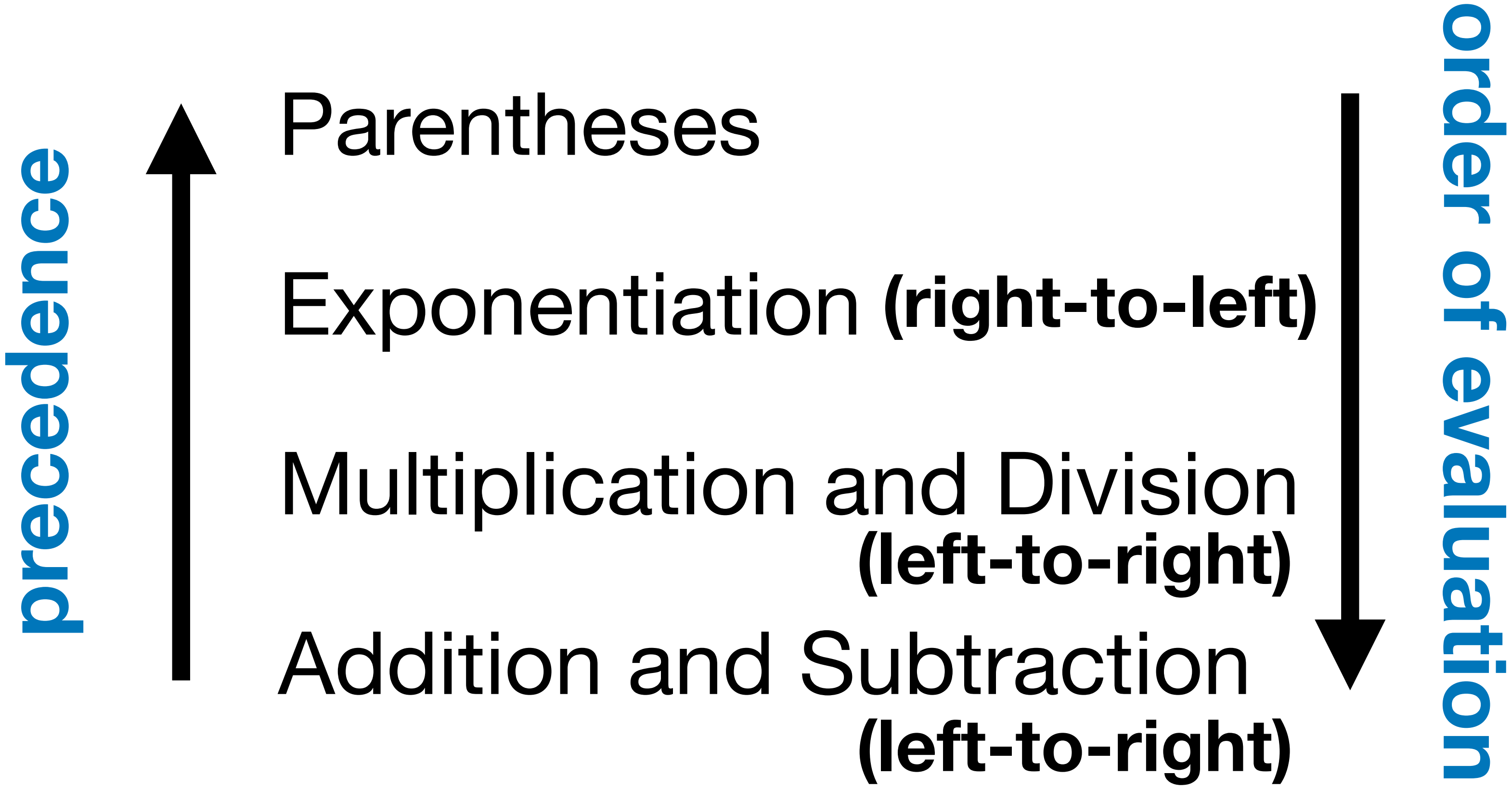
`(2 ** 2) ** 3`
=> 4^3 => 64

`2 ** (2 ** 3)`
=> 2^8 => 256 ✓

Order of Operations

We know parenthesized expressions get evaluated from inside to out. Are there any other rules? Yes: operator precedence.

Remember PEMDAS? BIDMAS? BODMAS?



precedence

- Parentheses
- Exponentiation **(right-to-left)**
- Multiplication and Division **(left-to-right)**
- Addition and Subtraction **(left-to-right)**

order of evaluation

Example:

`2 ** 2 ** 3`

`(2 ** 2) ** 3`
=> 4^3 => 64

`2 ** (2 ** 3)`
=> 2^8 => 256 ✓

PEMDAS Practice

What does the following expression evaluate to?

```
1 + 2 ** 3 / 4 * 5 - (6 % 7)
```

A. 4

B. 5

C. 6

D. 4.0

E. 5.0

F. 6.0

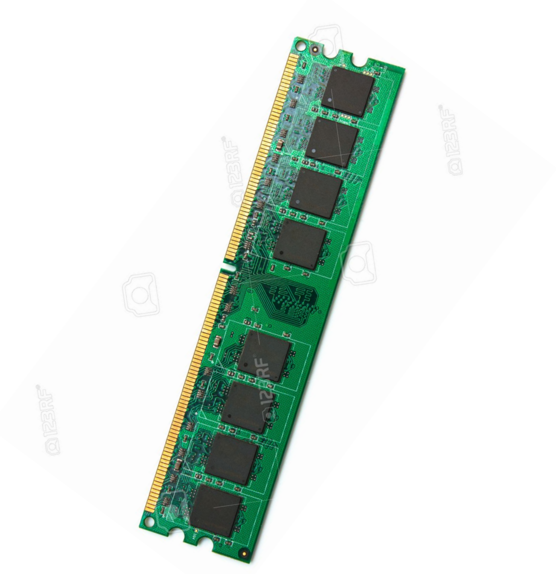
Questions?

Representing Numbers on Computers

- What happens “under the hood” when we execute:

```
    result = 5
```

- The value 5 gets stored somewhere in main memory (and we somehow keep track of where it’s stored).



Main Memory

Representing Numbers on Computers

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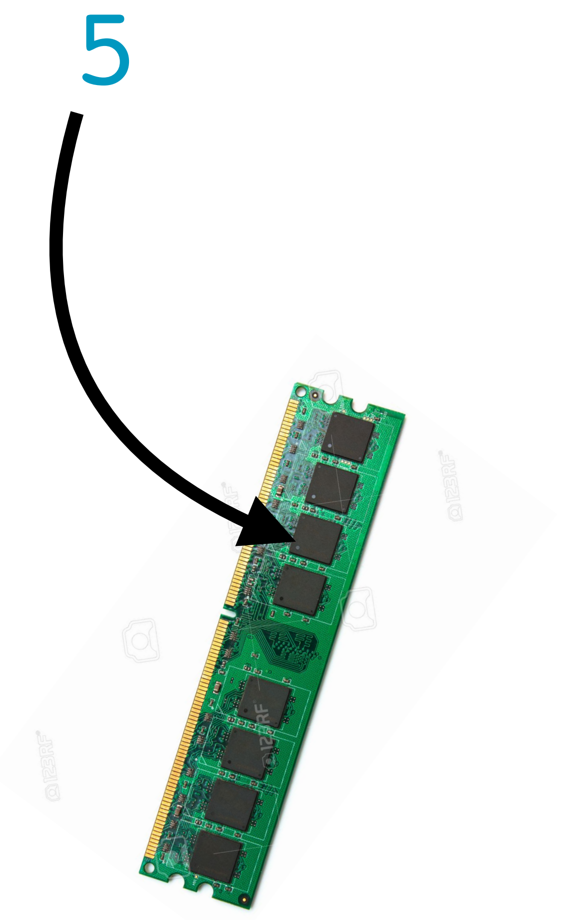
```
    result = 5
```

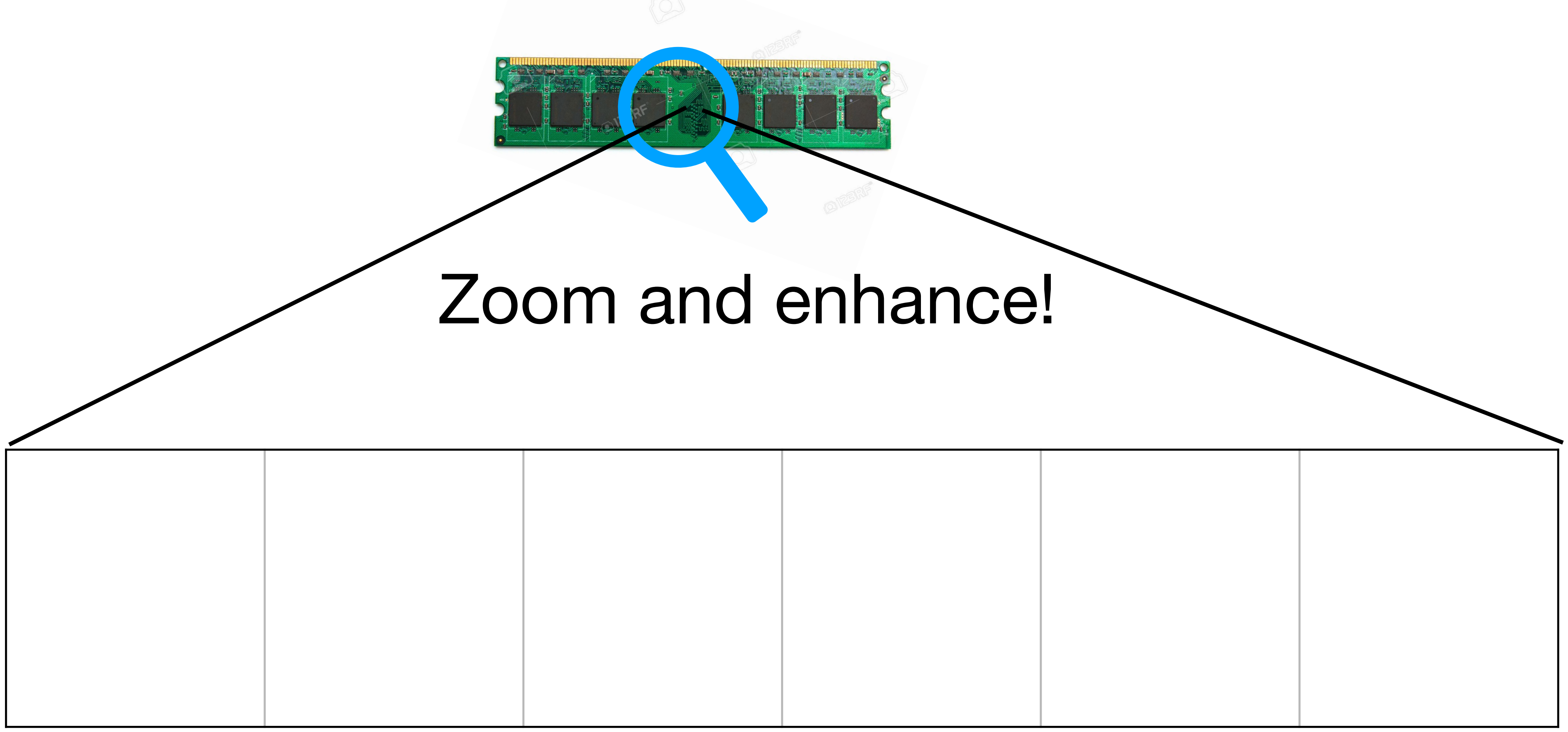
- The value 5 gets stored somewhere in main memory (and we somehow keep track of where it's stored).



