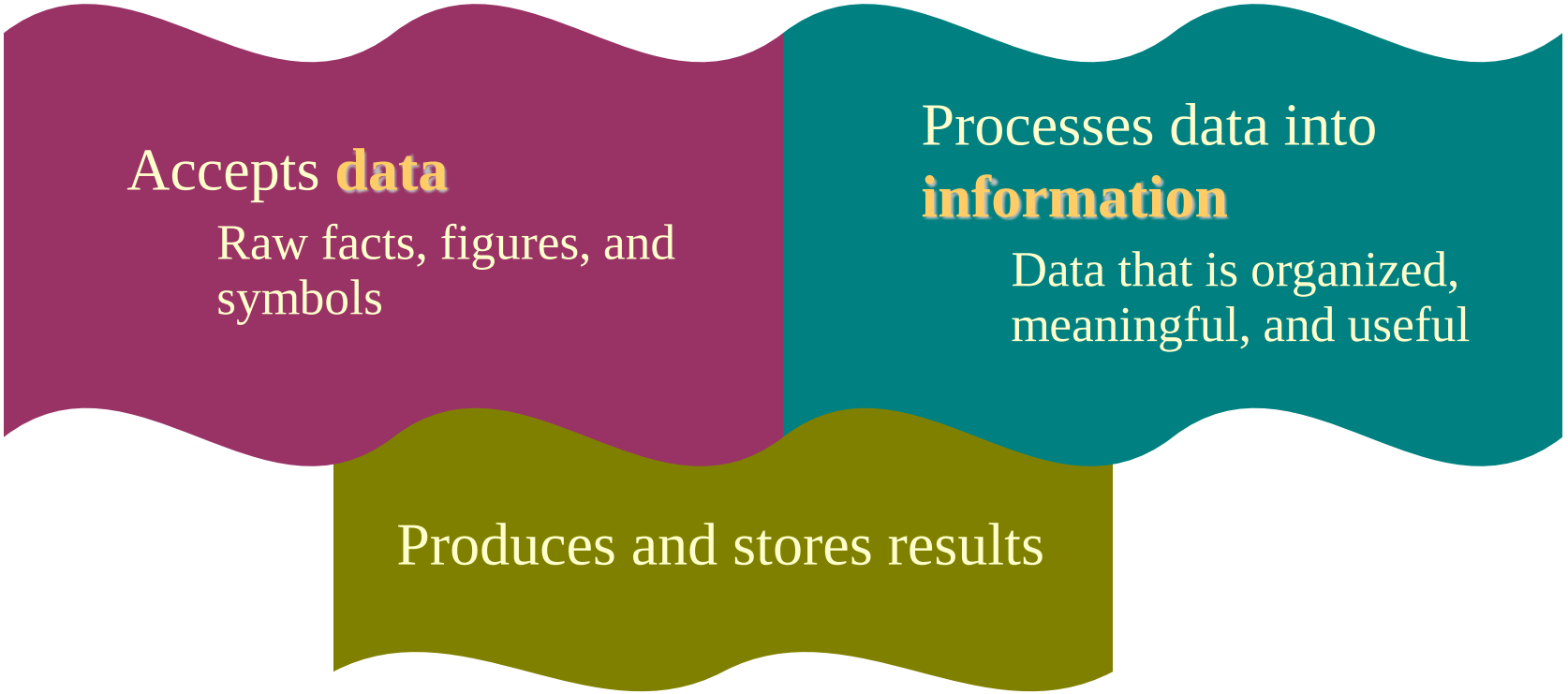
Unit 1. Computer Systems

- 1.1 Overview of Computer Systems
- 1.2 Evolution of Computer Systems
- 1.3 Data Representation in a Computer System

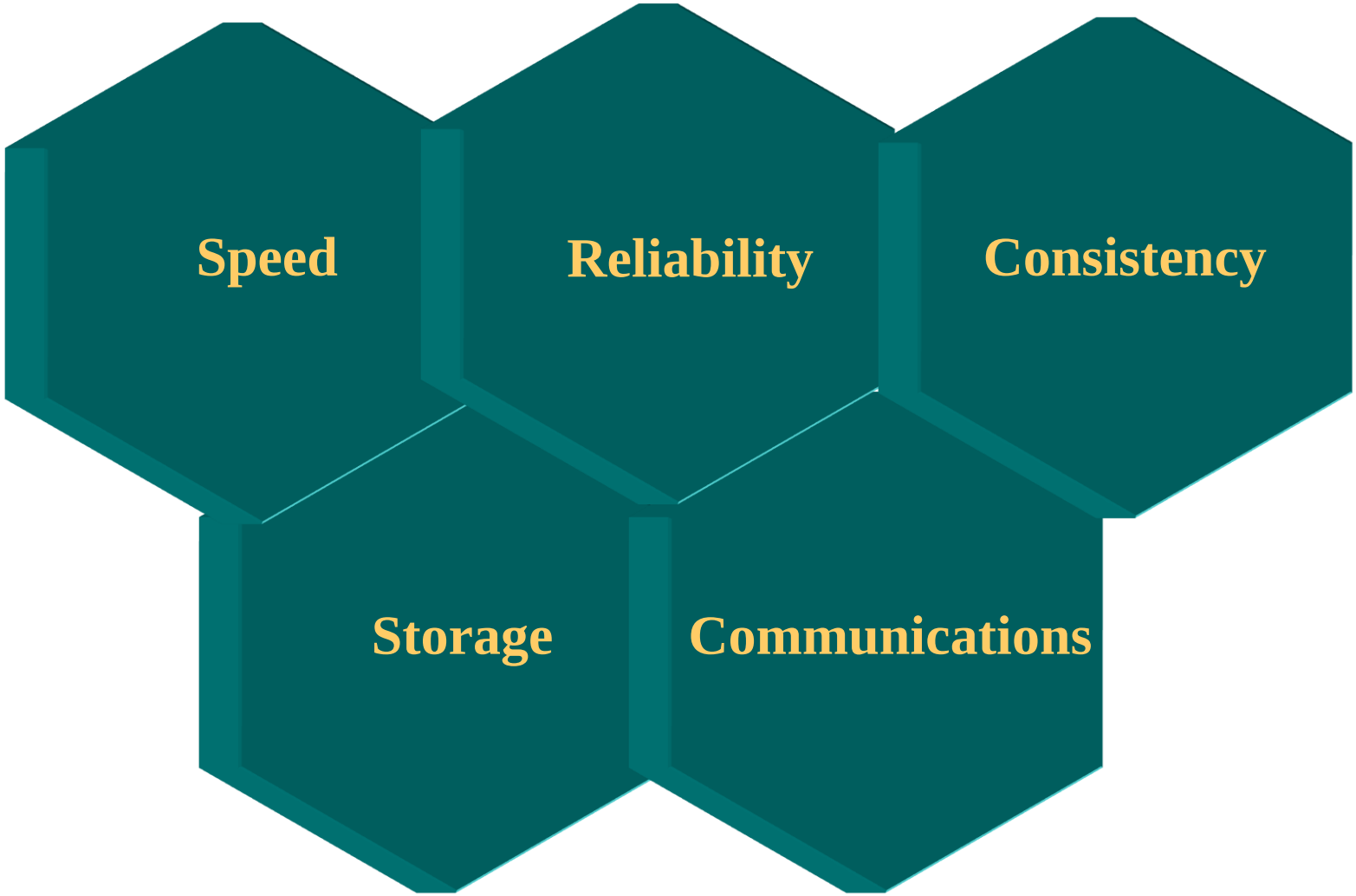
What Is a Computer (计算机)?

- How is a computer defined?
  - Electronic device operating under the control of instructions stored in its own memory



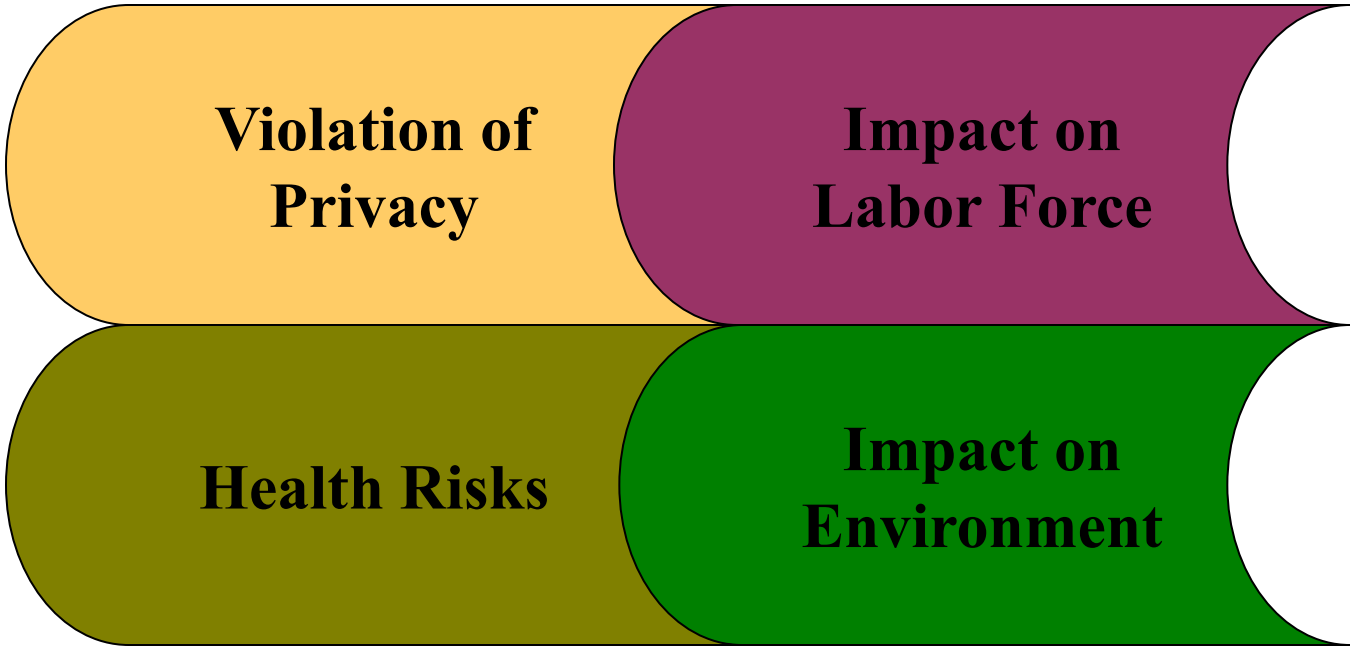
Advantages and Disadvantages of Using Computers

- What are the advantages of using computers?



