香港中文大學（深圳）
The Chinese University of Hong Kong, Shenzhen

Introduction to Computer Science: Programming Methodology

Lecture 1 Introduction

Tongxin Li

School of Data Science

Who I am (Tongxin Li)

- **Background**
  - Education: CUHK, Caltech
  - Working Experience:
    1. Amazon Web Services (2020, 2021), Applied Scientist Intern
    2. Assistant Professor (2022-present): SDS, CUHK-SZ

- **Contact**
  - Email: litongxin@cuhk.edu.cn

- **Research**
  - **General areas**: Machine learning, Power Systems
  - **Topics**: control & optimization, online algorithms, reinforcement learning

About this course

- This course is a required course for all SDS students.

- Need to sync between other 5 sessions (*meaning: I'd not customize/optimize many course materials that I really wish to*)

Learning Objectives

- This course introduces the basics of computer programming using Python

- Students will learn the basic elements of modern computer systems, key programming concepts, problem solving and basic algorithm design

A Message for Freshmen:

- University courses are very different from what you might have been familiar with in your high schools.
  - Languages
  - Assignments
  - Exams

- In your future university life, there are no more 班主任 (head teachers)
  - No one is watching you to finish the assignments
  - It is the right time to start being mature/independent
  - Make best use of tutorials (starting next week)
  - Check your e-mails often (say, once per day)
  - Assignments and important course announcements will be sent out via emails

Key Topics

- Introduction to modern computers
- Preliminary knowledge for computer programming
- Basic introduction to Python language
- Data types and operators in Python language
- Input/output
- Flow control and loop
- Function
- List
- Basic data structure
- Introduction to algorithm design
- Introduction to object oriented programming

Assessment

Assignments × 4	10% × 4
Mid-term quiz	20%
Final exam	40%

Course Materials

- All lecture notes and sample code used in classes will be provided to students via Blackboard (bb.cuhk.edu cn). They can also be found in the course web.

- Recommended readings
  - Online resources: https://www.python.org/doc/
  - Learning Python, 5th Edition, by Mark Lutz, Publisher: O'Reilly media

Course Components

Activity	Hours/week
Lecture	3 * 14
Tutorial	1 * 14

Indicative Teaching Plans

Week	Content/ topic/ activity
1	Introduction to modern computers; Preliminary knowledge for computer programming;
2	Basic introduction to Python language; Data types and operators in Python language; Input/output;
3	Flow control and loop;
4	Function;
5	List;
6	Introduction to object oriented programming, part I
7	Review for mid-term quiz;
8	Introduction to object oriented programming, part II
9	Data Structure, part I;
10	Data Structure, part II;
11	Introduction to algorithm design, part I;
12	Introduction to algorithm design, part II;
13	Introduction to algorithm design, part III;
14	Review for final exam;

Personal Web: *www.tongxin.me*

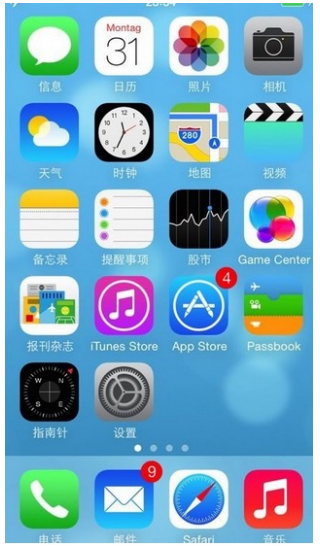
Course Web: *www.tongxin.me/CSC1001/*

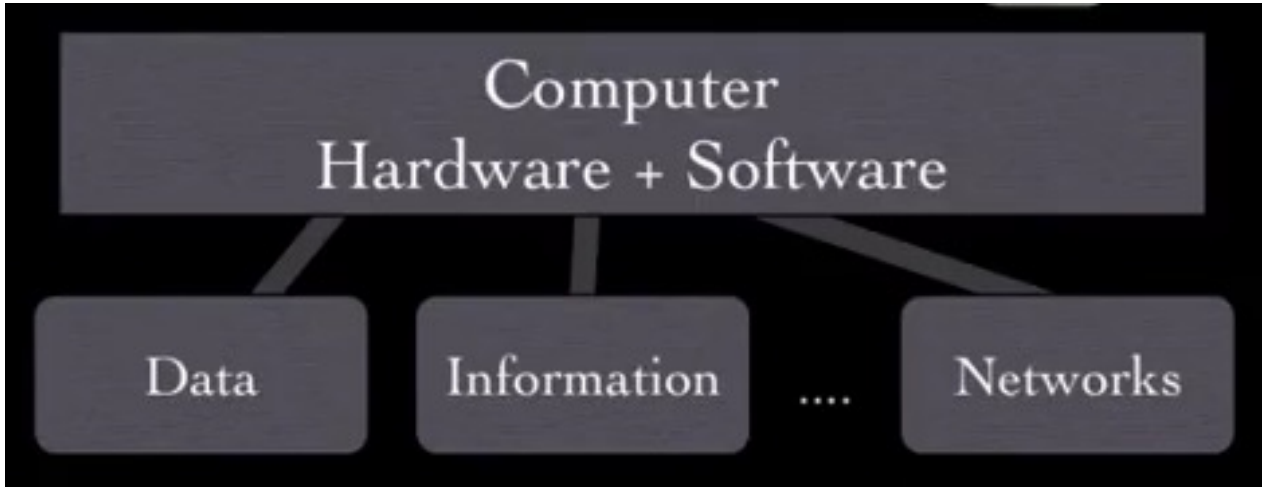
Why learn programming?

- Computer is built to help people solve problems
- Computer does not understand what we say
- We need to communicate with computers using their languages (computer programming language)
- Assembly, C, C++, Java and Python

User

Interface





Programmer

- Programmers solve problems like data, information, networks on behalf of users

Programmer

- Professional programmer writes computer programs and develops software
- A junior programmer gets a salary of 10-30k RMB in an INTERNET company like Tencent
- A programmer can earn up to 500k – 1m USD in Google!!
- Software and INTERNET are huge industries.

Why be a programmer?

- Even if you are NOT in the IT industry, programming is pervasive in your life,
  - Electrical/electronic engineer – control program
  - Economist – mathematical modeling
  - Salesman – analyzing sales data
  - …

What is Code? Software? Program?

- A sequence of instructions
- Computers take the instructions and execute them
- It is a little piece of our intelligence in the computer
- Intelligence which is re-usable

Computers are good at following instructions

- Humans can easily make mistakes when following a set of instructions

- On the contrary, computers (usually) won’t make mistakes, regardless of they are given 10 or 10 billion instructions !!

Computers

Are they computers ?