Main Memory

Representing Numbers on Computers

How are numbers stored in memory?



Zoom and enhance!

Memory is made of specialized electric circuits that provide cells that can “store” information by being in one of two states: on or off.

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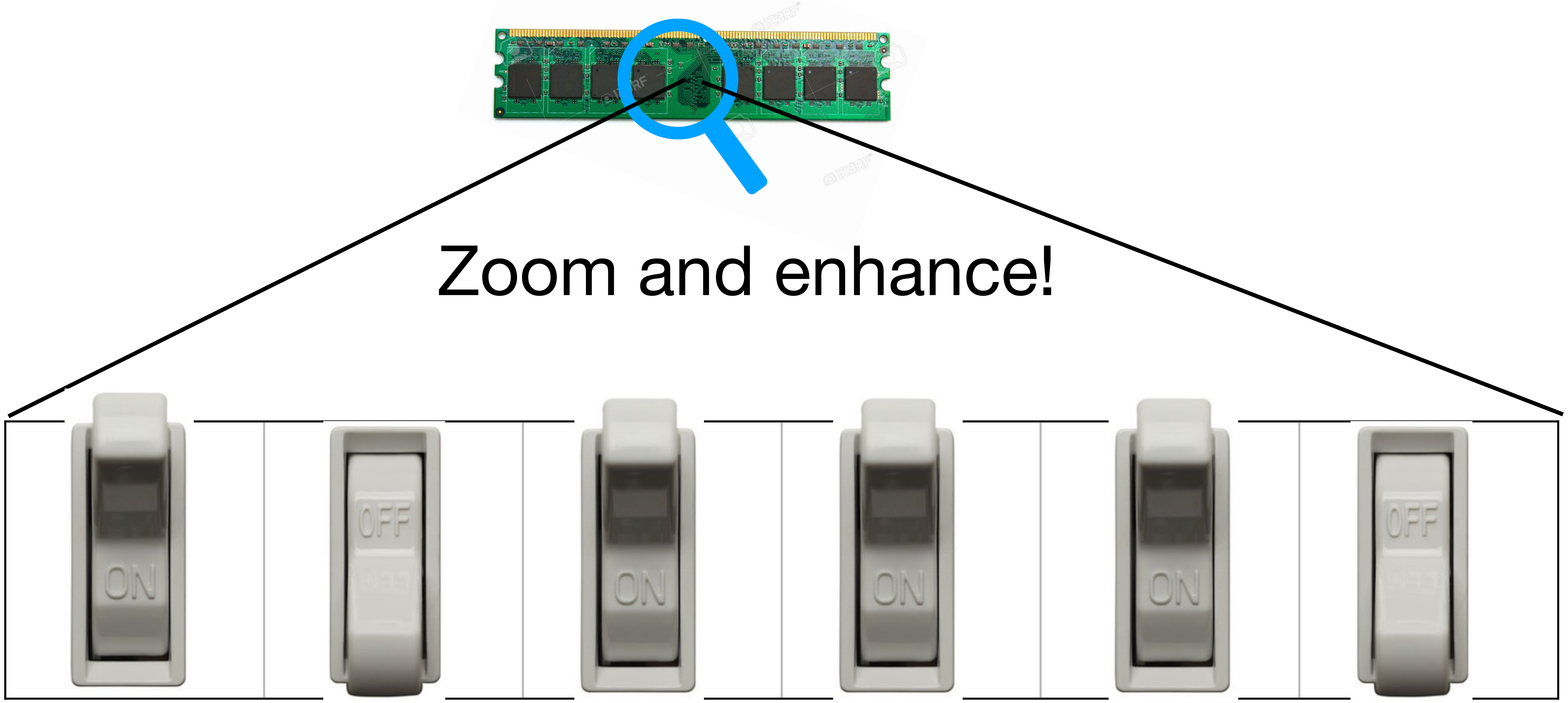

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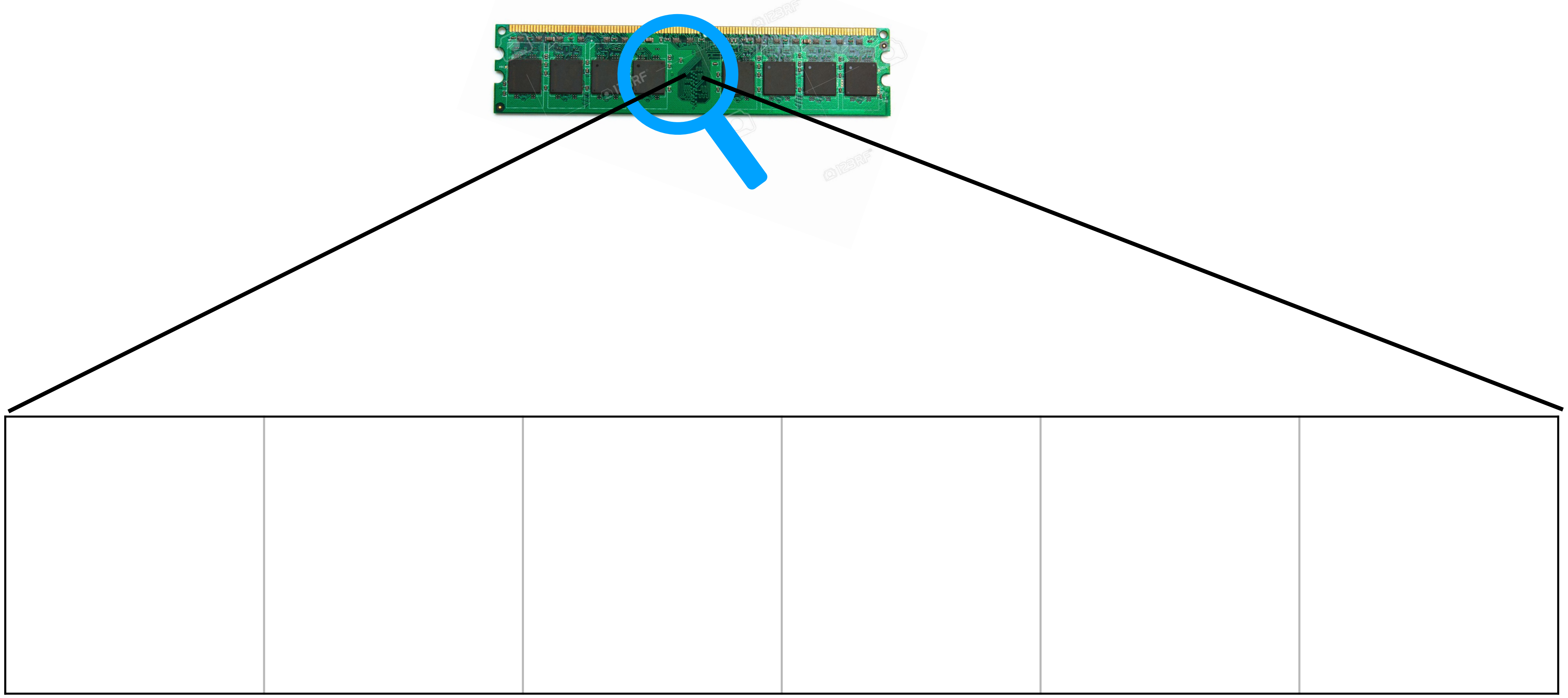

We impose mathematical meaning on these states:
“off” = 0
“on” = 1

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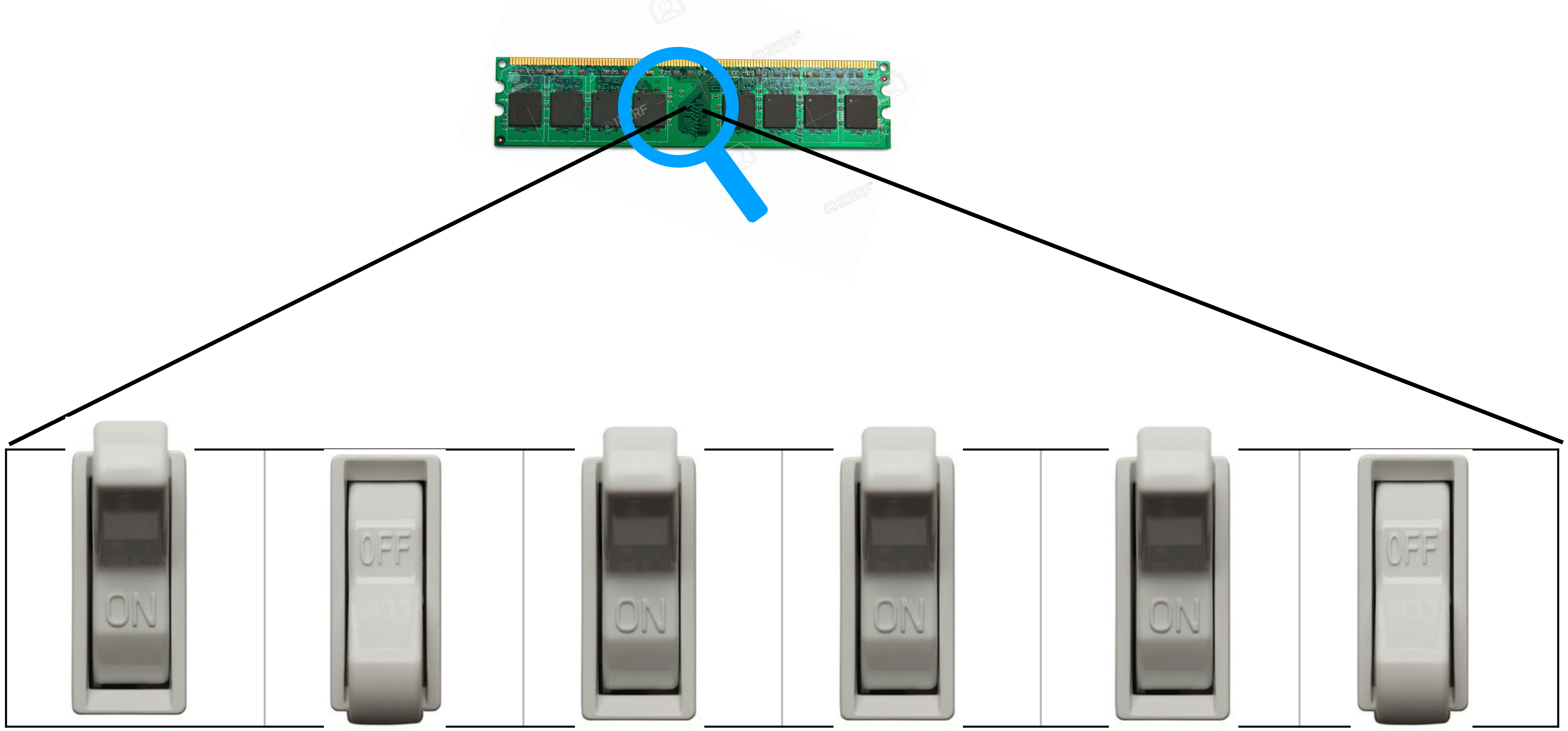