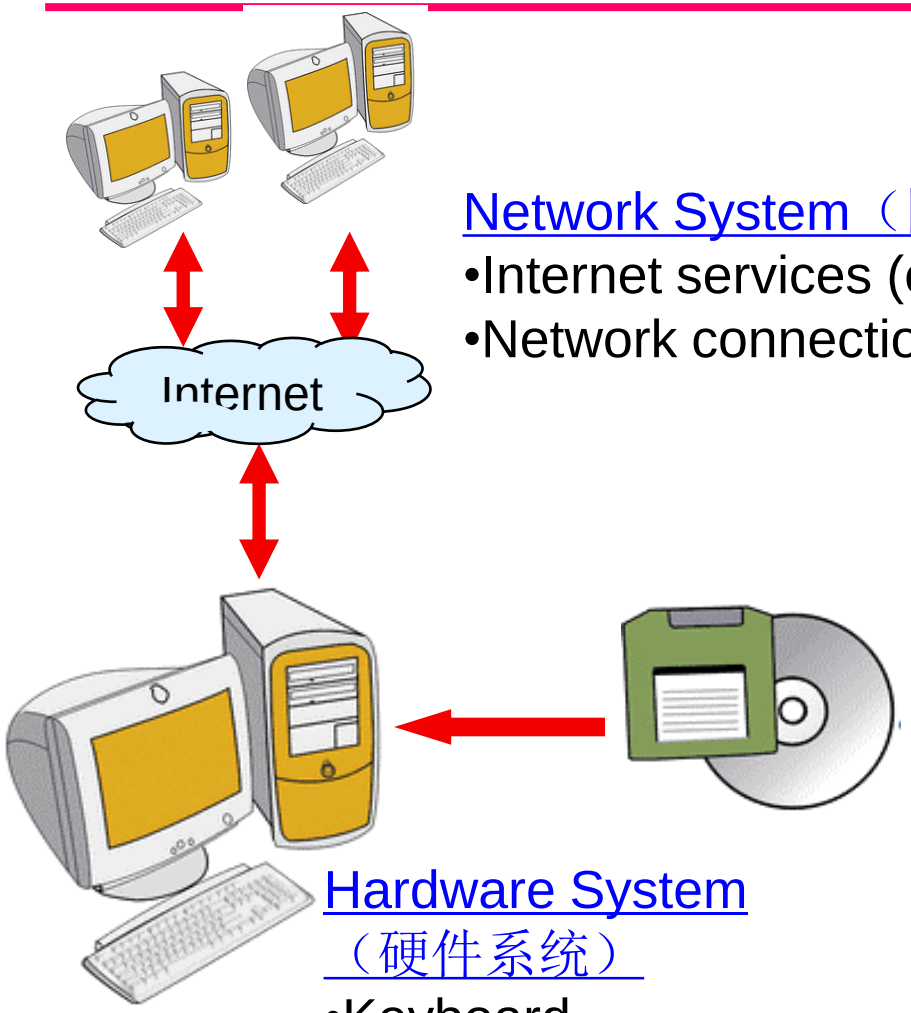
Advantages and Disadvantages of Using Computers

- What are the disadvantages of using computers?



1.1 Components of a Computer System
计算机组成部分

Components of a Computer System

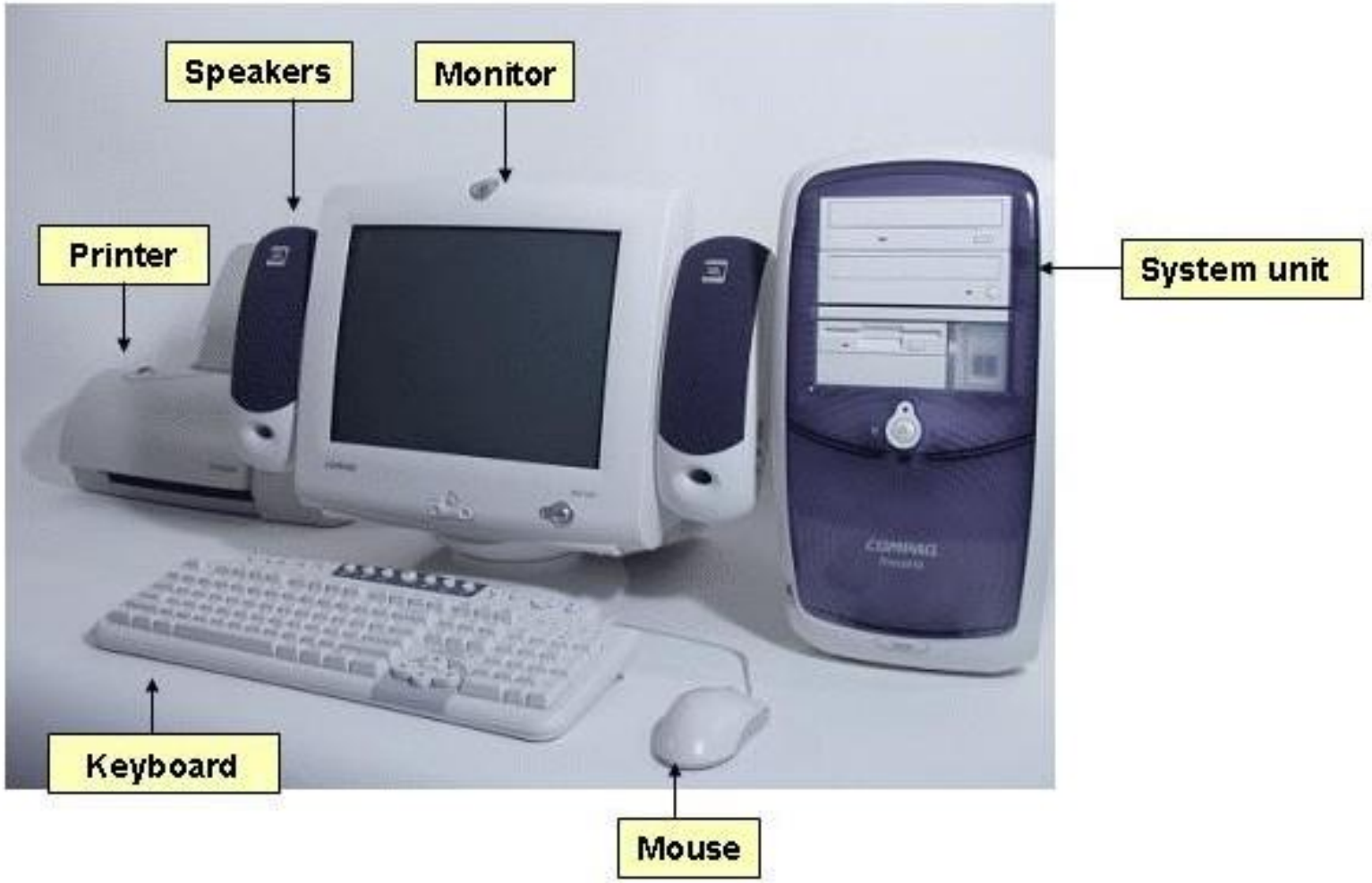


Network System（网络系统）
- Internet services (email)
- Network connections (modems, network cards)

Software System（软件系统）
- Operating System (Unix, Mac OS, Microsoft Windows)
- Web browser (Netscape, Internet Explorer)
- Office productivity applications (Microsoft Office, Star Office)