calculator

router

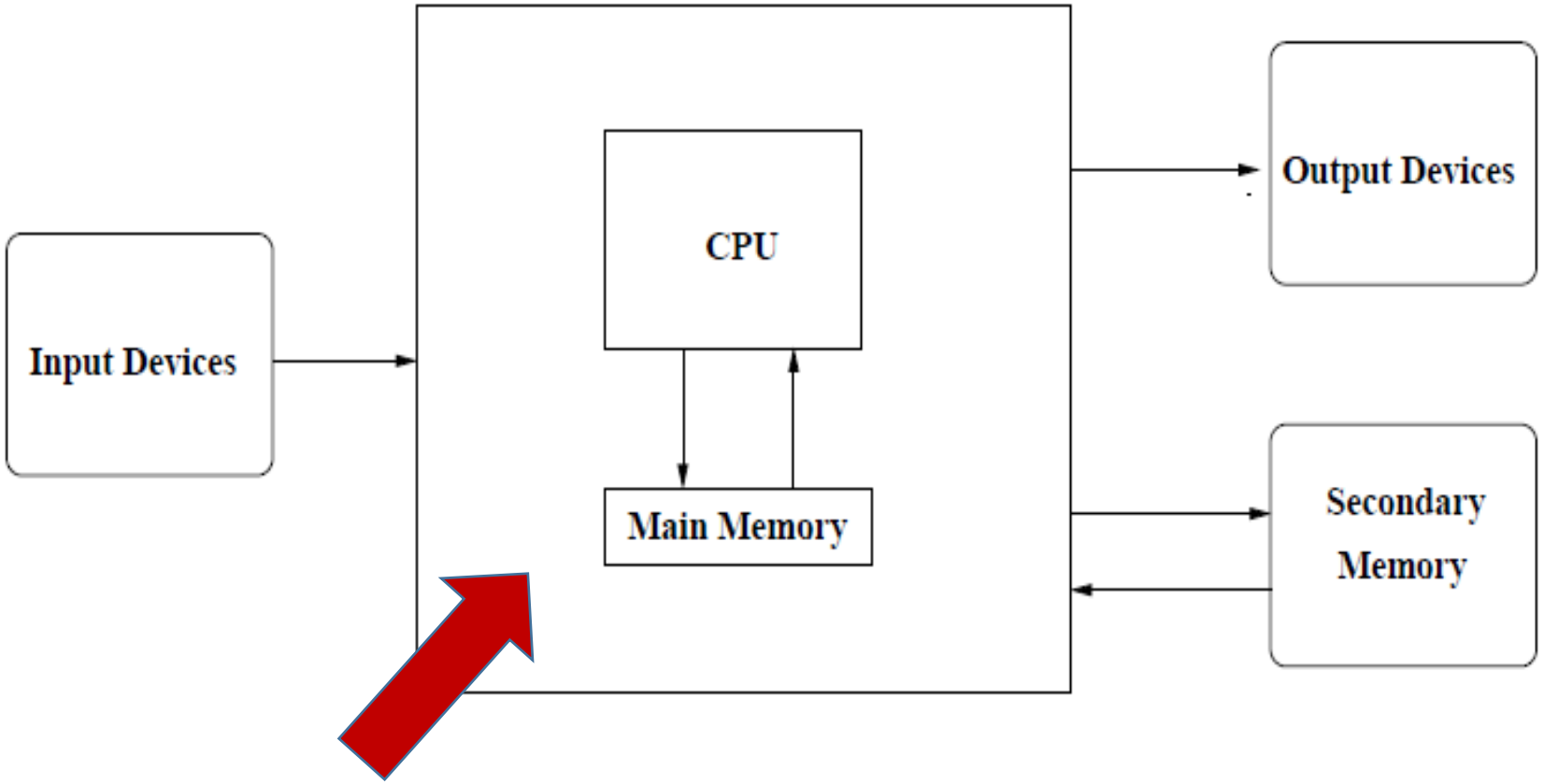
robot

smartwatch

Smart TV

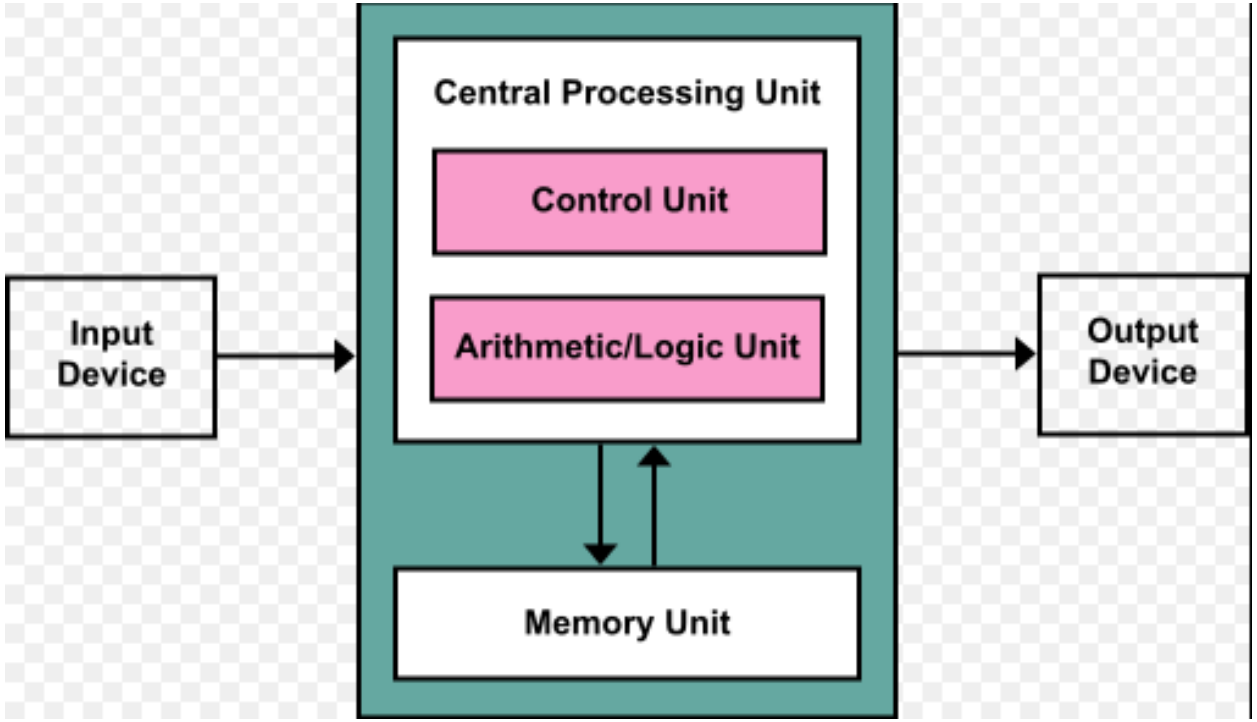
Smart glasses

Computer Hardware

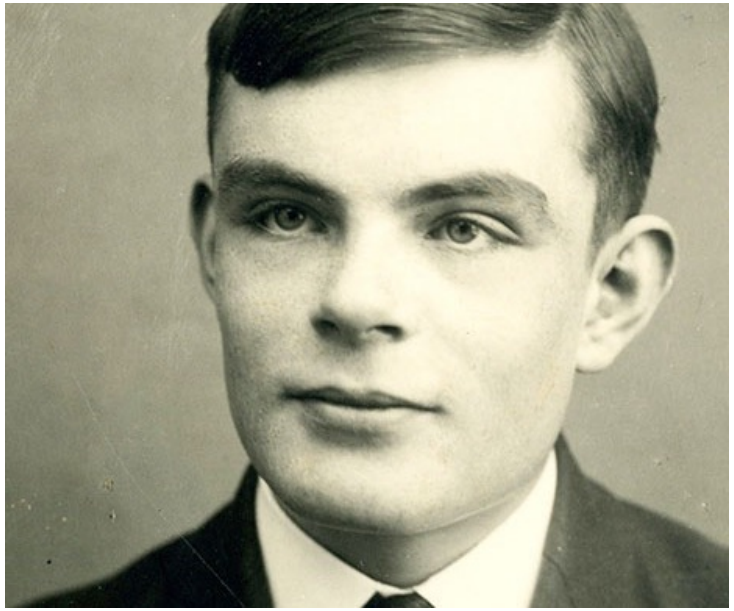


Von Neumann Architecture

- The modern computer architecture is proposed by John Von Neumann



The theoretical foundation of computer science

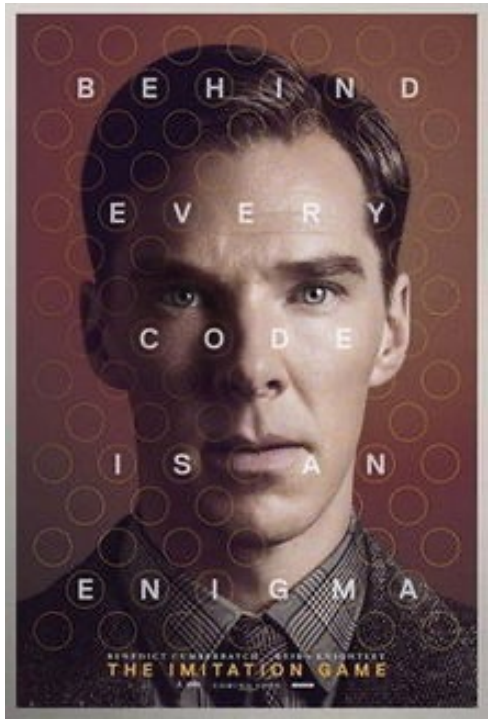


- The theoretical foundation of computer science are built by Alan Turing

- Father of theoretical computer science and artificial intelligence

- Computability theory and Turing test

A movie about Turing



模仿遊戲

The Imitation Game

Also another similar movie about John Nash： A beautiful mind (美丽心灵)