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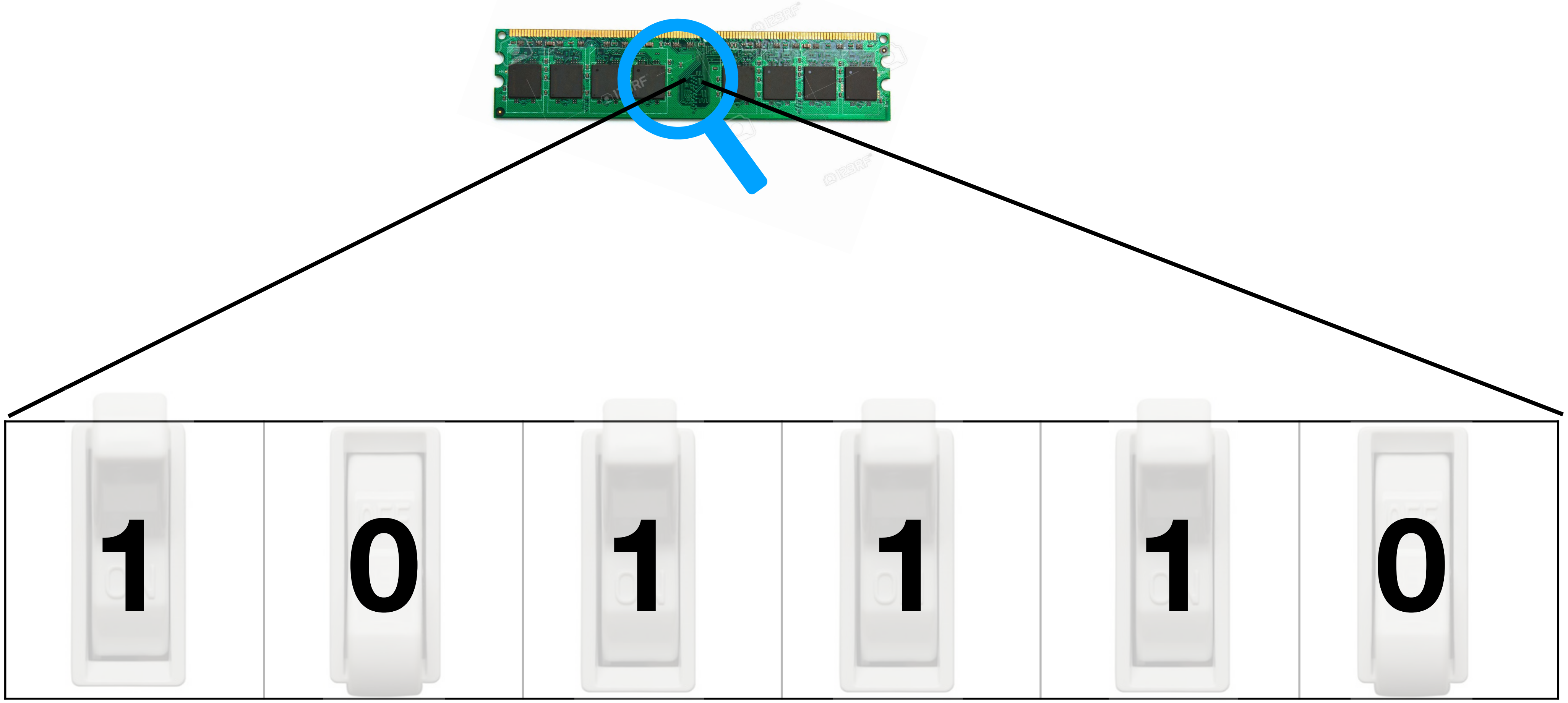

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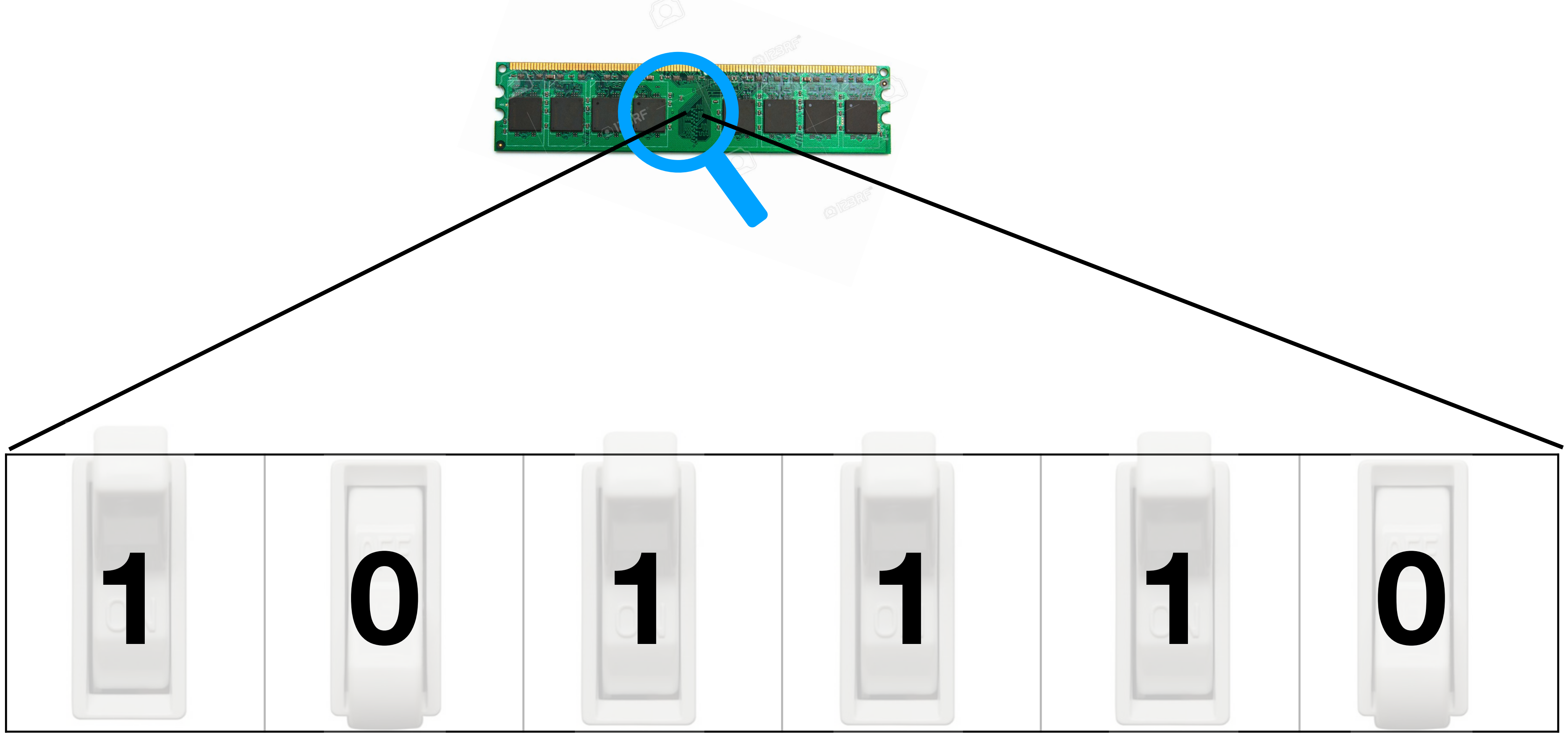
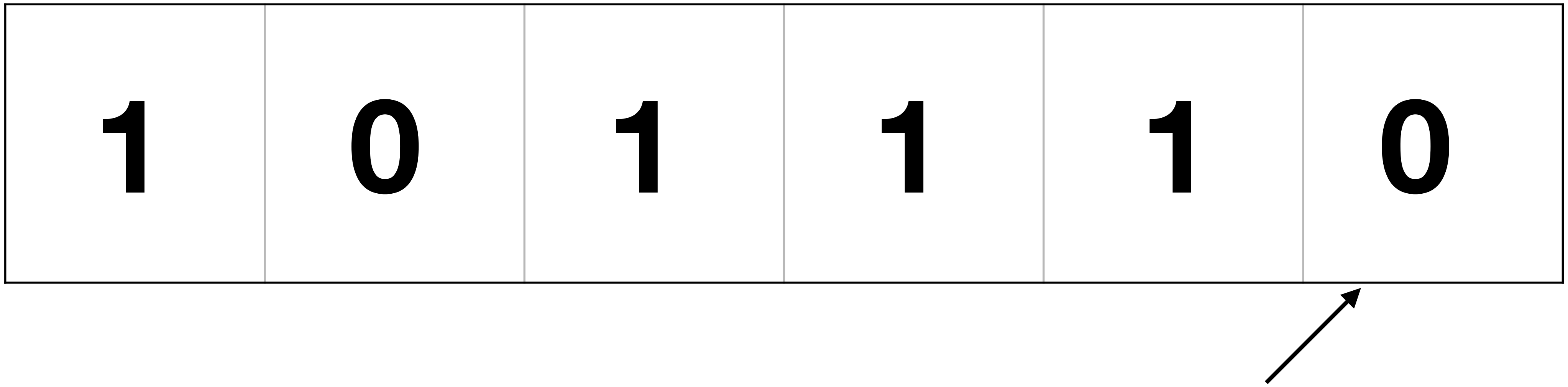


Each 1/0 memory location is called a bit.

Representing Numbers on Computers



1	0	1	1	1	0

Each 0/1 memory location stores one bit.

8 bits is called a byte.

Metric prefixes are used to represent numbers of bytes, e.g. **kilo**, **mega**, **giga**, etc.

In computer science, kilo is not actually 1000, it’s 1024.

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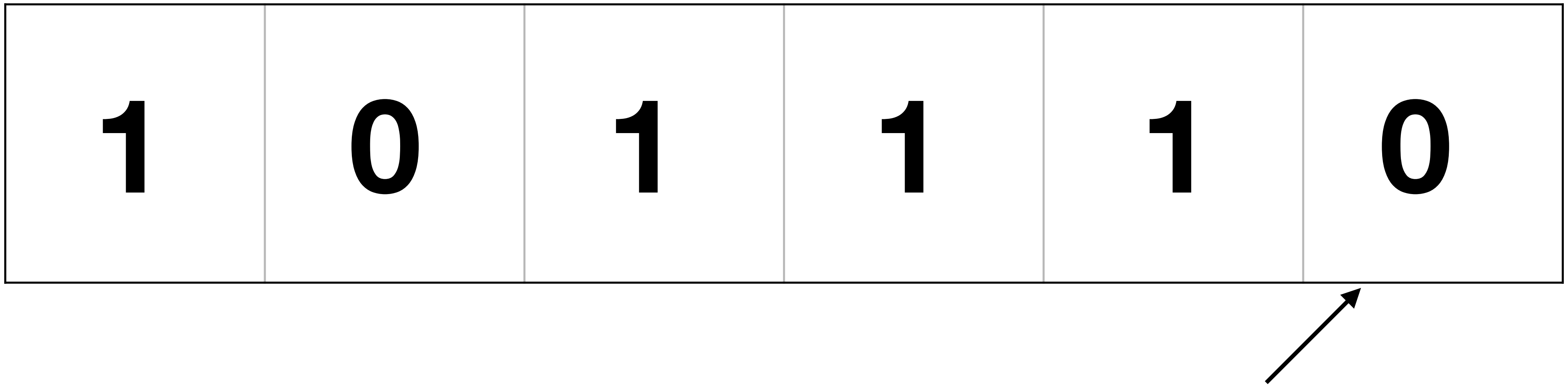