Hardware System（硬件系统）
- Keyboard
- Monitor
- System unit

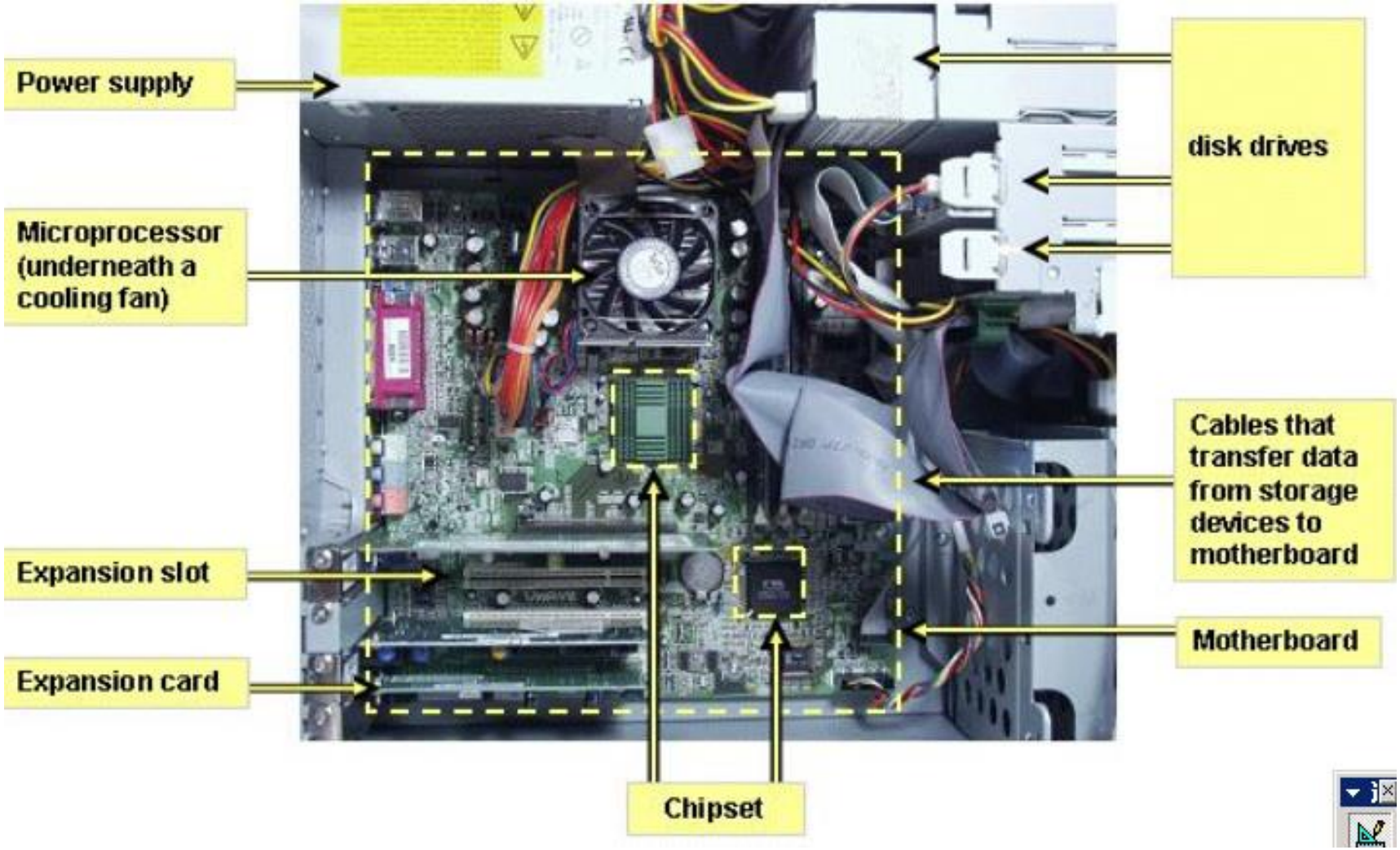
1. Hardware System



The Components of a Computer

- What is the system unit（系统单元）?
  - **Box-like case containing electronic components used to process data**

Components inside the system unit



The Components of a Computer

- What are two main components on the motherboard?

Central Processing Unit (CPU，中央处理单元)

Also called a **processor**

The electronic component that interprets and carries out the basic instructions that operate the computer

Memory（内存）

Consists of electronic components that store instructions waiting to be executed and data needed by those instructions

Peripheral Devices（外部设备）

- Equipment added to computer to enhance its functionality
- Modify and expand the basic computer system
- Examples of peripheral devices:
  - Keyboard
  - Monitor
  - Mouse
  - Printer
  - Scanner
  - Digital Video Camera
  - Graphic Tablet
  - Joy Stick

The Components of a Computer

- What is an input device（输入设备）?
  - **Hardware used to enter data and instructions**

The Components of a Computer

- What is an output device（输出设备）?
  - **Hardware that conveys information to one or more people**

Storage Devices（存储设备）

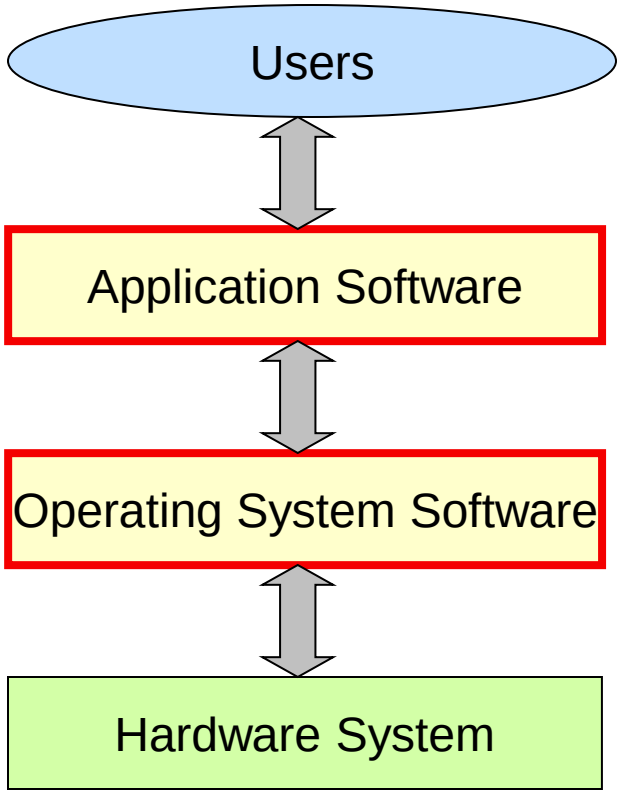
- Optical Disks
  - CD-ROM
  - CD-RW
  - DVD-ROM
- Magnetic Disks
  - Floppy disk
  - Hard disk (removable & fixed)

2. What is Software?

- Software is a set of computer instructions or data.
- Software receives input from the user and processes this input through the computer to produce output.
- Software directs how the computer interacts with the user.
- Software specifies how to process the user's data

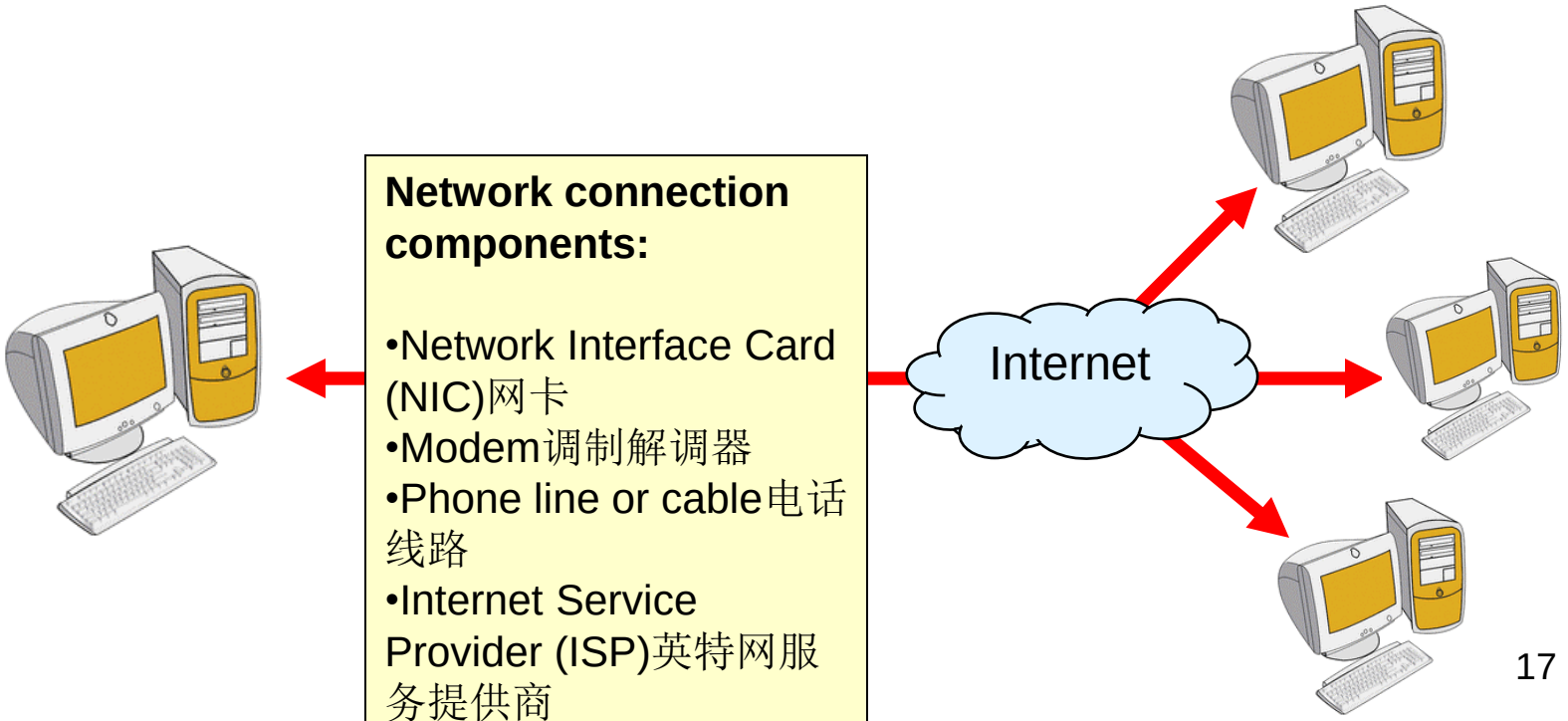
Software System

- Two categories: operating system (OS) software and application software.
- Operating system（操作系统软件） software, also called system software, is the master controller for all activities that take place within a computer
  - Examples of OS software:
    - Microsoft Windows
    - Unix
    - Mac OS
    - iseries
- Application software（应用软件） is a set of one or more computer programs that helps a person carry out a task
  - Examples of application software:
    - Microsoft Word
    - Internet Explorer
    - Macromedia Dreamweaver



3. Network System

- A network provides connections among computers to enable computers on a network to share data (e.g. documents), hardware (e.g. printers), and software resources (e.g. application programs).
- Network users can also send messages to each other.
- A network must be secured to protect data from unauthorized usage (e.g. using login name and password to gain access to a network).



Basic Computer Model

- All computers perform four basic operations
  - Input Data输入数据
  - Process Data处理数据
  - Store Data存储数据
  - Output Data输出数据

Basic Operations

- Input data is to feed information which can be supplied by any person, environment or other computer.
- Processing data is manipulating data by performing calculations, sorting lists of words or numbers, drawing pictures.
- Storing data is for future retrieval and processing. Memory holds data that is waiting to be processed, and storage areas hold data permanently until the data is deleted.
- Output data is the result produced by a computer, which includes reports, documents, music, graphs, pictures and movies.

Categories of Computers
计算机分类

Categories of Computers（计算机分类）

- Computers are classified based on their technology, function, physical size, performance and cost.
- The categories of computers include:
  - Personal computers个人计算机
  - Handheld computers手持式计算机
  - Mainframes大型机
  - Supercomputers 超级计算机
  - Embedded Computers嵌入式计算机

Personal Computer (PC)

- Designed to meet the computing needs of an individual

Desktop computers

Notebook computers

Personal Computers

- What is a desktop computer（桌面计算机）?
  - Designed so all of the components fit on or under a desk or table

Mobile Computers and Mobile Devices

- What is a notebook computer（膝上电脑）?
  - Portable, small enough to fit on your lap
  - Also called a laptop computer
  - Generally more expensive than a desktop computer

Mobile Computers and Mobile Devices

- What is a Tablet PC（平板电脑）?
  - Resembles a letter-sized slate
  - Allows you to write on the screen using a digital pen

Mobile Computers and Mobile Devices

- What is a handheld computer?