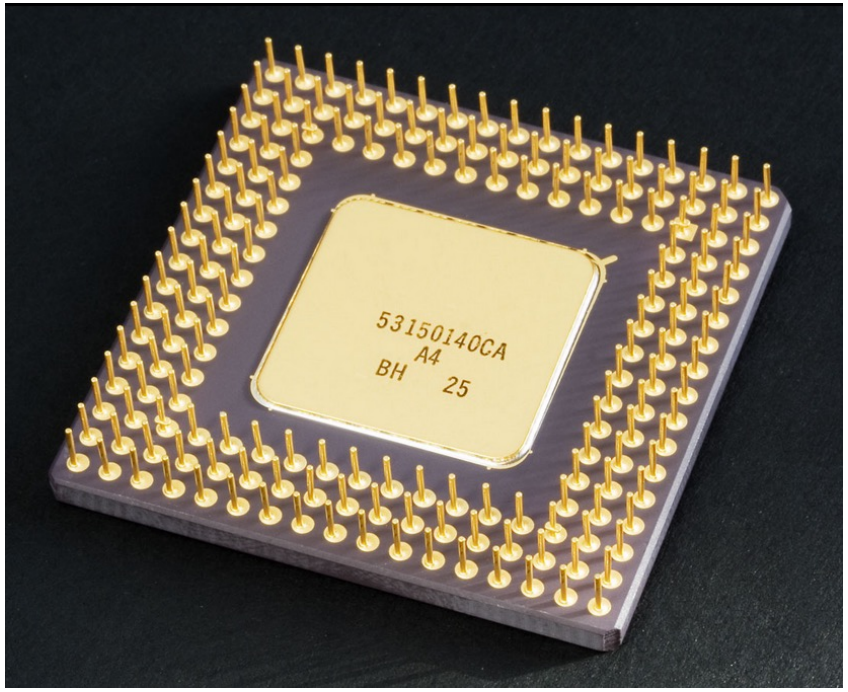
Key components in a computer

- Central processing unit (CPU): execute your program. Similar to human brain, very fast but not that smart
- Input device: take inputs from users or other devices
- Output device: output information to users or other devices
- Main memory: store data, fast and temporary storage
- Secondary memory: slower but large size, permanent storage

Central Processing Unit

- A processor contains two units, a control unit (CU) and an arithmetic/logic unit (ALU)
- CU is used to fetch commands from the memory
- ALU contains the electric circuits which can execute commands

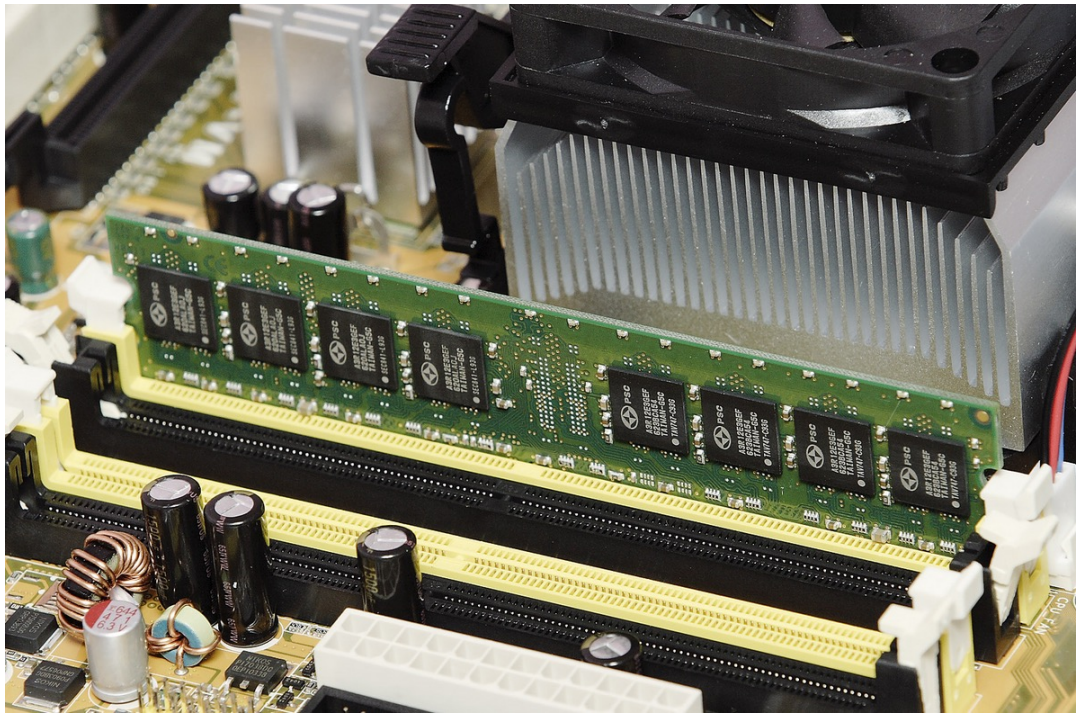
Central Processing Unit



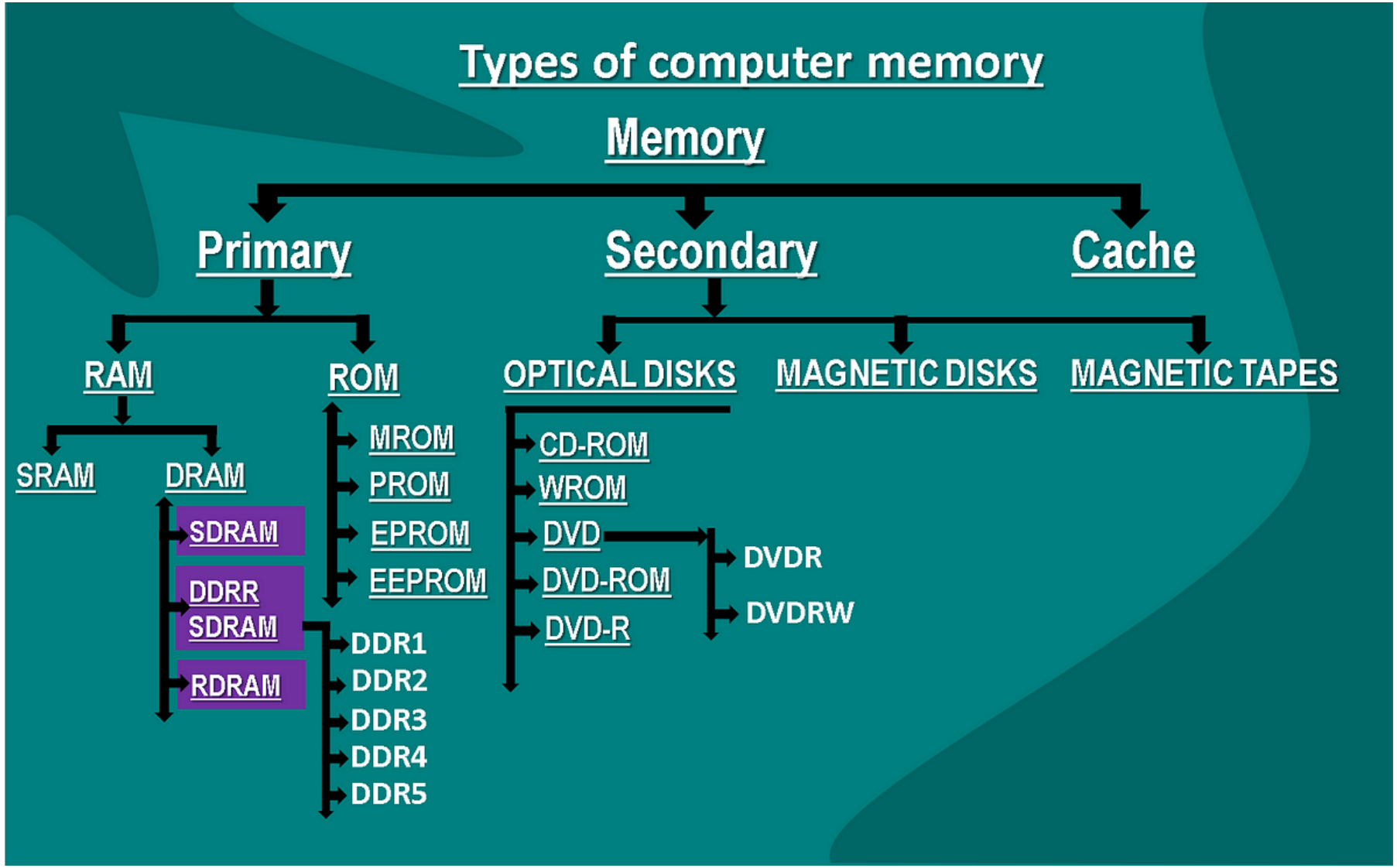
- Processor manufacturer: Intel, AMD, ARM, etc