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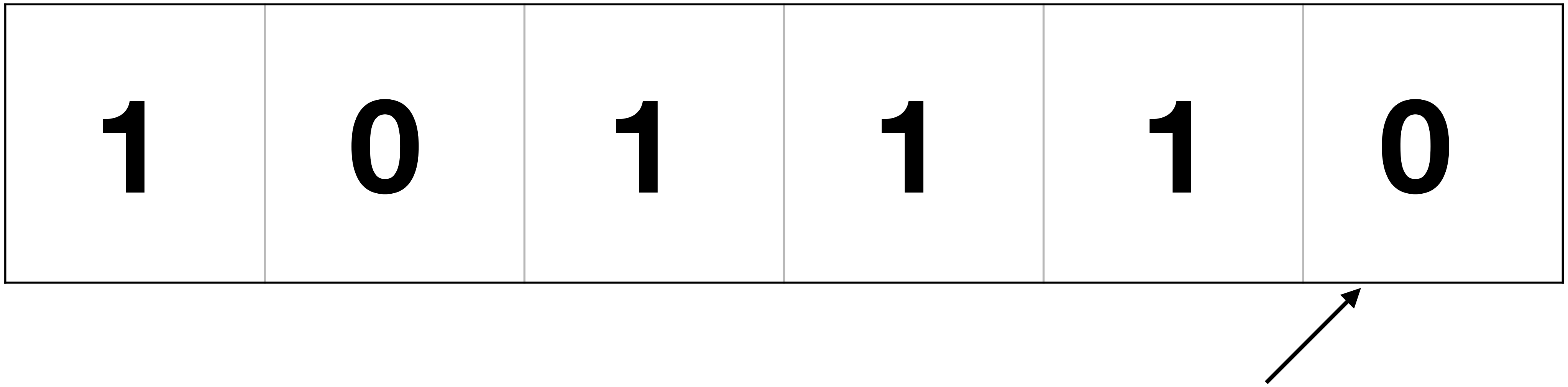

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- kilo = 10^3 = 1000
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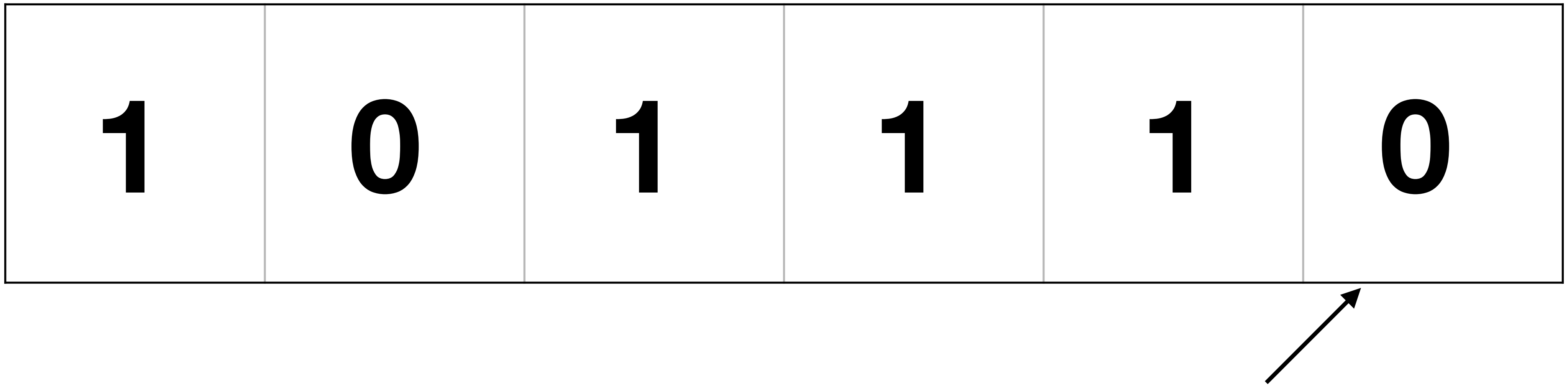

1 0 1 1 1 0

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Base 2 prefixes:

- kilobyte = 2^{10} = 1,024 bytes
- megabyte = 2^{20} = 1,048,576 bytes
- gigabyte = 2^{30} = 1,073,741,824 bytes
- terabyte = 2^{40} = 1,099,511,627,776 bytes

Binary Representation

In decimal:

$$\begin{array}{lll} 104 = & 1 * 10^2 & \text{(hundreds place)} \\ + & 0 * 10^1 & \text{(tens place)} \\ + & 4 * 10^0 & \text{(ones place)} \end{array}$$

Binary Representation

If all we can store is 0’s and 1’s, how do we represent other numbers (e.g., 23?)

- By representing numbers in base 2 (binary) instead of base 10 (decimal).
- Observation:

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- The decimal representation of a number is a sum of multiples of the powers of ten.

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- Key idea: use 2 here instead of 10.

Binary to Decimal

1	0	1	1	1	1

- In decimal, each digit represents a multiple of a power of **2**

Binary to Decimal

1	**0**	**1**	**1**	**1**	**1**
2^5	2^4	2^3	2^2	2^1	2^0

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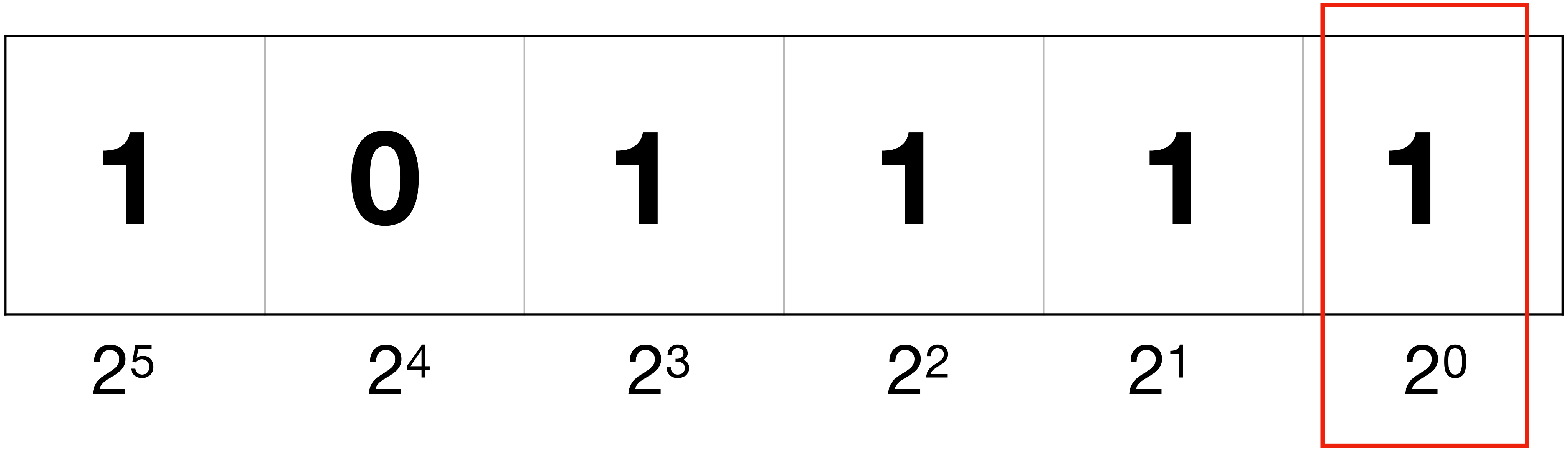

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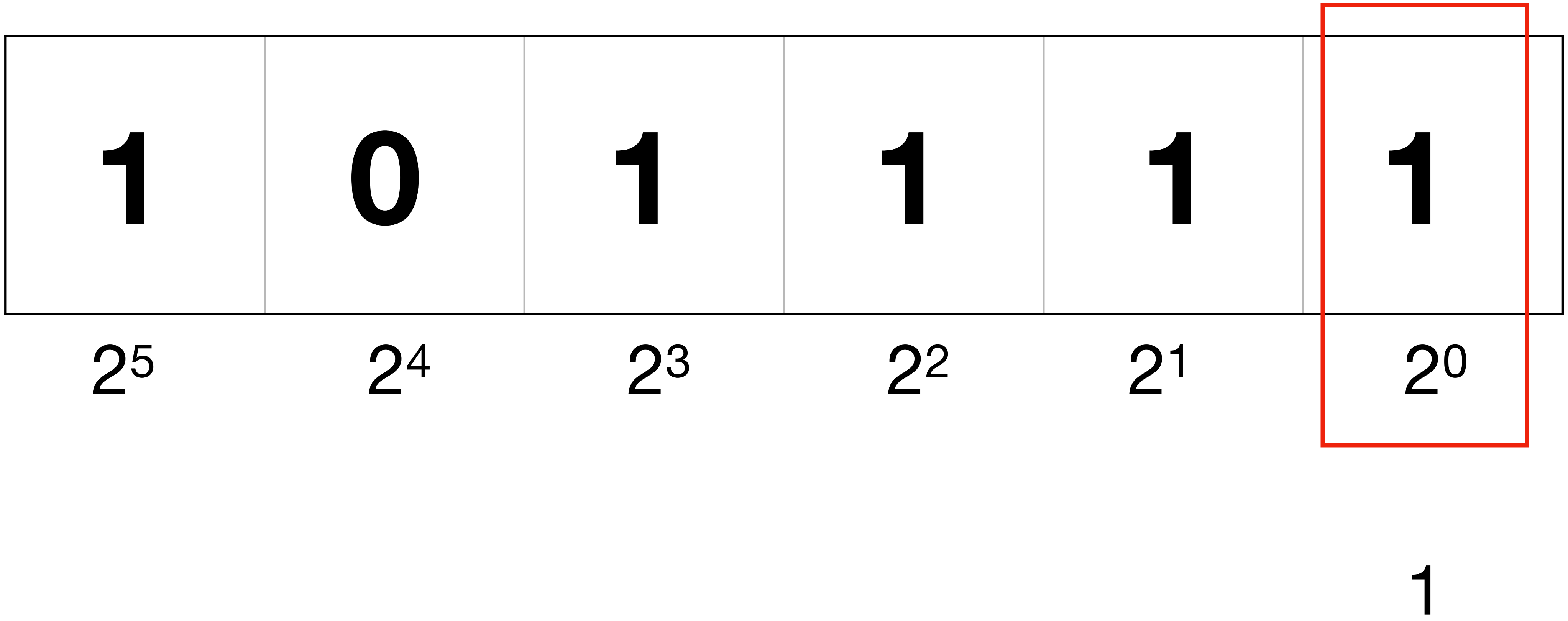