Mobile Computers and Mobile Devices

- What is a personal digital assistant (PDA，个人数字助理)?
  - Provides personal organizer functions
    - Calendar
    - Appointment book
    - Address book
    - Calculator
    - Notepad

Mobile Computers and Mobile Devices

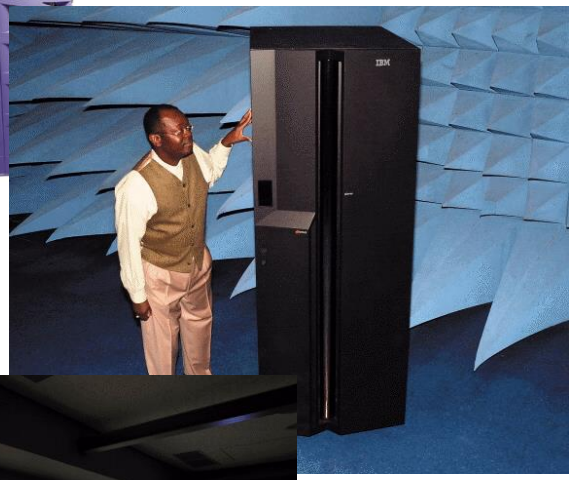
- What are smart phones（智能手机）?

Smartphones are mobile phones that also have some of the functions of a computer. They allow users to perform a wide range of tasks including accessing the internet, sending and receiving emails, managing calendars, playing games, and more. Smartphones typically have touch screens, allow users to install various applications (known as "**apps**") and often have high-quality **cameras** for photography and video calling.

Servers（服务器）

- What types of servers are there?

A server controls access to network resources and provides centralized storage



Mainframe Very powerful, expensive computer that supports thousands of computers

Supercomputer The fastest, most powerful, most expensive computer. Used for applications requiring complex mathematical calculations

Mainframe Computer

- It is a large and expensive computer that is capable of handling requests and passing data simultaneously to many users.
- Used by governments and large corporations to provide centralized storage and control
- Processes billions of data per second
- Handles communication between users
- Searches for requests given by user.

Supercomputer

- It is the fastest type of computer.
- Supercomputers are very expensive and are employed for specialized applications that require immense amounts of mathematical calculations.
- It is often used for:
  - Breaking codes
  - Modeling weather systems
  - Simulating nuclear explosions
- Examples: 太湖之光，Deep Blue, PARAM 1000

Supercomputer

目前世界上**最先进的超级计算机**包括以下几款：

1.Summit：美国Oak Ridge国家实验室的Summit超级计算机，是目前世界上最快的超级计算机，总计算能力达到了200 petaflops。

2.Sunway TaihuLight：中国苏州的Sunway TaihuLight超级计算机，是目前世界上最大的超级计算机，总计算能力达到了93 petaflops。

3.Sierra and Aurora：美国国家能源研究和开发局的Sierra和Aurora超级计算机，总计算能力分别为125 petaflops和180 petaflops。

4.Frontera：美国德克萨斯大学的Frontera超级计算机，总计算能力为23 petaflops。

5.Piz Daint：瑞士联邦理工学院的Piz Daint超级计算机，总计算能力为19 petaflops。

6.Frontier：这是TOP500中排名第一的系统，安装在田纳西州橡树岭国家实验室，由美国能源部运营。它目前使用8,699,904个内核实现了1.194 Exaflop/s。

这些超级计算机均以其强大的计算能力和高效的能源效率而著名，并被广泛应用于科学计算、物理模拟、人工智能等各种领域。

神威.太湖之光


“神威 · 太湖之光” 超级计算机
完全基于中国设计、制造的“神威•太湖之光”超级计算机是世界上首台运算速度超过十亿亿次的超级计算机，其采用的中央处理器是我国自主设计生产的“申威26010”众核处理器，因此也是国内第一台全部采用国产处理器构建的世界第一的超级计算机。
神威
太湖之光

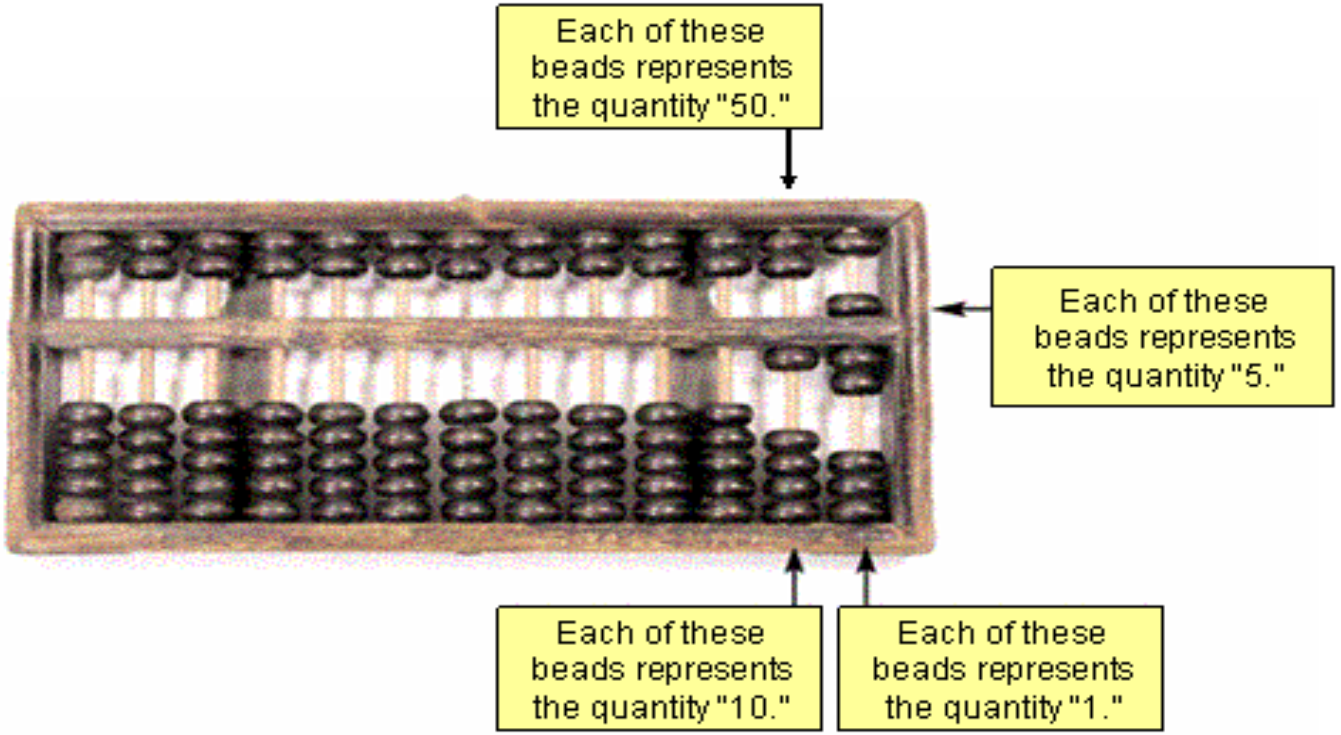
Embedded Computers

- What is an embedded computer?
  - An embedded computer is a **specialized** computer system that is designed for specific applications, such as those found in networks, communications, audio, video, and other fields. It differs from a general-purpose computer in that it is tailored for a specific task or set of tasks, often within a larger system or device.

1.2 Evolution of Computers
计算机的发展历史

Evolution of Computers

- Needed calculation devices to keep track of accounting for commerce
- 1200s—Manual Calculating Devices: the ***abacus***（算盘）



Evolution of Computers (cont.)

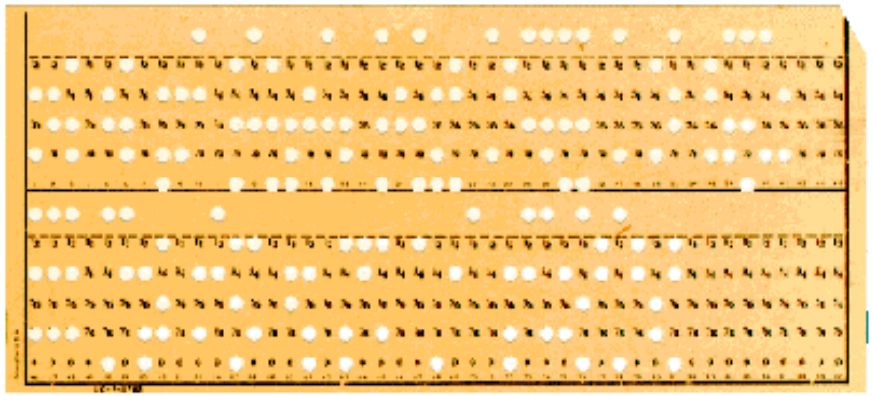
- 1600s—Mechanical Calculators

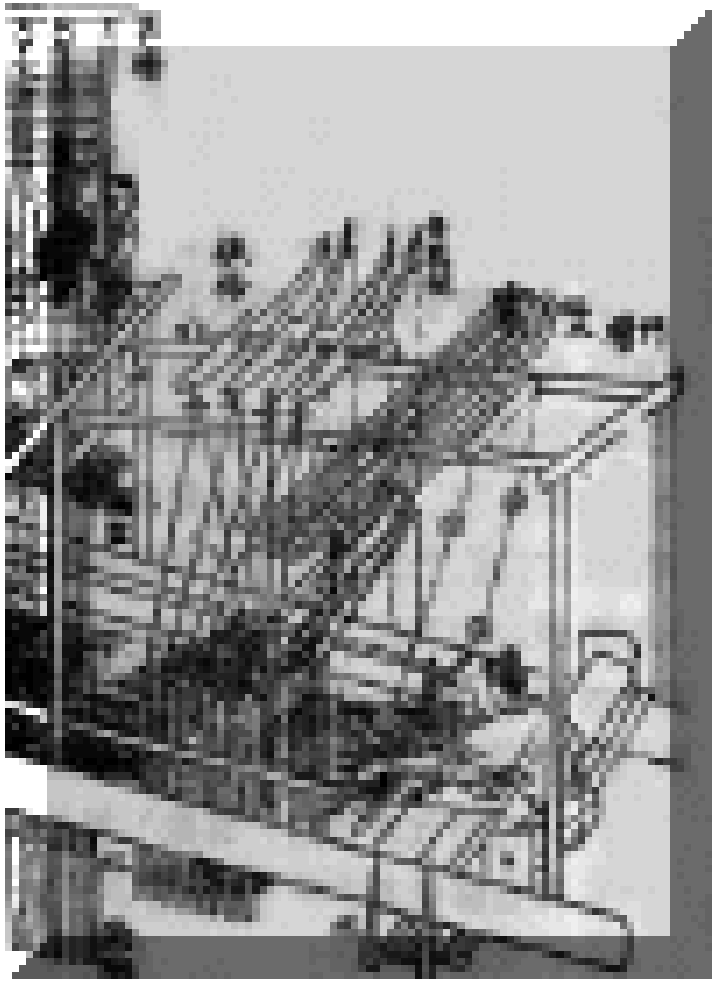
  (法国，Pascal，机械式计算机)
  - Used wheels, gears, and counters
  - To work a mechanical calculator, the operator enters the numbers for a calculation, and then pulls a lever or turns a wheel to carry out the calculation
  - Example: the Pascaline invented by Blaise Pascal. It used some principles o ove counters.