Memory/Storage

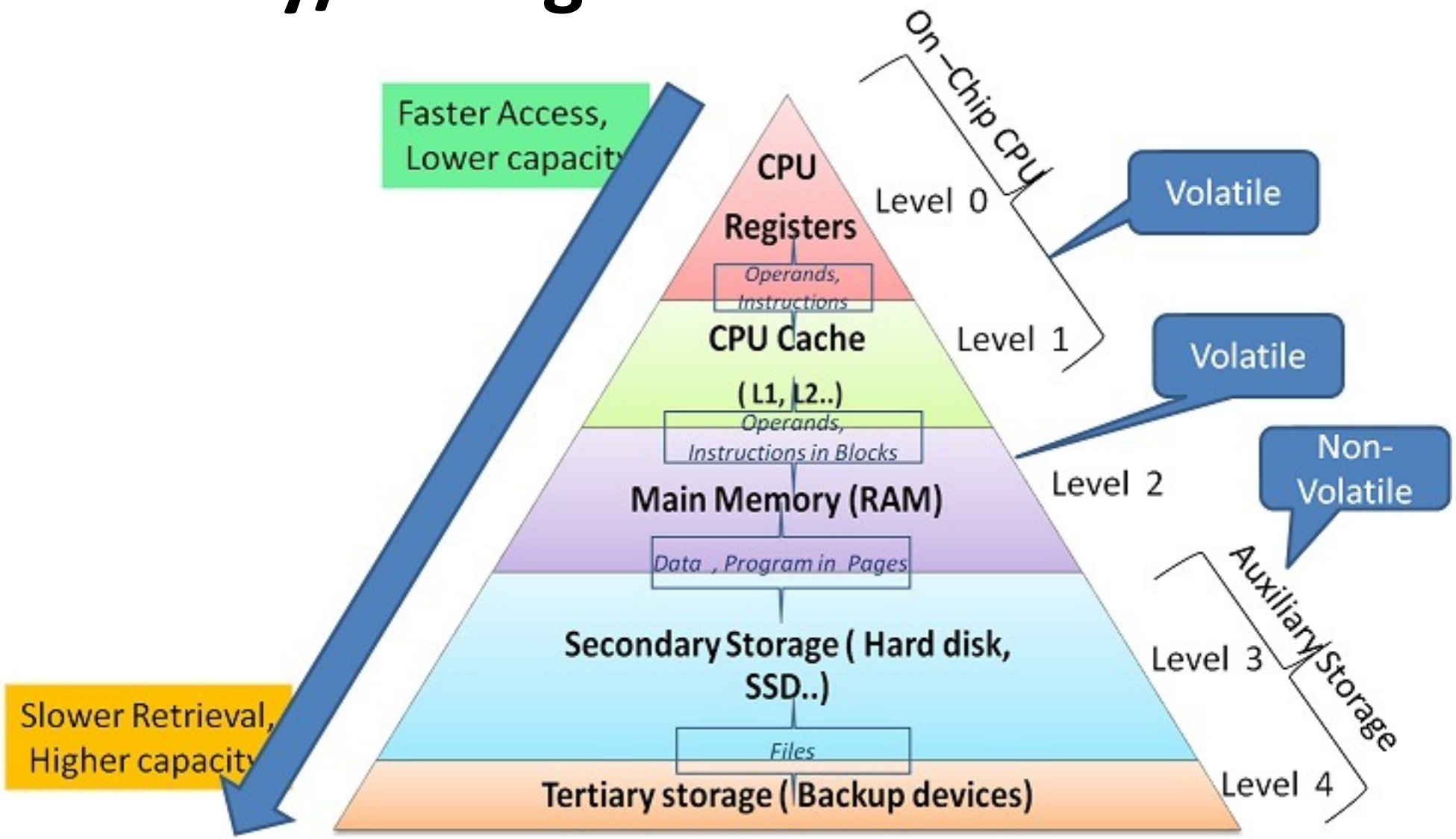
- High speed cache
- ROM
- RAM
- Flash
- Hard disk



Memory/Storage



Memory/Storage



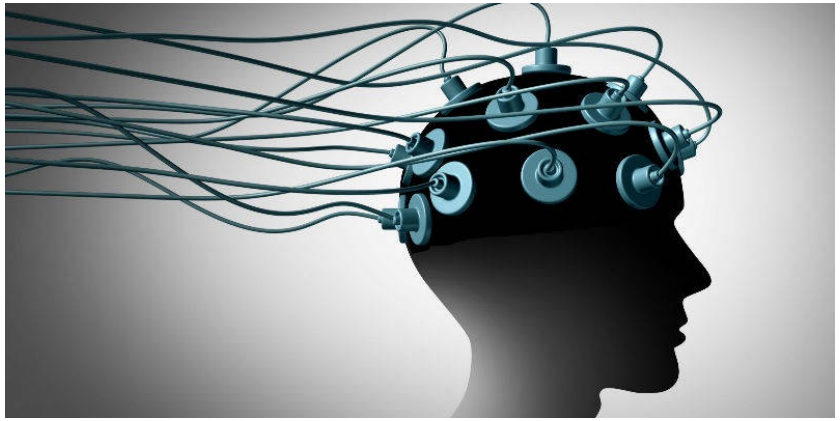
Input/output devices

- Input devices: mouse, keyboard, panel, touch screen, audio input, mind reading, etc

- Output devices: screen, audio output, etc

Any other input devices?

Any other input devices?



Any other onput devices?

Any other output devices?

VR

Holographic projection

How the hard disk works

http://v.youku.com/v_show/id_XNjA4NzMxNDk2.html?from=s1.8-1-1.2

What can a computer actually understand?

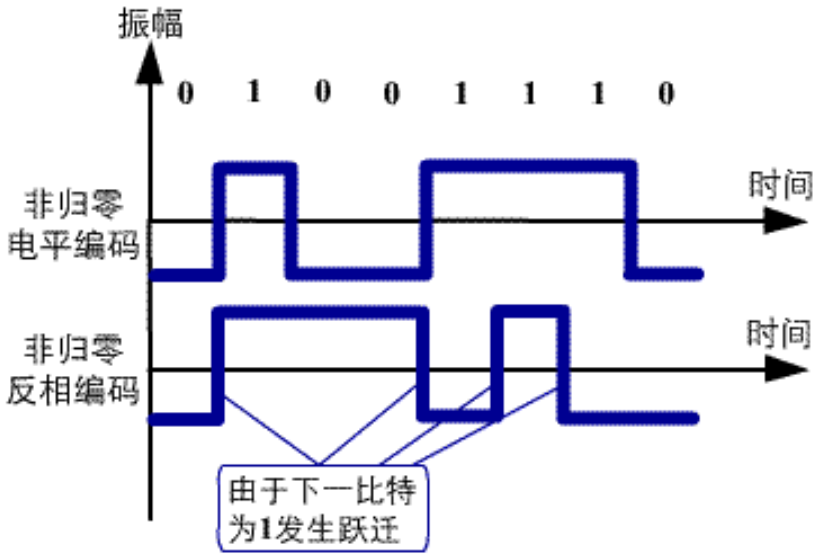
- The computers used nowadays can understand only binary number (i.e. 0 and 1)
- Computers use voltage levels to represent 0 and 1
- NRZL and NRZI coding
- The instructions expressed in binary code is called machine language