1	0	1	1	1	1
2^5	2^4	2^3	2^2	2^1	2^0
					1

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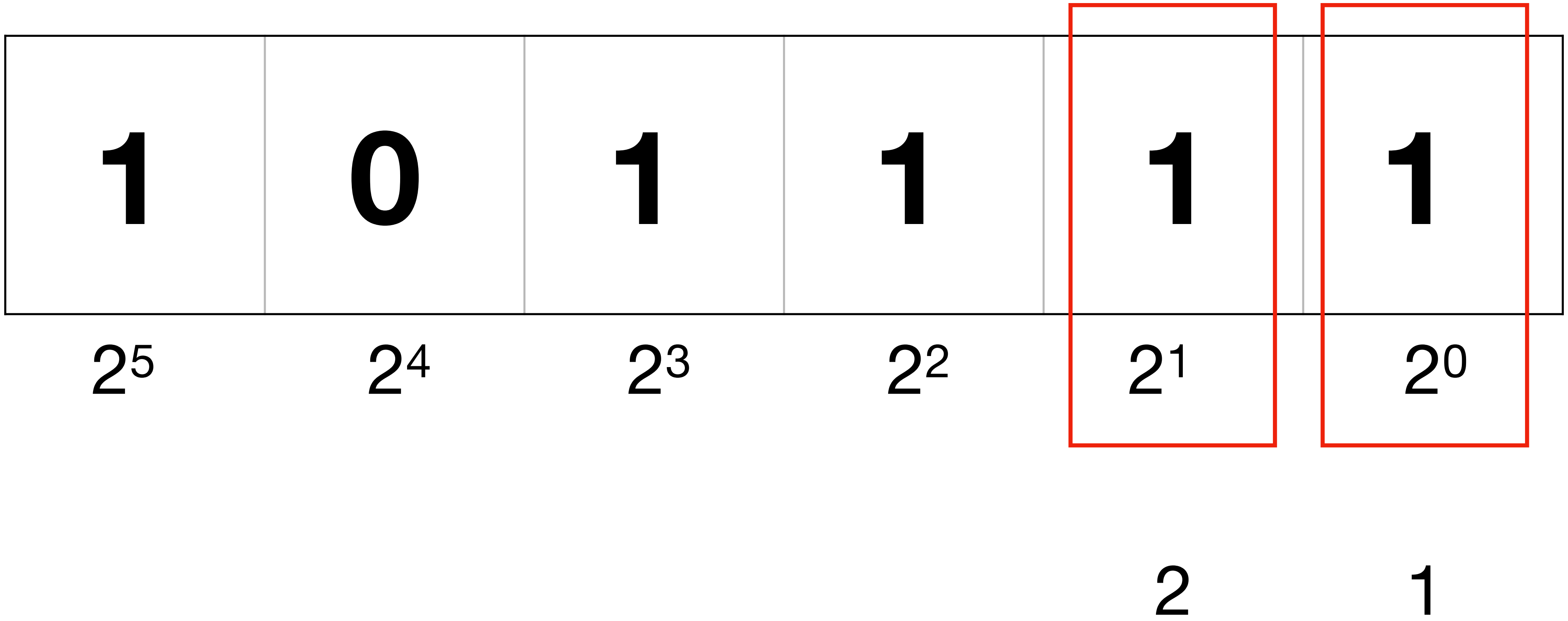

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2^5	2^4	2^3	2^2	2^1	2^0
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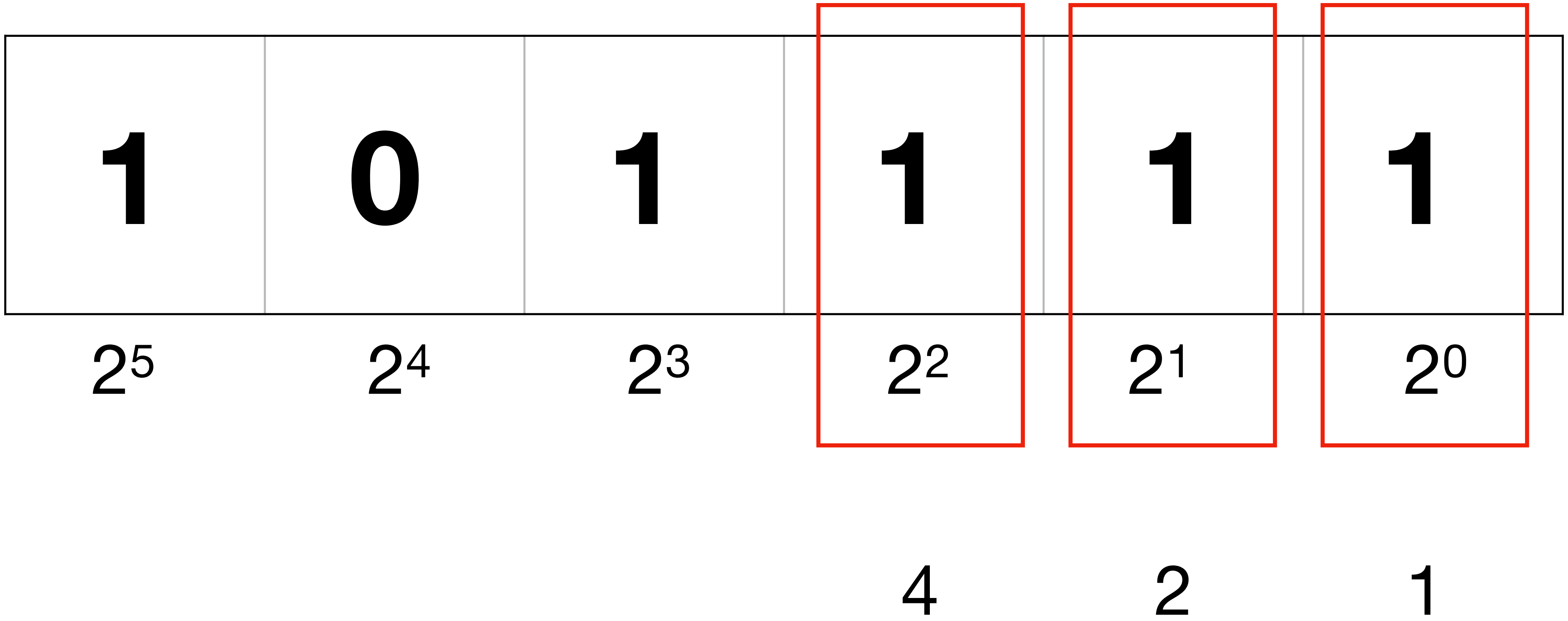

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2^5	2^4	2^3	2^2	2^1	2^0
			4	2	1

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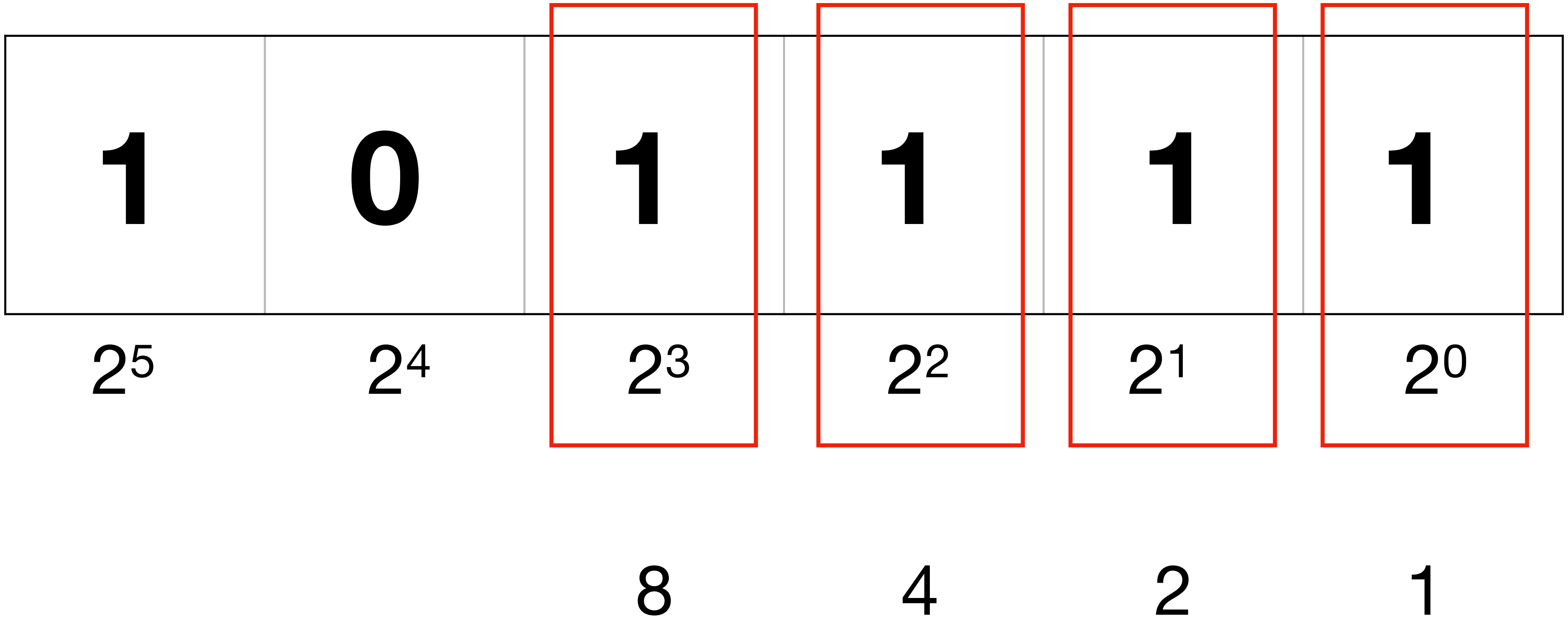