Evolution of Computers (cont.)

- 1800s—Punched Cards

  (法国，Jacquard，穿孔卡片)
  - Used holes following a specific pattern to represent the instructions given to the machine or stored data
  - Different program instructions can be stored on separate punched cards, which can be fed through the computing machine repeatedly.

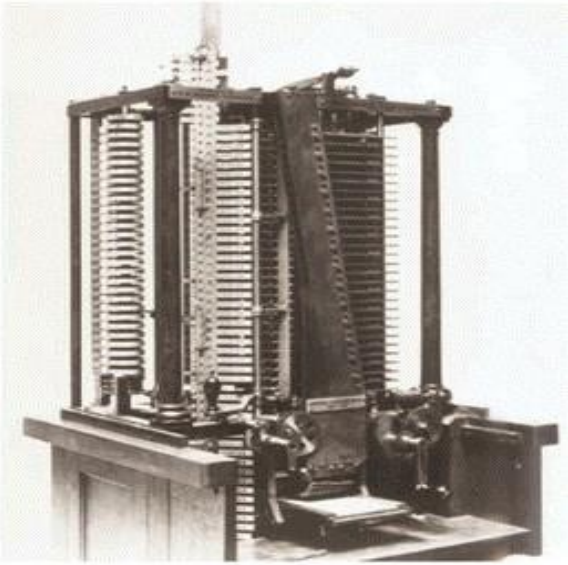




Evolution of Computers (cont.)

- 1834: Charles Babbage designed a new general-purpose calculating device, the Analytical Engine

  (英国， Babbage，分析机)
  - It includes the essential components of present-day computers, which are input, process, storage, and output of data.
  - which is the ancestor of modern computers.



Evolution of Computers (cont.)

- 1890: Herman Hollerith designed an electronic punched card tabulating device that enabled the U.S. Census Bureau to tabulate the 1890 census in six months, which would have otherwise taken more than 7 years.

  (美国，Hollerith，机电穿孔卡)
- 1896: Hollerith incorporated The Tabulating Machine (制表机) better known today as IBM (1924).

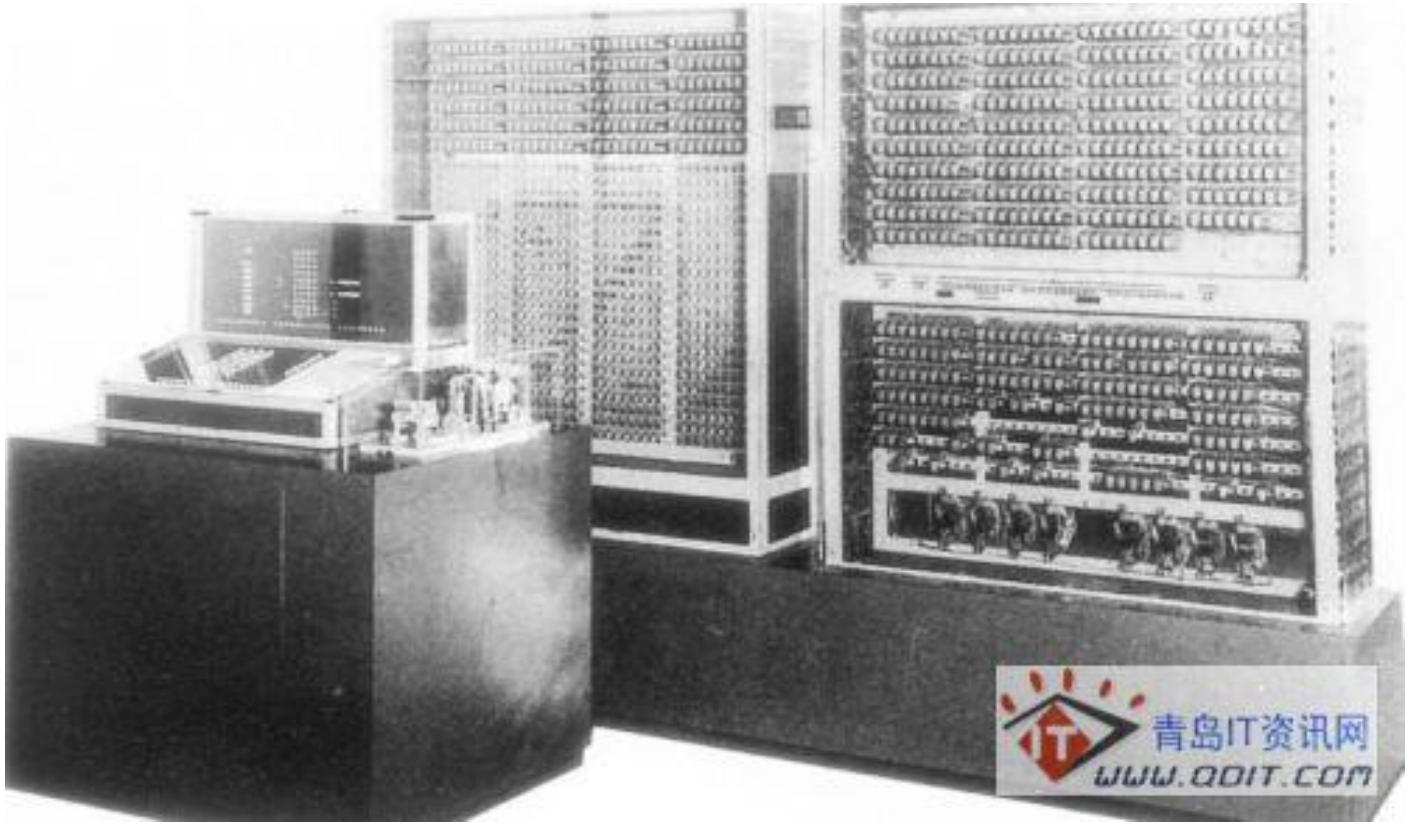
机电计算机

- 1941年，德国工程师康拉德•祖斯研制成功全部采用继电器的计算机Z-3，这是世界上第一台完全由程序控制的机电式计算机。采用了浮点计数法、二进制运算、带数字存储的指令格式等。