0 0 0 1 numerical value 2^0

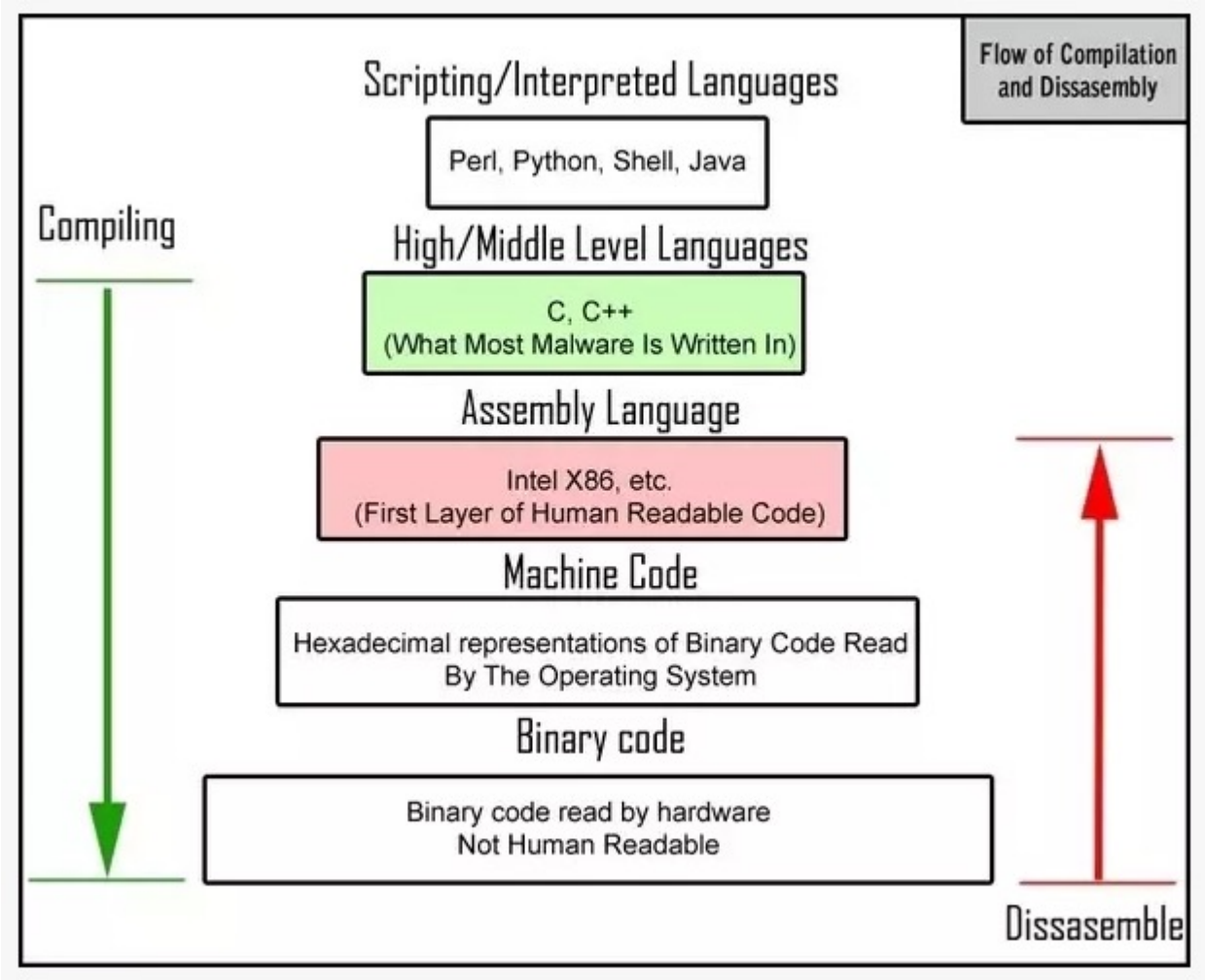
0 0 1 0 numerical value 2^1

0 1 0 0 numerical value 2^2

1 0 0 0 numerical value 2^3



Programing Language



https://www.quora.com/I-am-an-11th-grader-I-find-it-quite-difficult-to-write-C++-code-especially-when-the-only-way-to-practice-is-to-solve-maths-problems-Should-I-keep-learning-C++-or-drop-it-for-C

Review of last lecture

- **Von Neumann Architecture**
- **CPU and memory**
- **Input devices and output devices**

Low level language – Assembly Language

- An assembly language is a low-level programming language, in which there is a very strong (generally one-to-one) correspondence between the language and machine code instructions.

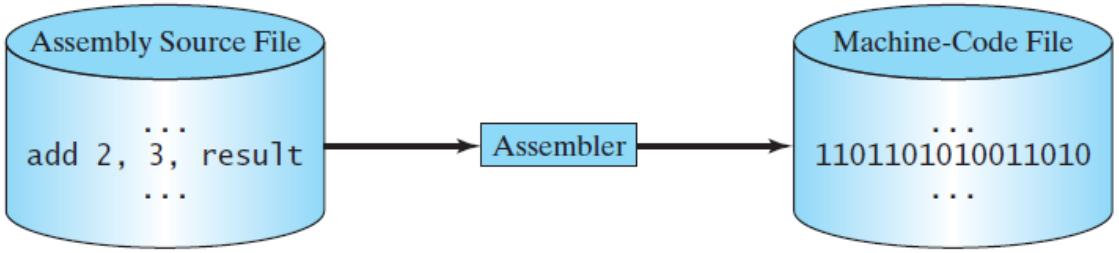
- Each assembly language is specific to a particular computer architecture

- Assembly language is converted into executable machine code by a utility program referred to as an assembler

```
                        ****************************************
                        * FUNCTION: INHEX - INPUT HEX DIGIT
                        * INPUT: none
                        * OUTPUT: Digit in acc A
                        * CALLS: INCH
                        * DESTROYS: acc A
                        * Returns to monitor if not HEX input

C01E 8D F0      INHEX   BSR     INCH        GET A CHAR
C020 81 30              CMP A   #'0         ZERO
C022 2B 11              BMI     HEXERR      NOT HEX
C024 81 39              CMP A   #'9         NINE
C026 2F 0A              BLE     HEXRTS      GOOD HEX
C028 81 41              CMP A   #'A
C02A 2B 09              BMI     HEXERR      NOT HEX
C02C 81 46              CMP A   #'F
C02E 2E 05              BGT     HEXERR
C030 80 07              SUB A   #7          FIX A-F
C032 84 0F      HEXRTS  AND A   #$0F        CONVERT ASCII TO DIGIT
C034 39                 RTS

C035 7E C0 AF   HEXERR  JMP     CTRL        RETURN TO CONTROL LOOP
```



C Language (1969 - 1973)

- C was developed by Dennis Ritchie between 1969 and 1973 at AT&T Bell Labs
- One of the early high-level programming language
- Somewhere between assembly and other high level languages
- Provide powerful functionalities for low level memory manipulations
- Have the highest efficiency within high level languages
- Very widely used in low level applications, such as operating systems, embedded programming, super computers, etc

C++ Language (1979)

- C++ was developed by Bjarne Stroustrup at Bell Labs since 1979
- Inherent major features of C
- An object oriented programming language, supporting code reuse
- High efficiency and powerful in low level memory manipulation
- Still could be platform dependent

Java Language (1995)

- Java was developed by James Gosling at Sun Microsystems (which has since been acquired by Oracle Corporation) and released in 1995
- A new generation of general-purpose object oriented programming language
- Platform independent, “write once, run anywhere” (WORA)
- Java is one of the most popular programming languages currently in use

Popular Java Software?

Popular Java Software?

Most games use C++

Python (1991)

- Developed by Guido van Rossum in 1989, and formally released in 1991
- An open source, object oriented programming language
- Powerful libraries
- Powerful interfaces to integrate other programming languages (C/C++, Java, and many other languages)
- In AI research, people mainly use Python.

Popular Python Software?

Popular Python Software?

Do they use Python 100%?

Popular Python Software?