1	0	1	1	1	1
2^5	2^4	2^3	2^2	2^1	2^0
		8	4	2	1

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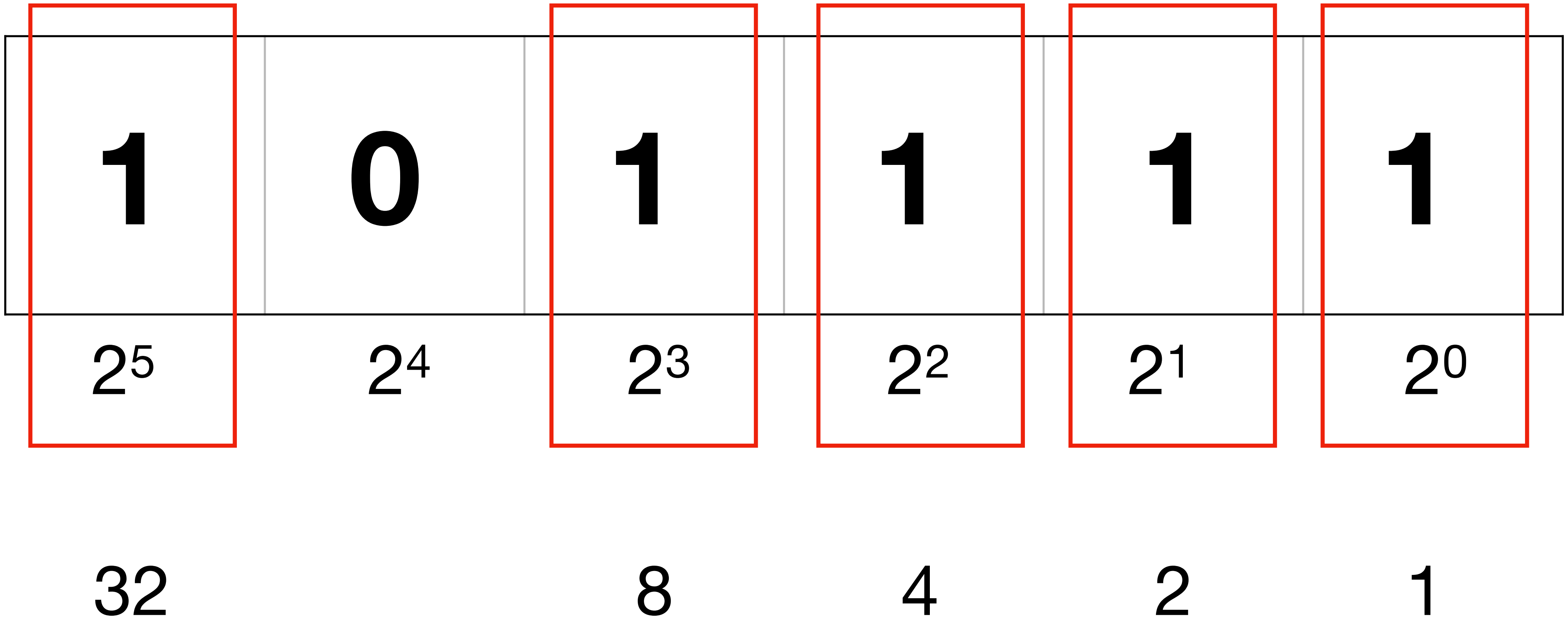
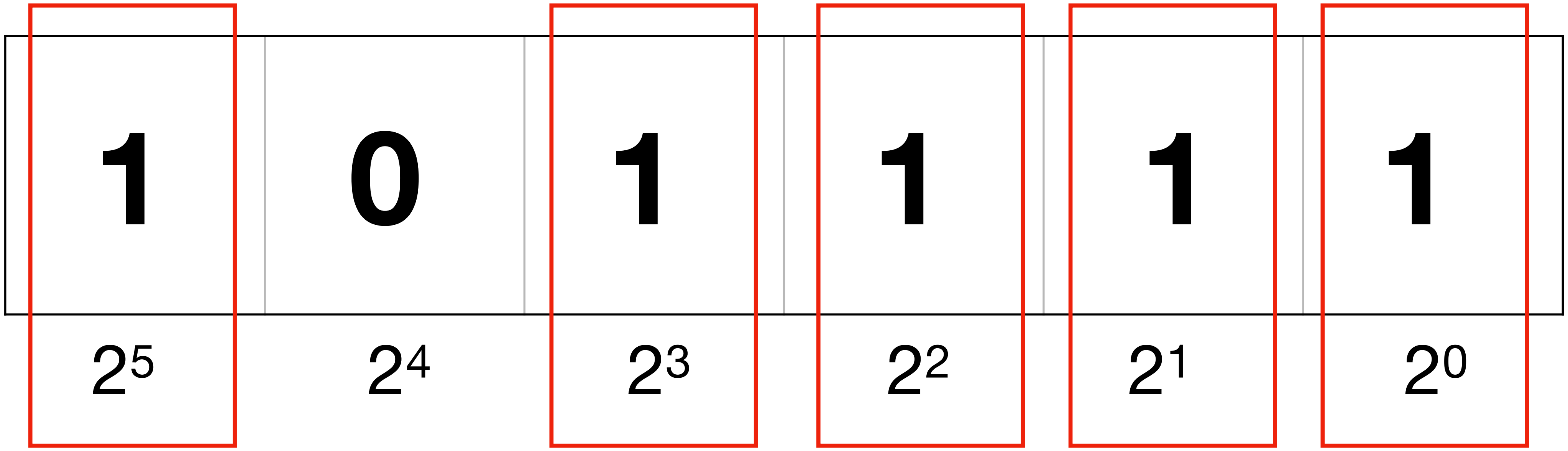
Binary to Decimal



1	0	1	1	1	1
2^5	2^4	2^3	2^2	2^1	2^0
32		8	4	2	1

- In decimal, each digit represents a multiple of a power of **2**

Binary to Decimal



1	0	1	1	1	1
2^5	2^4	2^3	2^2	2^1	2^0

32 + 8 + 4 + 2 + 1

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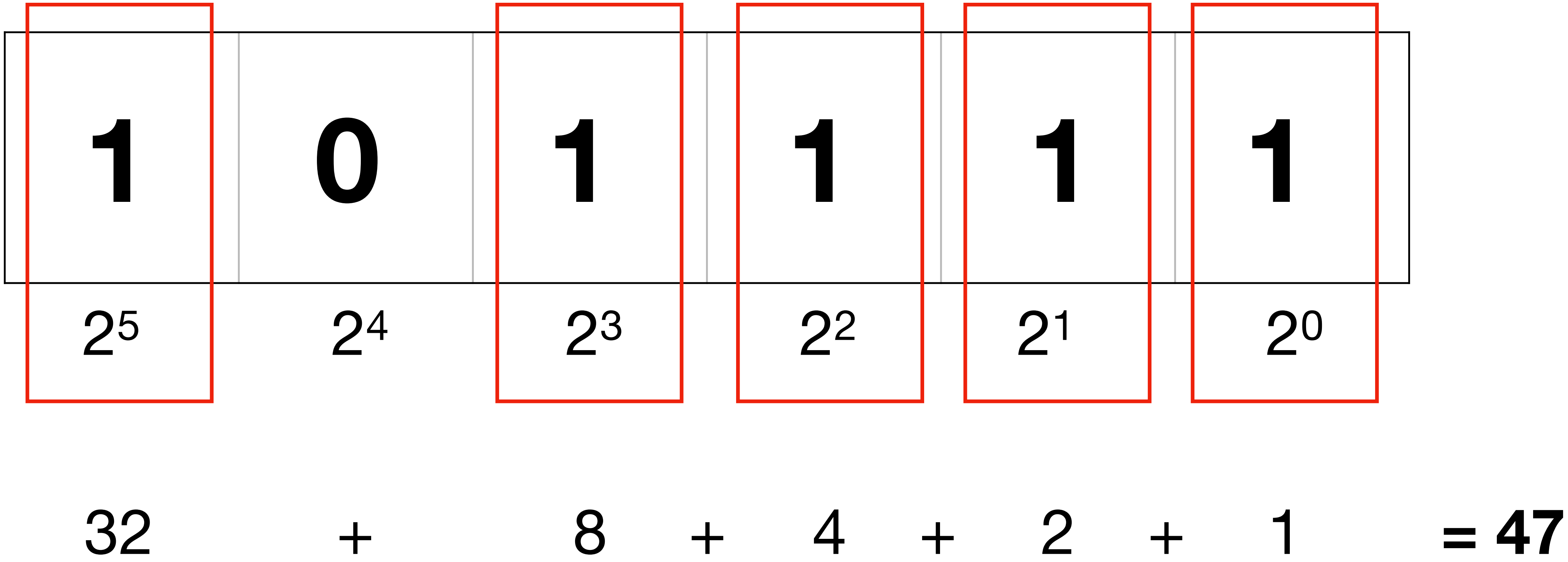
Binary to Decimal



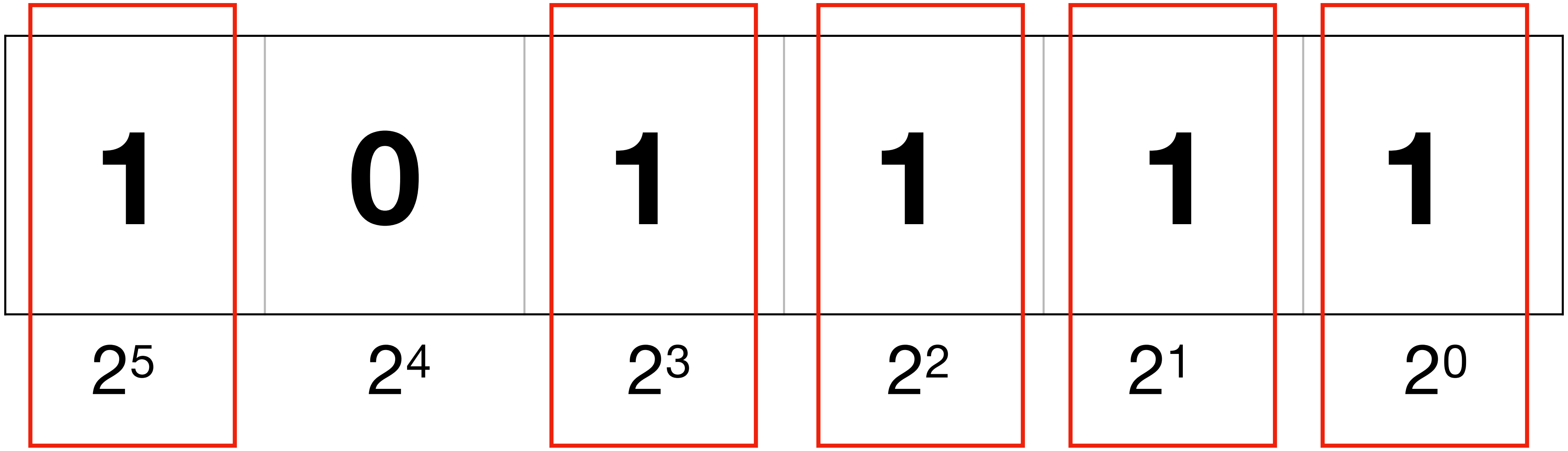
1 0 1 1 1 1

2^5 2^4 2^3 2^2 2^1 2^0

32 + 8 + 4 + 2 + 1 **= 47**

- In decimal, each digit represents a multiple of a power of **2**

Binary to Decimal



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2^5	2^4	2^3	2^2	2^1	2^0

32 + 8 + 4 + 2 + 1 **= 47**

- In decimal, each digit represents a multiple of a power of **2**
- 10111 in binary is 47 in decimal.

Decimal to Binary

Converting decimal to binary goes the other way.

Problem: write 23 as a sum of powers of 2

Decimal to Binary

Converting decimal to binary goes the other way.

Problem: write 23 as a sum of powers of 2

$$\begin{aligned} 23 = \; & ? * 2^4 \; (16) \\ + \; & ? * 2^3 \; (8) \\ + \; & ? * 2^2 \; (4) \\ + \; & ? * 2^1 \; (2) \\ + \; & ? * 2^0 \; (1) \end{aligned}$$

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\end{array}
$$

The binary representation of the decimal number 23 is:

A. 10111
B. 11101
C. 01100
D. 11110

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$$\begin{array}{lllll}
23 = & ? * 2^4 & (16) & 1 & (23-16 = 7\text{ left}) \\
+ & ? * 2^3 & (8) & & \\
+ & ? * 2^2 & (4) & & \\
+ & ? * 2^1 & (2) & & \\
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23 =	? * 2^4 (16)	1	(23-16 = 7 left)
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+	$? * 2^0$	(1)		

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B. 11101
C. 01100
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That’s how `int` works.

- What about `str` and `float`?

How do you store strings?

A `str` is a sequence of letters (or characters).

1. Agree by convention on a number that represents each character.
2. Convert that number to binary.
3. Store a sequence of those numbers to form a string.

How do you store strings?