第一位全部采用电器元件来制造计算机的德国工程师康拉德·祖斯

41

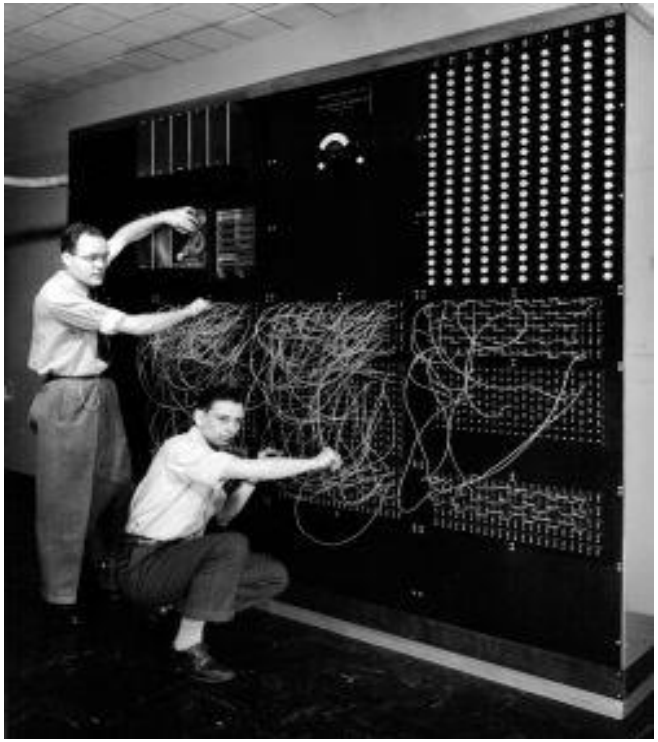
机电计算机

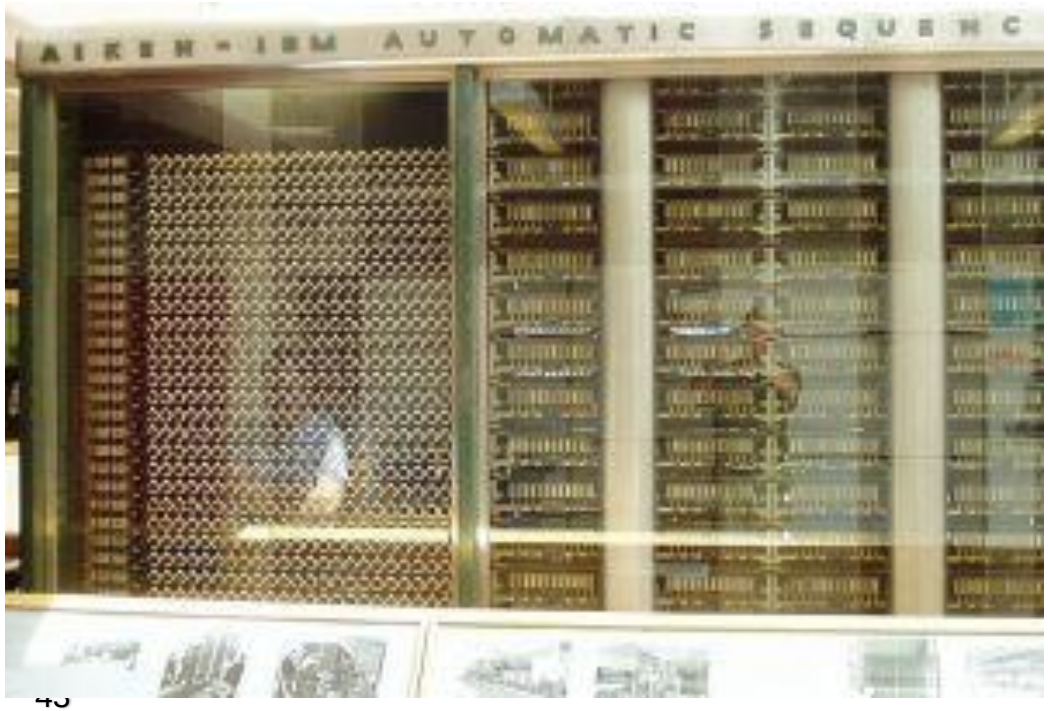


Z-3

机电计算机

- Mark-Ⅰ
  - 电磁式计算机Mark Ⅰ，也叫“自动序列受控计算机”，在计算机发展史上占据重要地位，是计算机“史前史”里最后一台著名的计算机，发明者是**美国哈佛大学艾肯博士**。
  - 1944年，机电计算机Mark-Ⅰ投入运行，长15.5米，高2.4米，由75万个零部件组成，加法0.3秒，乘法6秒。运行时噪音很大，可靠性也不是特别高，但仍用了15年。





Mark III

Mark 3 上时代封面

计算机的产生

- ENIAC（埃尼阿克）
  - –世界上第一台电子计算机于1946年在美国研制成功，取名ENIAC（Electronic Numerical Integrator And Calculator）。电子数字积分仪和计算机
  - –ENIAC奠定了电子计算机的发展基础，开辟了一个计算机科学技术的新纪元。有人将其称为人类第三次产业革命开始的标志。

计算机的产生

ENIAC（埃尼阿克）

不足之处：

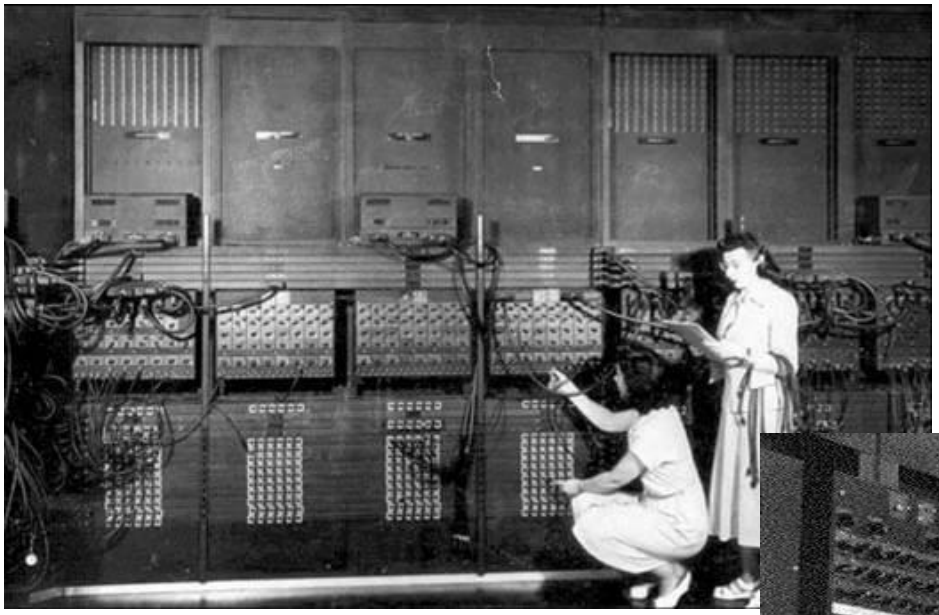
–耗电量惊人，功率为l50千瓦，常常因为电子管烧坏而需要停机检修。

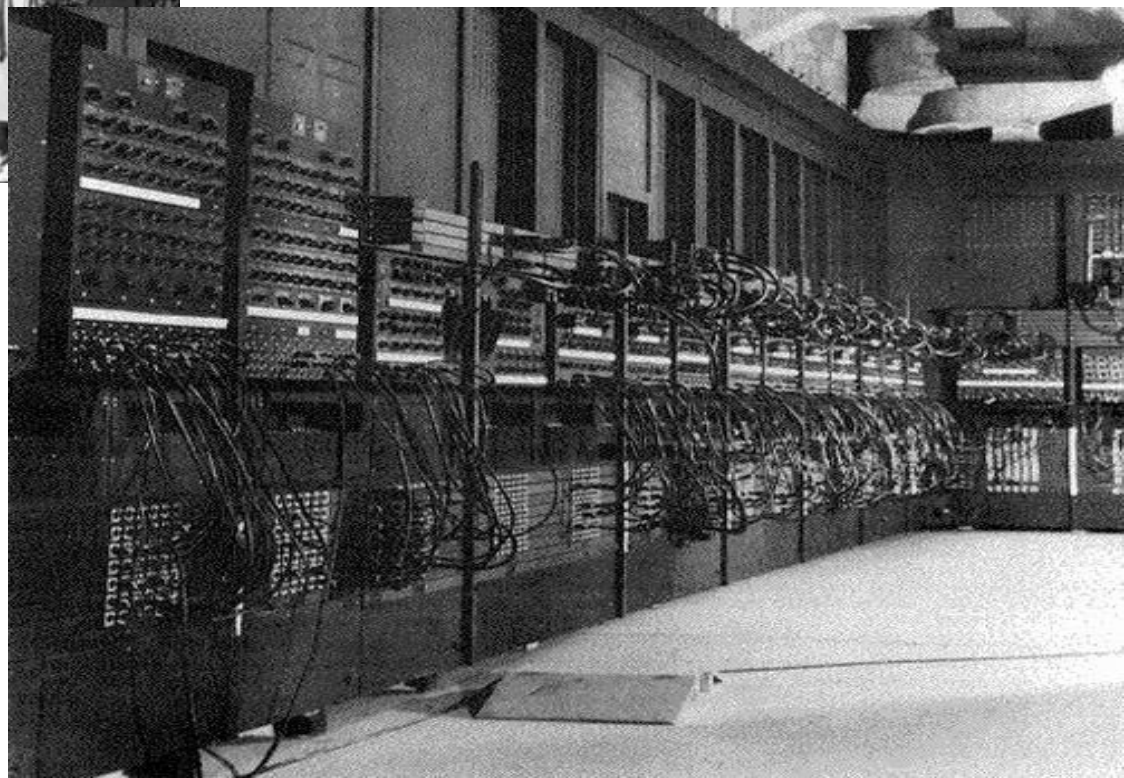
–存储容量小，至多只能存20个字长为10位的十进制数。

–与后来的存储程序型的计算机不同，它的程序是外插型的，即用线路连接的方式实现。使用很不方便。

–使用的仍然是十进制。基本结构和机电式计算机没有什么区别，显示了电子器件在提高运算速度上的可能性，却没有最大限度发挥电子技术的巨大潜力。

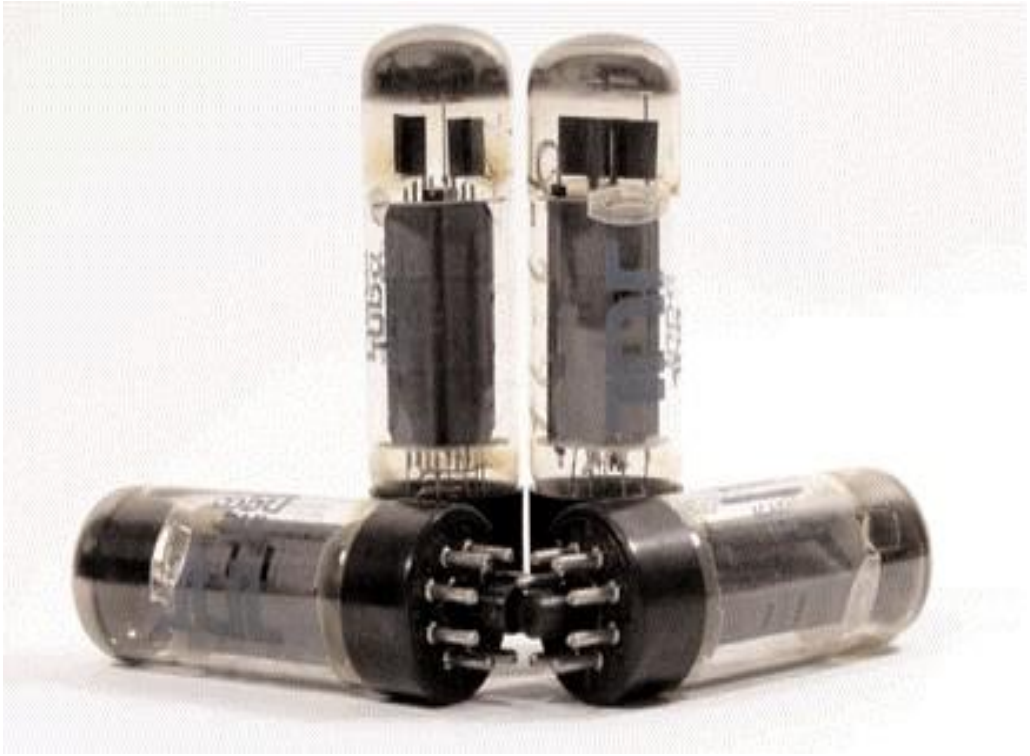
The first computer - ENIAC





Evolution of Computers (cont.)

- 1940s—Vacuum Tubes（真空管）
  - Used to control the flow of electrons. Since vacuum tubes responded faster than mechanical components, faster computations were possible. But, the tubes consumed a lot of power and burned out quickly.