Python (1991)

- **Python is evolving …**

- The best way to keep track of the updates is to learn by really using Python (not by taking lectures)

From https://www.python.org/doc/versions/

Python Documentation by Version

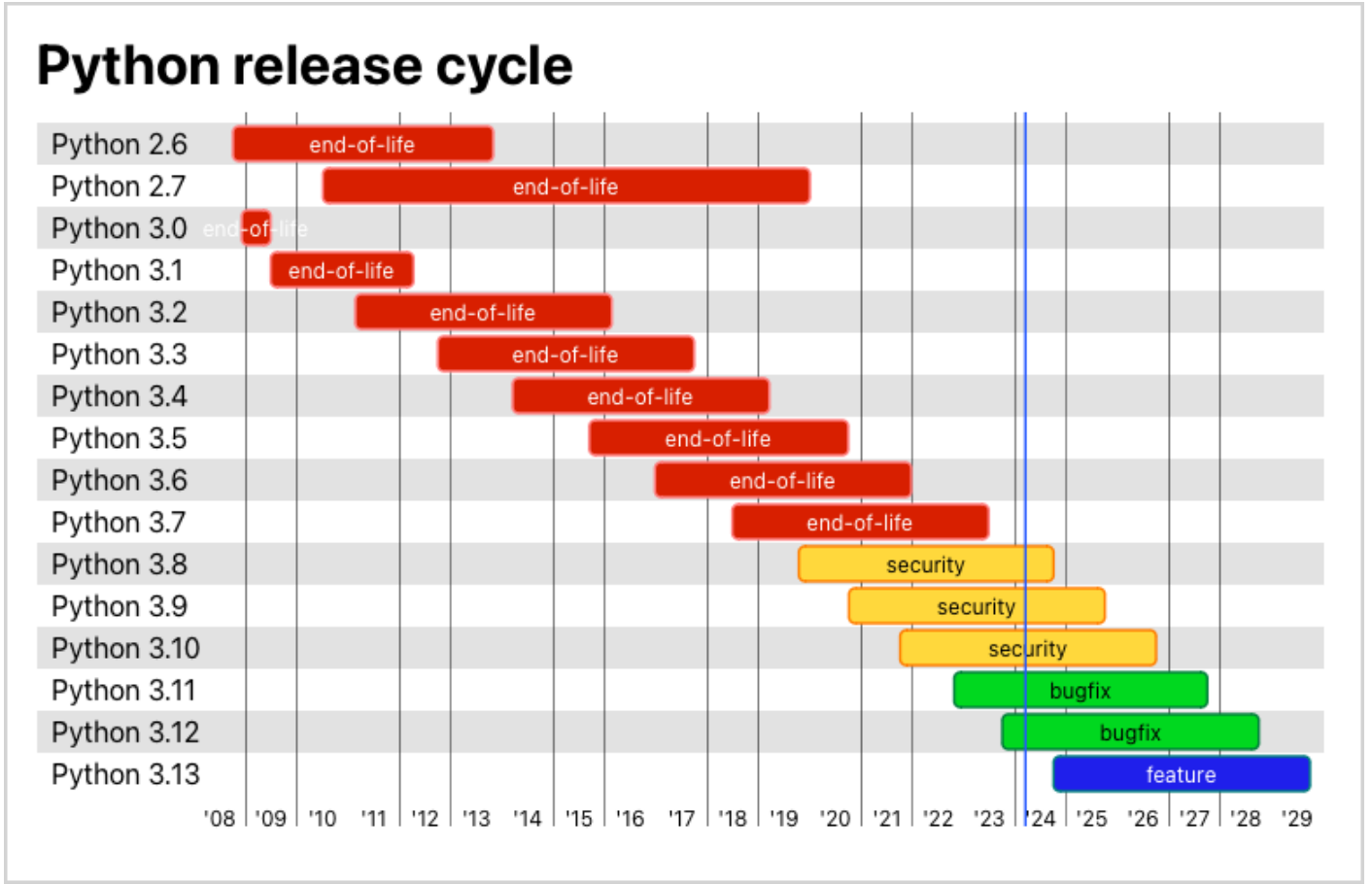
Some previous versions of the documentation remain available online. Use the list below to select a version to view.

For unreleased (in development) documentation, see In Development Versions.

- Python 3.12.5, documentation released on 6 August 2024.
- Python 3.12.4, documentation released on 6 June 2024.
- Python 3.12.3, documentation released on 9 April 2024.
- Python 3.12.2, documentation released on 6 February 2024.
- Python 3.12.1, documentation released on 8 December 2023.
- Python 3.12.0, documentation released on 2 October 2023.
- Python 3.11.9, documentation released on 2 April 2024.
- Python 3.11.8, documentation released on 6 February 2024.
- Python 3.11.7, documentation released on 4 December 2023.
- Python 3.11.6, documentation released on 2 October 2023.
- Python 3.11.5, documentation released on 24 August 2023.
- Python 3.11.4, documentation released on 6 June 2023.
- Python 3.11.3, documentation released on 5 April 2023.
- Python 3.11.2, documentation released on 8 February 2023.
- Python 3.11.1, documentation released on 6 December 2022.
- Python 3.11.0, documentation released on 24 October 2022.
- Python 3.10.14, documentation released on 19 March 2024.
- Python 3.10.13, documentation released on 24 August 2023.
- Python 3.10.12, documentation released on 6 June 2023.
- Python 3.10.11, documentation released on 5 April 2023.
- Python 3.10.10, documentation released on 8 February 2023.
- Python 3.10.9, documentation released on 6 December 2022.
- Python 3.10.8, documentation released on 8 October 2022.

Python (1991)

- **Python is evolving …**
- **The goal of this course:**
  - ~~Keep track of recent updates~~ ❌
  - Provide you a comprehensive knowledge base of programming via Python ✓
  - Our students have very diverse backgrounds …



Language efficiency v.s. development efficiency

- High level languages cannot be executed directly
- High level languages must be converted into low level languages first
- Lower level languages have higher language efficiency (they are faster to run on a computer)
- Higher level languages have higher development efficiency (it is easier to write programs in these languages)

Operating Systems

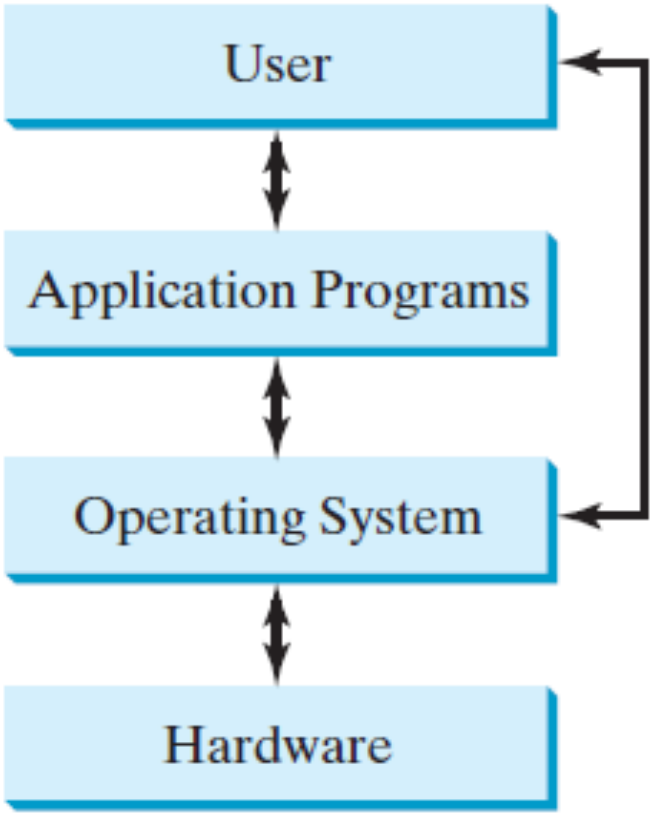
- The operating system (OS) is a low level program, which provides all basic services for managing and controlling a computer's activities

- Applications are programs which are built based upon an OS

- Main functions of an OS:

✓ Controlling and monitoring system activities
✓ Allocating and assigning system resources
✓ Scheduling operations

- Popular OS: Windows, Mac OS, Linux, iOS, Android…



- Break

Slogan for Python

Life is short, use Python

Data Representation and Conversion

- We use positional notation (进位记数法) to represent or encode numbers in a computer
- Data are stored essentially as binary numbers in a computer
- In practice, we usually represent data using either binary (二进制), decimal (十进制), octal (八进制) or hexadecimal (十六进制) number systems
- We may need to convert data between different number systems

The basic idea of positional notation

- Each positional number system contains two elements, a base (基数) and a set of symbols
- Using the decimal system (十进制系统) as an example, its base is 10, and the symbols are {0, 1, 2, 3, 4, 5, 6, 7, 8, 9}
- When a number “hits” 9, the next number will not be a different symbol, but a “1” followed by a “0” (逢十进一)

Decimal number system

- In the decimal number system, the base is 10, the symbols include 0, 1, 2, 3, 4, 5, 6, 7, 8, 9
- Every number can be decomposed into the sum of a series of numbers, each is represented by a positional value times a weight
- $N = a_n \times 10^n + a_{n-1} \times 10^{n-1} + a_{n-2} \times 10^{n-2} \ \ldots\ldots + a_0 \times 10^0 + a_{-1} \times 10^{-1} + a_{-2} \times 10^{-2} \ \ldots$
- a_n is the positional value (ranging from 0 to 9), while 10^n represents the weight

Binary number system

- In the binary system, the base is 2, we use only two symbols 0 and 1
- “10” is used when we hit 2 (逢二进一)
- $N = a_n \times 2^n + a_{n-1} \times 2^{n-1} + a_{n-2} \times 2^{n-2} \ \ldots\ldots + a_0 \times 2^0 + a_{-1} \times 2^{-1} + a_{-2} \times 2^{-2} \ldots$
- a_n is the positional value (ranging from 0 to 1), while 2^n represents the weight

Why use binary number?