Various conventions exist:
ASCII, Unicode

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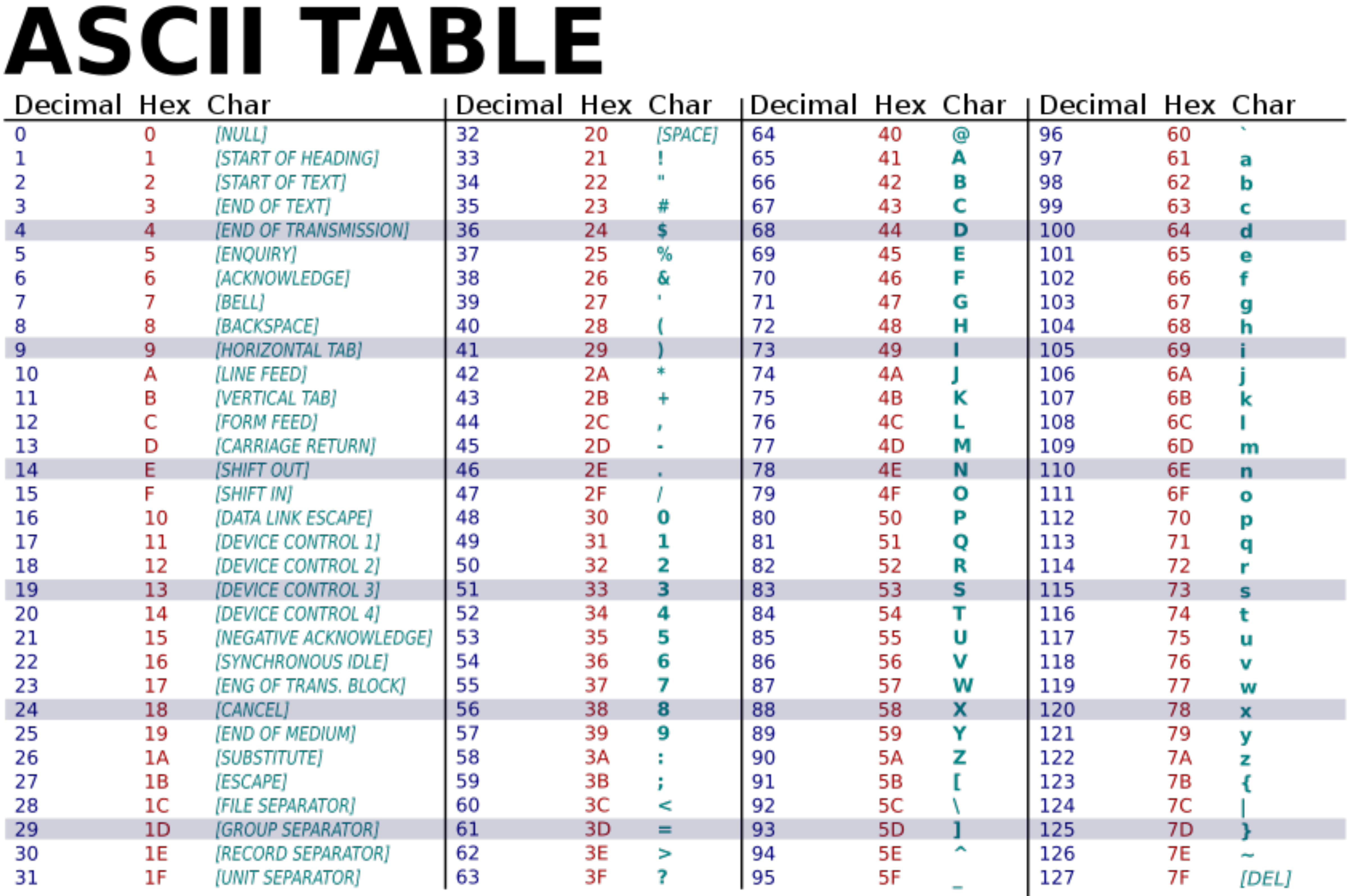
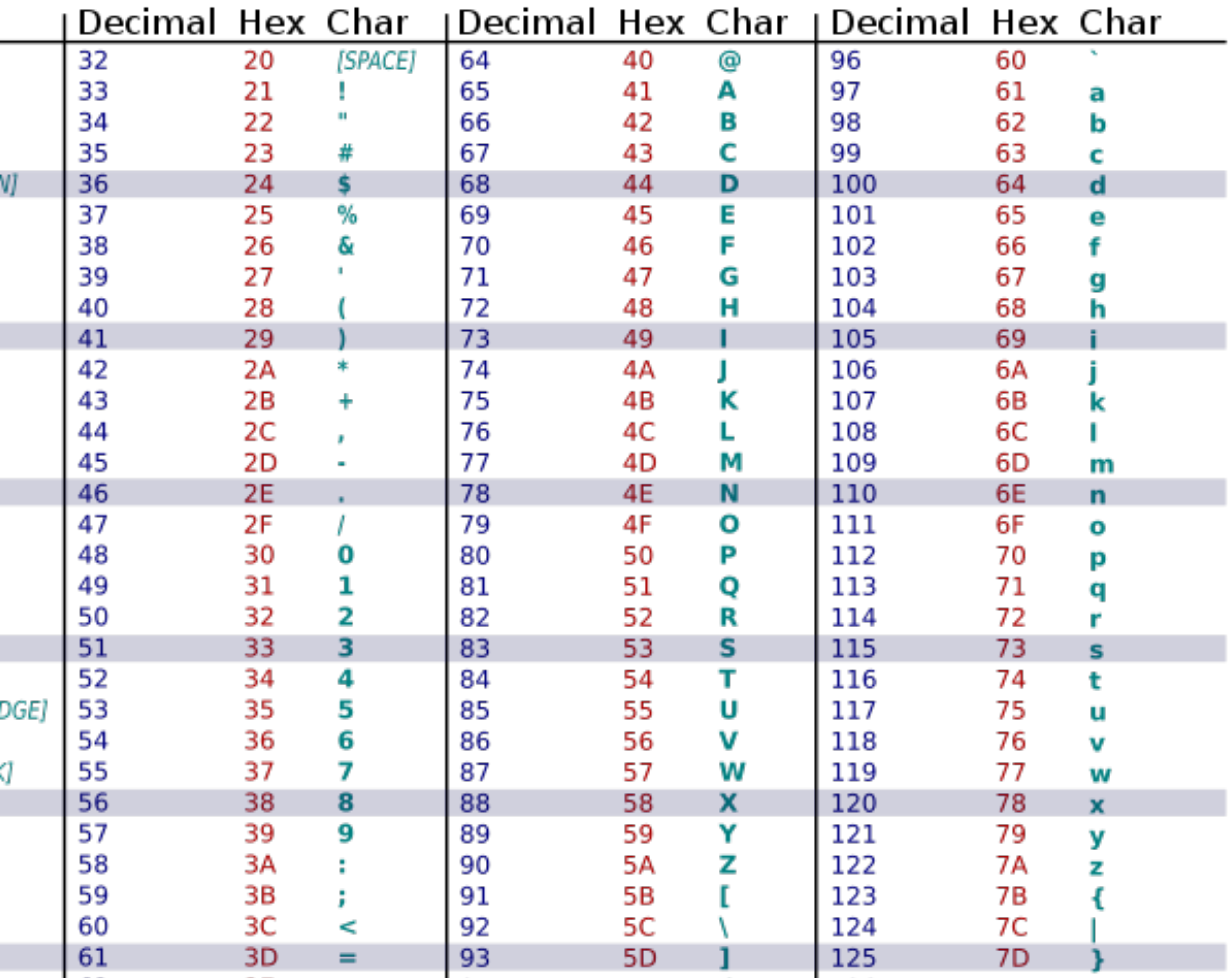


ASCII TABLE

Decimal	Hex	Char	Decimal	Hex	Char	Decimal	Hex	Char	Decimal	Hex	Char
0	0	[NULL]	32	20	[SPACE]	64	40	@	96	60	`
1	1	[START OF HEADING]	33	21	!	65	41	A	97	61	a
2	2	[START OF TEXT]	34	22	"	66	42	B	98	62	b
3	3	[END OF TEXT]	35	23	#	67	43	C	99	63	c
4	4	[END OF TRANSMISSION]	36	24	$	68	44	D	100	64	d
5	5	[ENQUIRY]	37	25	%	69	45	E	101	65	e
6	6	[ACKNOWLEDGE]	38	26	&	70	46	F	102	66	f
7	7	[BELL]	39	27	'	71	47	G	103	67	g
8	8	[BACKSPACE]	40	28	(	72	48	H	104	68	h
9	9	[HORIZONTAL TAB]	41	29	)	73	49	I	105	69	i
10	A	[LINE FEED]	42	2A	*	74	4A	J	106	6A	j
11	B	[VERTICAL TAB]	43	2B	+	75	4B	K	107	6B	k
12	C	[FORM FEED]	44	2C	,	76	4C	L	108	6C	l
13	D	[CARRIAGE RETURN]	45	2D	-	77	4D	M	109	6D	m
14	E	[SHIFT OUT]	46	2E	.	78	4E	N	110	6E	n
15	F	[SHIFT IN]	47	2F	/	79	4F	O	111	6F	o
16	10	[DATA LINK ESCAPE]	48	30	0	80	50	P	112	70	p
17	11	[DEVICE CONTROL 1]	49	31	1	81	51	Q	113	71	q
18	12	[DEVICE CONTROL 2]	50	32	2	82	52	R	114	72	r
19	13	[DEVICE CONTROL 3]	51	33	3	83	53	S	115	73	s
20	14	[DEVICE CONTROL 4]	52	34	4	84	54	T	116	74	t
21	15	[NEGATIVE ACKNOWLEDGE]	53	35	5	85	55	U	117	75	u
22	16	[SYNCHRONOUS IDLE]	54	36	6	86	56	V	118	76	v
23	17	[ENG OF TRANS. BLOCK]	55	37	7	87	57	W	119	77	w
24	18	[CANCEL]	56	38	8	88	58	X	120	78	x
25	19	[END OF MEDIUM]	57	39	9	89	59	Y	121	79	y
26	1A	[SUBSTITUTE]	58	3A	:	90	5A	Z	122	7A	z
27	1B	[ESCAPE]	59	3B	;	91	5B	[	123	7B	{
28	1C	[FILE SEPARATOR]	60	3C	<	92	5C	\	124	7C	|
29	1D	[GROUP SEPARATOR]	61	3D	=	93	5D	]	125	7D	}
30	1E	[RECORD SEPARATOR]	62	3E	>	94	5E	^	126	7E	~
31	1F	[UNIT SEPARATOR]	63	3F	?	95	5F	_	127	7F	[DEL]