Evolution of Computers (cont.)

- Invention of the compiler by Grace Hopper
- A compiler enables program instructions to be written in English and then translated into a language that the machine can understand.
- This invention made the task of programming easier and faster.

Evolution of Computers (cont.)

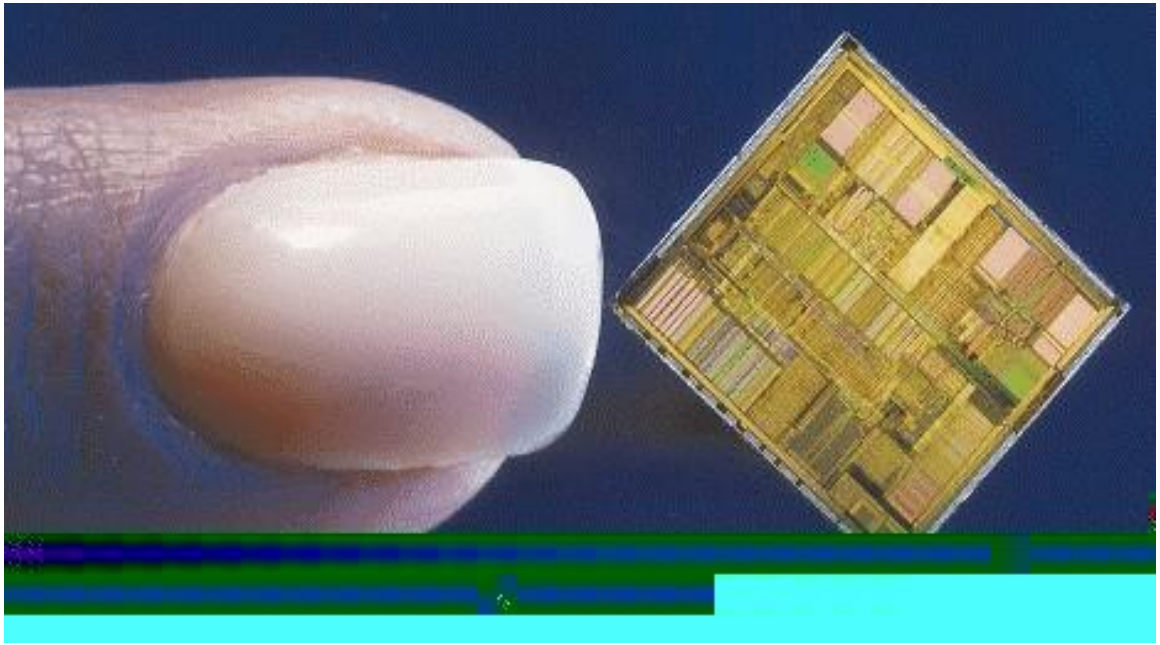
- 1950s—Transistors （晶体管）
  - Smaller, cheaper, more reliable, and consumed less power than vacuum tubes.
  - Could perform 200,000 to 250,000 calculations per second.

Evolution of Computers (cont.)

- 1960s—Integrated Circuits （集成电路）
  - Thin slice of silicon packed with microscopic circuit elements such as wire, transistors, capacitors, and resistors.
  - Enabled the equivalent of thousands of vacuum tubes or transistors to be packed onto a single miniature chip about the size of your fingernail
  - Reduces the physical size, weight, and power requirements for devices such as computers

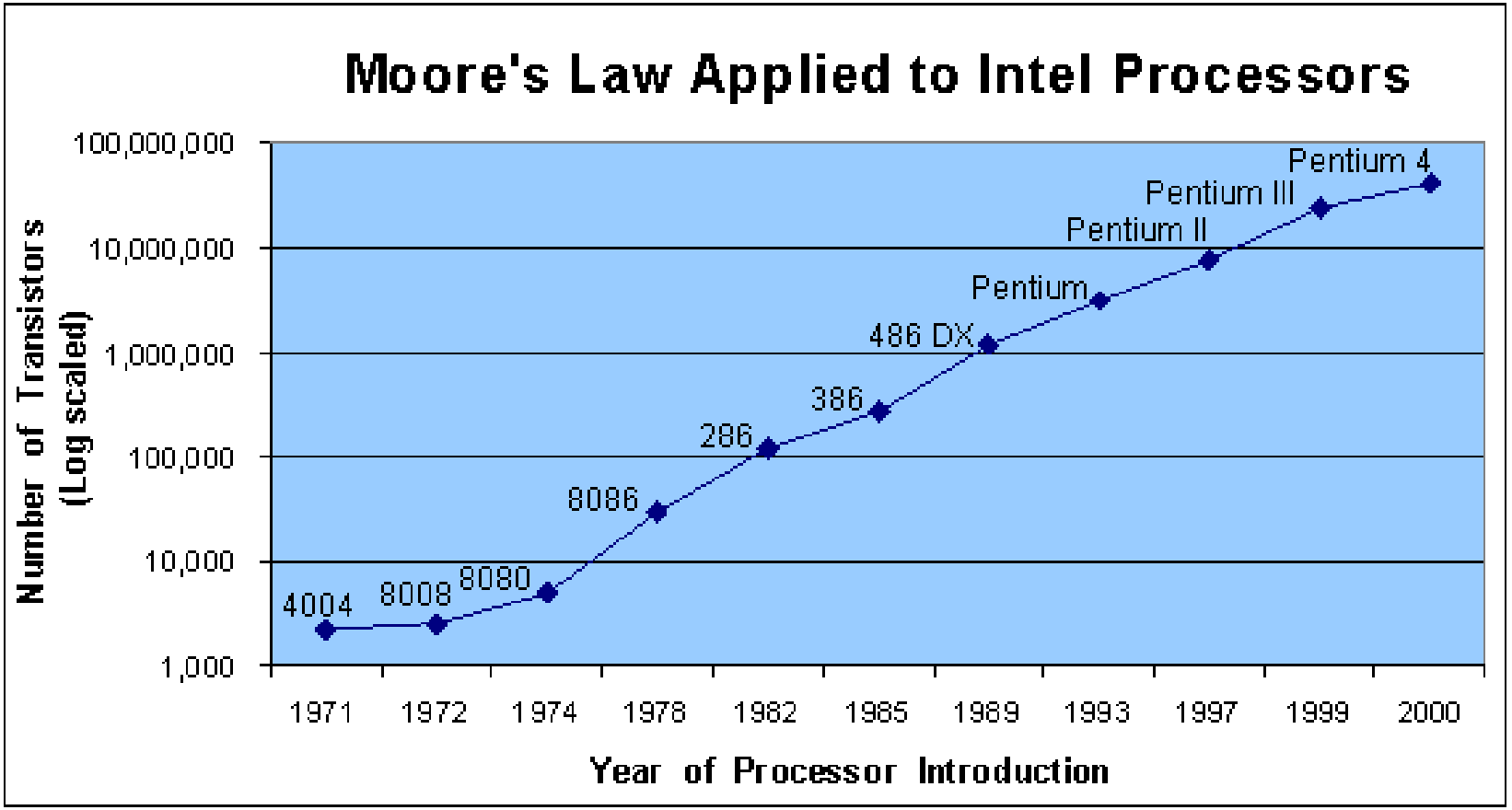
Evolution of Computers (cont.)

- 1970s to Present—Microprocessor （微处理器）
  - Combined components of a computer on a microchip
  - Can be manufactured and then programmed for various purposes



Evolution of Computers (cont.)

- Pace of Processor Advancement：摩尔定律



Applications of Computer Systems
计算机的应用（自学）

Applications of Computer Systems

- In Education
  - Multimedia-Facilitated Learning
  - Simulation-Based Education
  - Intelligent Machine-Based Training
  - Interactive Learning

Applications of Computer Systems

- In Business
  - Supply Chain Management
  - Project Management
  - Customer Relationship Management
  - Sales and Marketing Using Electronic Commerce
  - Manufacturing Research

App of Computer Systems (cont.)

- In Entertainment
  - Movies
  - Video Games
  - Music
  - Digital Photography
  - Travel
  - Wearable Computer Systems
- Developing new applications of computer systems:
  - Research at Carnegie Mellon University
    - http://www.cs.cmu.edu/research/projects/
  - Research at Massachusetts Institute of Technology Media Lab
    - http://www.media.mit.edu/

Computer Industry

- Computer industry encompasses those companies that manufacture handheld computers, personal computers, high-end workstations, servers, mainframes, and supercomputers
- Information technology industry (or IT industry), is typically used to refer to the companies that develop, produce, sell, or support computers, software, and computer-related products
- IT companies include:
  - Equipment manufacturers
  - Chipmakers
  - Software publishers
  - Service companies
  - Retailers

Computer Industry (cont.)

- The 1990s spawned a group of Internet-based companies that came to be called “dot coms”, from the companies’ domain names, which inevitably ended with “.com” and many of the companies even incorporated “.com” into their official company names
- Amazon.com was one of the first Internet-based companies

Computer Industry (cont.)

- Governments and private businesses have discovered that they can become much more efficient with a liberal application of computers and other information technologies
- As businesses globalize, they encounter new competitors with technological advantages
- Bottom line: if your business competitors turn to technology, so must you

Examples of Computer Usage

- What are five categories of computer users?
  - Home User
  - Small Office/Home Office User
  - Mobile User
  - Power User
  - Large Business User

Examples of Computer Usage

- What software is available for a home user个人用户?
  - Personal Finance Management
  - Web access
  - Communications
  - Entertainment

Examples of Computer Usage

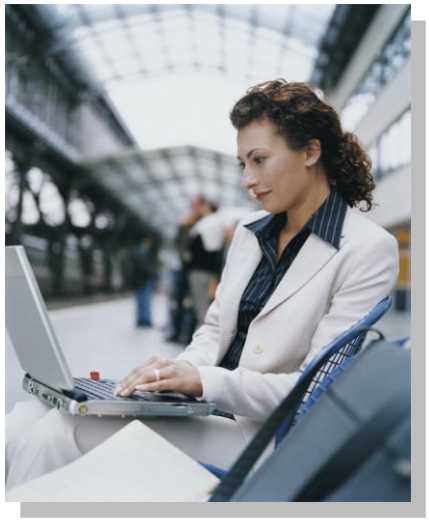
•What software is available for a small office/home office (SOHO，小型办公或家庭用户) user?