- Easy to implement physically
- Simple calculation rules
- Easy to combine arithmetic and logic operations
- Against noise (for analog signal)

Hexadecimal number system

- In the hexadecimal system, the base is 16, we use 16 symbols {0, 1, 2, 3, 4, 5, 6, 7, 8, 9, a, b, c, d, e, f}
- “10” is used when we hit 16 (逢十六进一)
- $N = a_n \times 16^n + a_{n-1} \times 16^{n-1} + a_{n-2} \times 16^{n-2} \ \ldots\ldots + a_0 \times 16^0 + a_{-1} \times 16^{-1} + a_{-2} \times 16^{-2} \ldots$
- a_n is the positional value (ranging from 0 to 15), while 16^n represents the weight

Octal number system

Converting binary number into decimal number

Example $(1101.01)_2$

$$=(1\times2^3+1\times2^2+0\times2^1+1\times2^0+0\times2^{-1}+1\times2^{-2})_{10}$$

$$=(13.25)_{10}$$

Practice $(10110.11)_2=(?)_{10}$

Converting binary number into decimal number

Answer

(10110.11)

$=(1\times2^4+0\times2^3+1\times2^2+1\times2^1+0\times2^0+1\times2^{-1}+1\times2^{-2})_{10}=(22.75)_{10}$.

Converting octal number into decimal number

Example $(24.67)_8=(2 \times 8^1+ 4 \times 8^0+6 \times 8^{-1}+7 \times 8^{-2})_{10}$

$=(20.859375)_{10}$

Practice $(35.7)_8= (?)_{10}$

Converting octal number into decimal number

Answer

$$(35.7)_8=(3\times8^1+5\times8^0+7\times8^{-1})_{10}$$
$$=(29.875)_{10}$$

Converting hexadecimal number into decimal number

Example $(2AB.C)_{16}$

$$=(2\times16^{2}+10\times16^{1}+11\times16^{0}+12\times16^{-1})_{10}$$

$$=(683.75)_{10}$$

Practice $(A7D.E)_{16}=(?)_{10}$

Converting hexadecimal number into decimal number

Answer

$$(A7D.E)_{16}=(10\times16^{2}+7\times16^{1}+13\times16^{0}+14\times16^{-1})_{10}$$
$$=(2685.875)_{10}$$

Converting other number system into decimal system

- Other number system can also be converted into decimal system in a similar way

- We just need to change the corresponding base

Some tests: converting into **decimal** system

- $(110110)\_2 = (?)\_10$
- $(101011.11)\_2 = (?)\_10$
- $(120)\_8 = (?)\_10$
- $(34.01)\_8 = (?)\_10$
- $(\mathrm{BCA})\_16 = (?)\_10$
- $(\mathrm{E05.C})\_8 = (?)\_10$

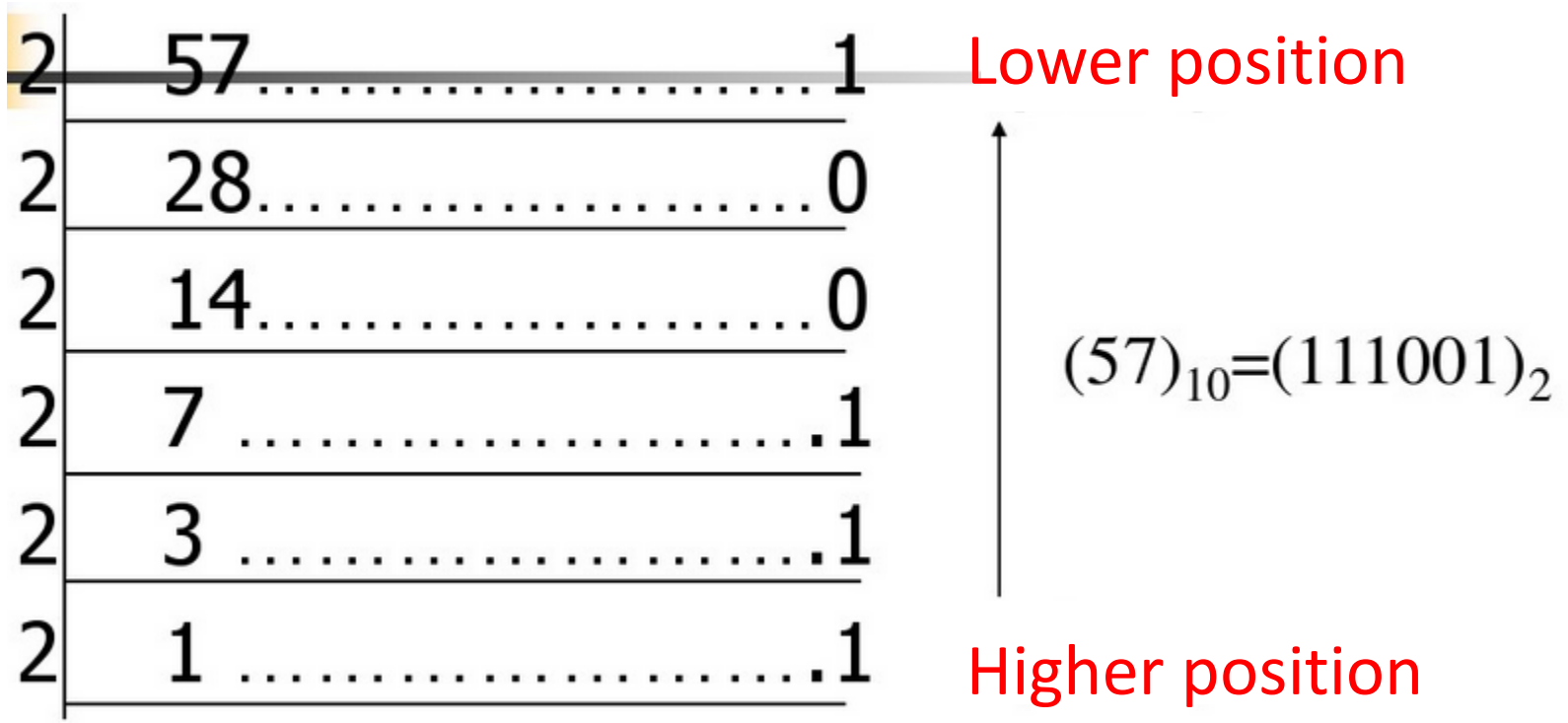
Some tests: converting into **decimal** system

- $(110110)\_2 = (\mathbf{118})\_10$
- $(101011.11)\_2 = (\boldsymbol{43.75})\_10$
- $(120)\_8 = (\mathbf{80})\_10$
- $(34.01)\_8 = (\boldsymbol{28.015625})\_10$
- $(\mathrm{BCA})\_16 = (\boldsymbol{3018})\_10$
- $(\mathrm{E05.C})\_8 = (\boldsymbol{3589.75})\_10$

https://www.rapidtables.com/convert/number/hex-to-decimal.html

Converting decimal integer into binary integer

Example: $(57)_{10} = (?)_2$



Converting decimal fraction into binary fraction

How to convert fractions to binary?

STEP 1: Take a decimal fraction and start multiplying by two the decimal part.

STEP 2: Every time the result is smaller than 1 , add a 0 to the binary representation. If the result is greater or equal to 1 , add a 1 to the binary representation and subtract 1 from the multiplication result.