	Decimal	Hex	Char	Decimal	Hex	Char	Decimal	Hex	Char
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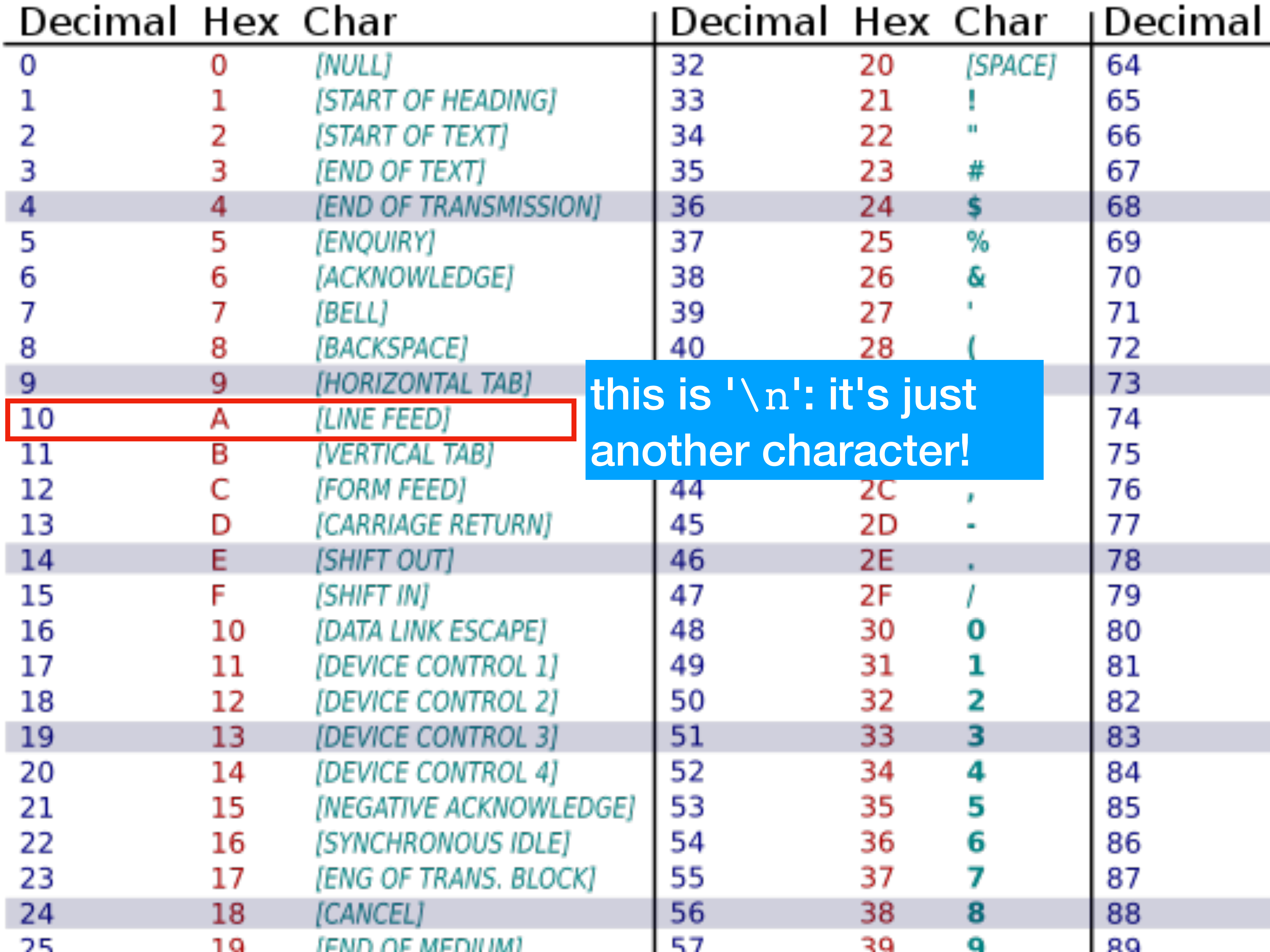
	33	21	!	65	41	A	97	61	a
	34	22	"	66	42	B	98	62	b
	35	23	#	67	43	C	99	63	c
N]	36	24	$	68	44	D	100	64	d
	37	25	%	69	45	E	101	65	e
	38	26	&	70	46	F	102	66	f
	39	27	'	71	47	G	103	67	g
	40	28	(	72	48	H	104	68	h
	41	29	)	73	49	I	105	69	i
	42	2A	*	74	4A	J	106	6A	j
	43	2B	+	75	4B	K	107	6B	k
	44	2C	,	76	4C	L	108	6C	l
	45	2D	-	77	4D	M	109	6D	m
	46	2E	.	78	4E	N	110	6E	n
	47	2F	/	79	4F	O	111	6F	o
	48	30	0	80	50	P	112	70	p
	49	31	1	81	51	Q	113	71	q
	50	32	2	82	52	R	114	72	r
	51	33	3	83	53	S	115	73	s
	52	34	4	84	54	T	116	74	t
DGE]	53	35	5	85	55	U	117	75	u
	54	36	6	86	56	V	118	76	v
K]	55	37	7	87	57	W	119	77	w
	56	38	8	88	58	X	120	78	x
	57	39	9	89	59	Y	121	79	y
	58	3A	:	90	5A	Z	122	7A	z
	59	3B	;	91	5B	[	123	7B	{
	60	3C	<	92	5C	\	124	7C	|
	61	3D	=	93	5D	]	125	7D	}



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2	2	[START OF TEXT]	34	22	"	66
3	3	[END OF TEXT]	35	23	#	67
4	4	[END OF TRANSMISSION]	36	24	$	68
5	5	[ENQUIRY]	37	25	%	69
6	6	[ACKNOWLEDGE]	38	26	&	70
7	7	[BELL]	39	27	'	71
8	8	[BACKSPACE]	40	28	(	72
9	9	[HORIZONTAL TAB]				73
10	A	[LINE FEED]				74
11	B	[VERTICAL TAB]				75
12	C	[FORM FEED]	44	2C	,	76
13	D	[CARRIAGE RETURN]	45	2D	-	77
14	E	[SHIFT OUT]	46	2E	.	78
15	F	[SHIFT IN]	47	2F	/	79
16	10	[DATA LINK ESCAPE]	48	30	0	80
17	11	[DEVICE CONTROL 1]	49	31	1	81
18	12	[DEVICE CONTROL 2]	50	32	2	82
19	13	[DEVICE CONTROL 3]	51	33	3	83
20	14	[DEVICE CONTROL 4]	52	34	4	84
21	15	[NEGATIVE ACKNOWLEDGE]	53	35	5	85
22	16	[SYNCHRONOUS IDLE]	54	36	6	86
23	17	[ENG OF TRANS. BLOCK]	55	37	7	87
24	18	[CANCEL]	56	38	8	88
25	19	[END OF MEDIUM]	57	39	9	89

this is `'\n'`: it's just another character!

That’s how `str` works.

- What about `float`?
- It’s harder to write 4.3752 as a sum of powers of two.

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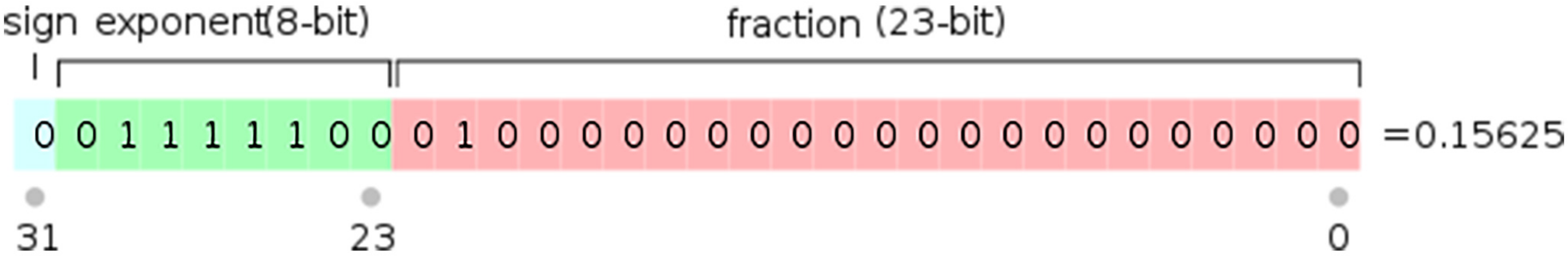

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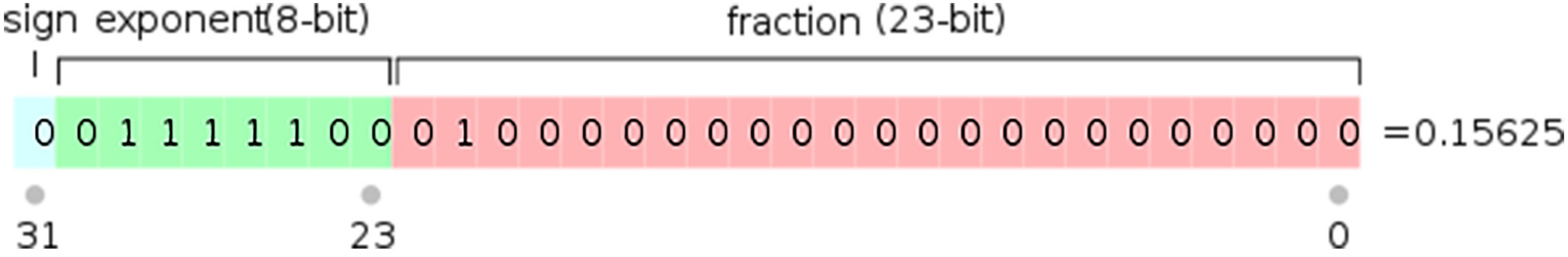

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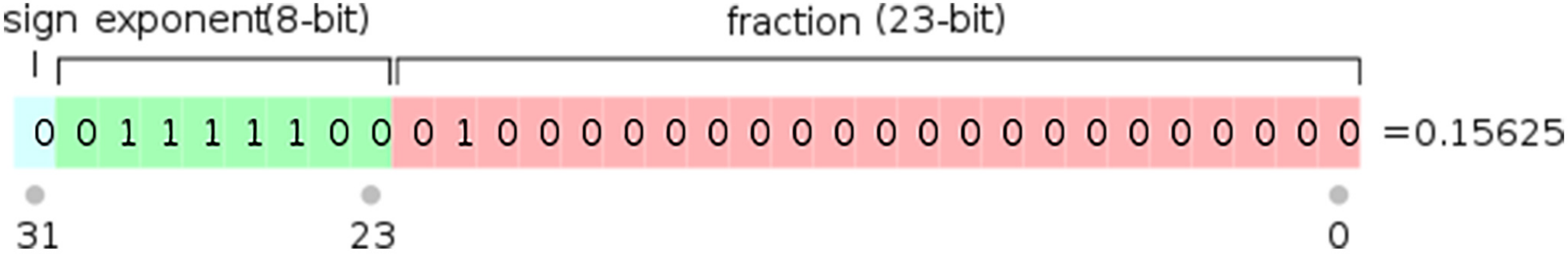

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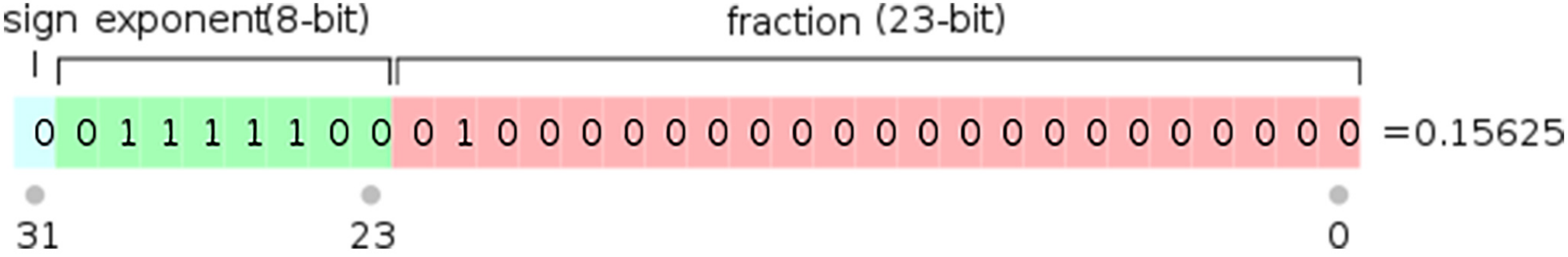

- Base and exponent are represented as base-2 integers, so the precision is finite: not all numbers can be represented!

Exercises

- Convert 1010101 to decimal.

- Convert 1023 to binary.

Next week

Making decisions:

`if` statements and boolean logic.