Converting decimal fraction into binary fraction

Example: $(0.875)_{10} = (?)_2$

$0.875 \times 2 = \mathbf{1}.75$ Integer part: **1**

$0.75 \times 2 = \mathbf{1}.5$ Integer part: **1**

$0.5 \times 2 = \mathbf{1}$ Integer part: **1**

Higher position

Lower position

Answer: $(0.875)_{10} = (0.111)_2$

Practice: $(0.6875)_{10} = (?)_2$

Converting decimal fraction into binary fraction

Answer:

$0.6875 \times 2 = \mathbf{1}.375$ Integer part: **1**

$0.375 \times 2 = \mathbf{0}.75$ Integer part: **0**

$0.75 \times 2 = \mathbf{1}.5$ Integer part: **1**

$0.5 \times 2 = \mathbf{1}$ Integer part: **1**

Higher position

Lower position

So, $(0.6875)_{10} = (0.1011)_2$

Converting decimal number into binary number

- For a decimal number that has both integer and fractional parts
- Convert the integer and fractional parts separately
- Example: $(215.3125)_{10} = (?)_2$

Converting decimal number into binary number

Answer:

$$(215)_{10} = (11010111)_2$$
$$(0.3125)_{10} = (0.0101)_2$$
$$(215.3125)_{10} = (11010111.0101)_2$$

The one-to-one relationship between binary and octal numbers

There is a “one-to-one” (一一对应) relationship between three digits binary number and one digit octal number

$$
\begin{aligned}
(0)_8 &= (000)_2 \\
(1)_8 &= (001)_2 \\
(2)_8 &= (010)_2 \\
(3)_8 &= (011)_2 \\
(4)_8 &= (100)_2 \\
(5)_8 &= (101)_2 \\
(6)_8 &= (110)_2 \\
(7)_8 &= (111)_2
\end{aligned}
$$

Converting octal number into binary number

- Convert each octal digit into binary number of three digits
- Keep the digit order unchanged
- Example: $(0.754)_8 = (?)_2$

$$(0.754)_8 = (\underline{000}.\underline{111}\ \underline{101}\ \underline{100})_2$$
$$= (0.1111011)_2$$

- Practice: $(16.327)_8 = (?)_2$

Converting octal number into binary number

Answer:

$$(16.327)_8$$
$$= (\underline{001\ 110}.\ \underline{011}\ \underline{010}\ \underline{111})_2$$
$$= (1110.011010111)_2$$

Converting hexadecimal number into binary number

- Convert each hexadecimal digit into binary number of four digits

- Keep the digit order unchanged

- Example: $(4C.2E)_{16} = (?)_2$

$$
\begin{aligned}
&(4C.2E)_{16} \\
&= (\underline{0100}\ \underline{1100}.\underline{0010}\ \underline{1110})_2 \\
&= (1001100.0010111)_2
\end{aligned}
$$

- Practice: $(AD.7F)_{16} = (?)_2$

Converting hexadecimal number into binary number

Answer:

$$(AD.7F)_{16}$$
$$= (\underline{1010}\ \underline{1101}.\underline{0111}\ \underline{1111})_{2}$$
$$= (10101101.01111111)_{2}$$

Converting binary number into octal number

- Starting from lower positions, convert every three digits of the integer part into an octal digit
- When there is not enough higher positions in the integer part, fill with 0
- Starting from higher positions, convert every three digits of the fractional part into an octal digit
- When there is not enough lower positions in the fractional part, fill with 0
- Keep the digit order unchanged

Converting binary number into octal number

Example:

$(0.10111)_2 = (\underline{000}.\ \underline{101}\ \underline{110})_2 = (0.56)_8$

$(11101.01)_2 = (\underline{011}\ \underline{101}.\ \underline{010})_2 = (35.2)_8$

Practice:

$(1101101.011)_2$

Converting binary number into octal number

Answer:

$$(1101101.011)_2 = (\underline{001}\ \underline{101}\ \underline{101}.\ \underline{011})_2$$
$$= (155.3)_8$$

Converting binary number into hexadecimal number

- Starting from lower positions, convert every four digits of the integer part into an octal digit
- When there is not enough higher positions in the integer part, fill with 0
- Starting from higher positions, convert every four digits of the fractional part into an octal digit
- When there is not enough lower positions in the fractional part, fill with 0
- Keep the digit order unchanged

Converting binary number into hexadecimal number

Example:

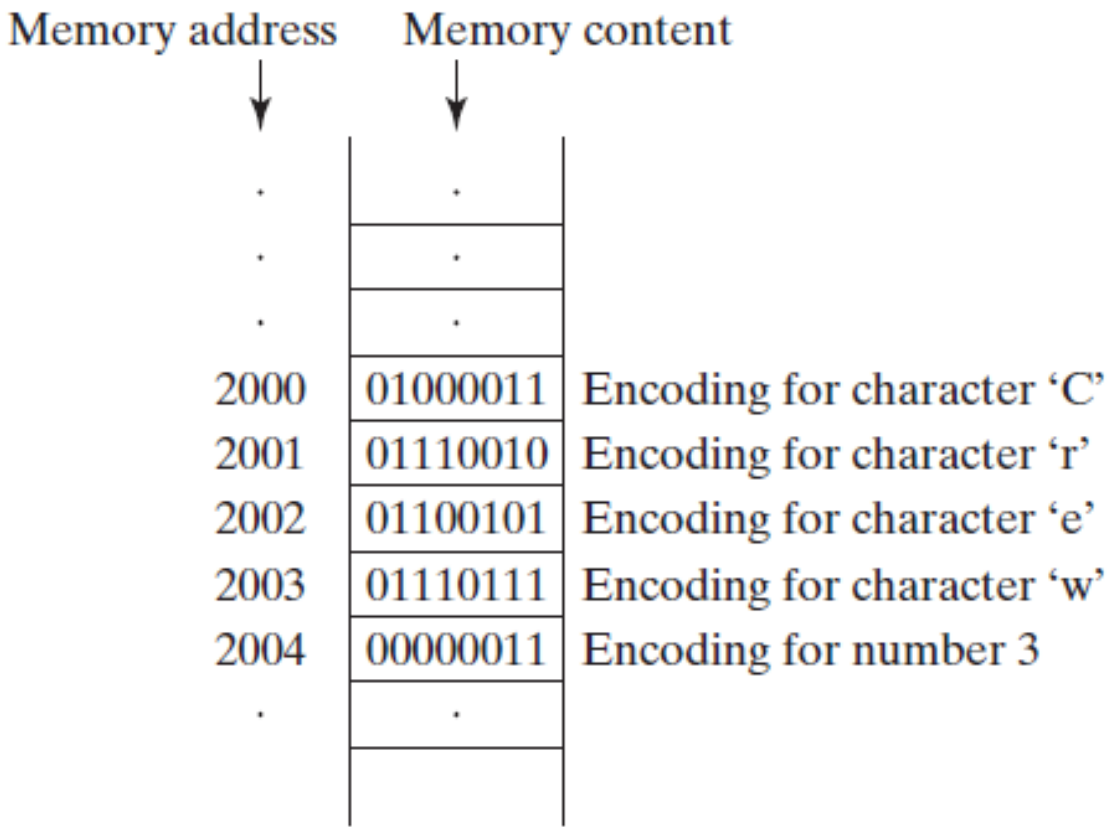
$$(11101.01)_2 = (\underline{0001}\ \underline{1101}.\ \underline{0100})_2$$
$$= (1D.4)_{16}$$

The units of information (data)

- Bit (比特/位): a binary digit which takes either 0 or 1
- Bit is the smallest information unit in computer programming
- Byte (字节): 1 byte = 8 bits, every English character is represented by 1 byte
- KB (千字节)：1 KB = 2^10 B = 1024 B
- MB (兆字节)：1MB = 2^20 B = 1024 KB
- GB (千兆字节)：1GB = 2^30 B = 1024 MB
- TB (兆兆字节)：1TB = 2^40 B = 1024 GB

Memory and addressing

- A computer's memory consists of an ordered sequence of bytes for storing data
- Every location in the memory has a unique address
- The key difference between high and low level programming languages is whether programmer needs to deal with memory addressing directly



Practice

- $(135.8125)_{10} = \ (10000111.1101)_{2}$
- $(1314.205)_{8} = \ (1\ 011\ 001\ 100.010\ 000\ 101)_{2}$
- $(0101010000.0010110011)_{2} = (520.1314)_{8}$
- $(0101010000.0010110011)_{2} = (150.2CC)_{16}$

Thanks