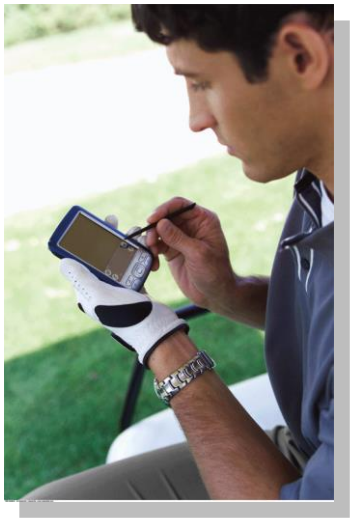
- **Productivity software**
- **Specialty software**
- **Web usage**
- **E-mail**

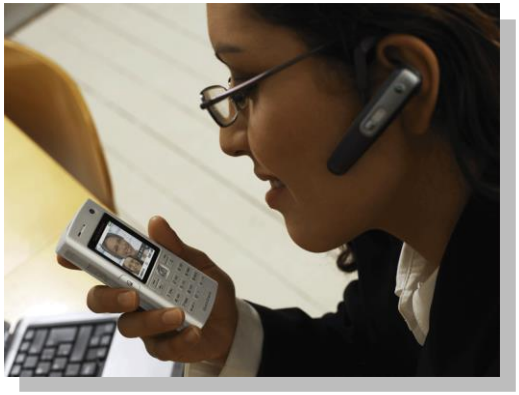
Examples of Computer Usage

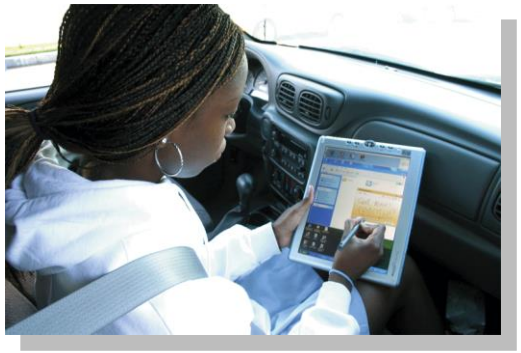
•What is available for a mobile user移动用户?

- **Hardware**
  - Notebook computers
  - PDAs
  - Smart phones
  - Tablet PCs
- **Software**
  - Word processing
  - Spreadsheet
  - Presentation graphics software







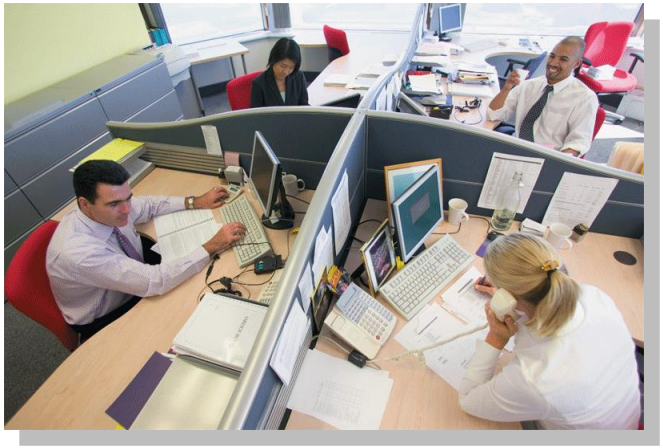


Examples of Computer Usage

- What are the needs of a power user高级用户?
  - Speed and large amounts of storage
  - Types of power users
    - Engineers
    - Architects
    - Desktop publishers
    - Graphic artists

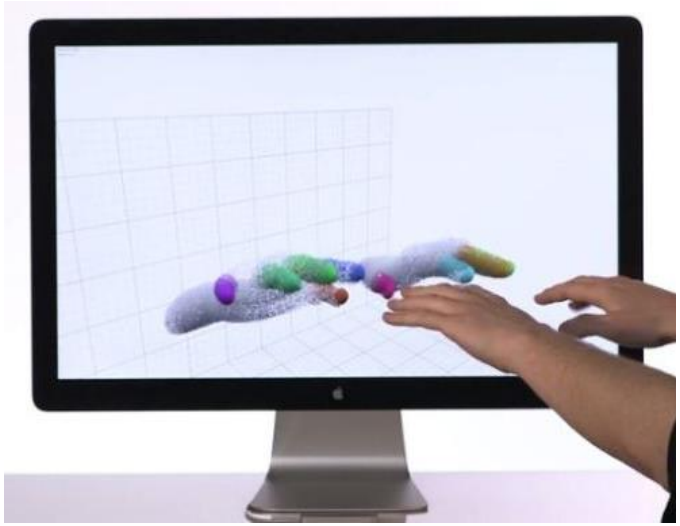
Examples of Computer Usage

- What are the needs of the large business user大型商业用户?
  - Payroll
  - Inventory
  - E-commerce
  - Desktop publishing



HOT and Future

Human-computer Interaction



```
private function loadData():Boolean {
    //@query:'busy cursor'
    //@source: http://livedocs.adobe.com/flex/3/html/cursorma
    CursorManager.setBusyCursor();

    URLLoader
    return tru
}
ript>
edApplication>
```

URLLoader

URLLoader

Flex 3 - Working with external data

http://livedocs.adobe.com/flex/3/html/17_Networking_and

```
package
{
    import flash.display.Sprite;
    import flash.events.*;
    import flash.net.URLLoader;
    import flash.net.URLLoaderDataFormat;
    import flash.net.URLRequest;
```

This system, called **Blueprint**, combines an IDE plugin and custom search engine to enable new kinds of user interactions such as

- instant Web search without leaving the IDE's code editor,
- browsing through search results that are automatically formatted in a "code-centric" format, which is more useful to programmers than plain Web pages,
- fast copy-and-paste of retrieved example code snippets into the user's code base,
- and links between the copied code and its source, to support notifications if the source gets updated.

HOT and Future

Cloud Computing

- IaaS
- PaaS
- SaaS

HOT and Future

Big data

Examples of big data

- In just four hours on "black Friday" 2012, Walmart handled 10 million cash register transactions – almost 5,000 items per second
- VISA processes more than 172,800,000 card transactions each day
- More than 5 billion people are calling, texting, tweeting and browsing websites on mobile phones

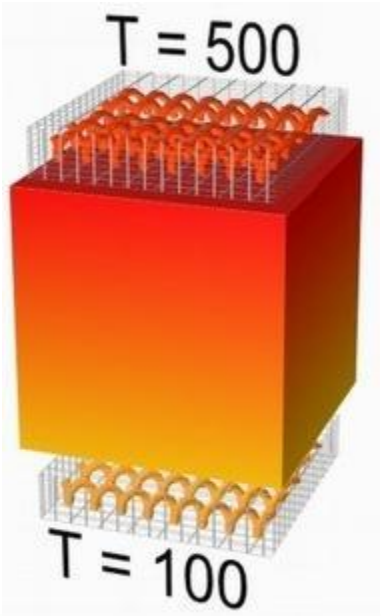
Technologies:

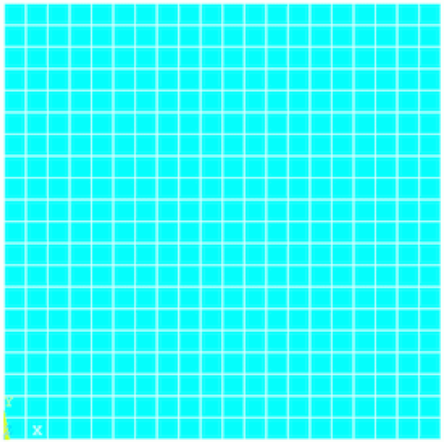
- Distributed Database (Greenplum, cluster, 支付宝)
- Distributed File System (Google GFS, Hadoop)
- Massively Parallel Processing (MPP, MapReduce)

HOT and Future

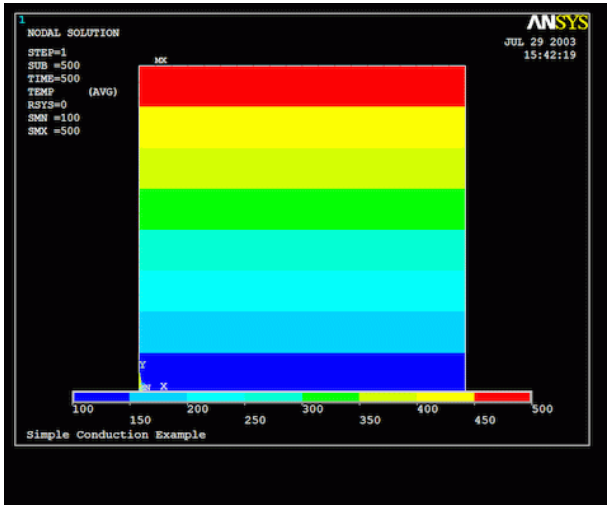
Simulation

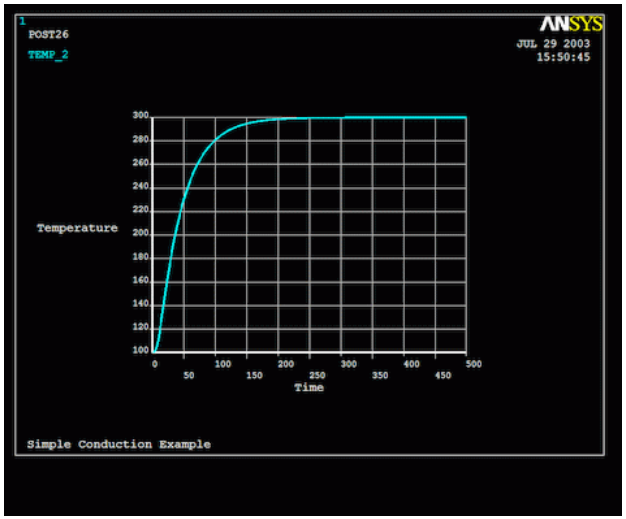
Finite Element Analysis ----- ANSYS ---- Thermal Analysis





Geometry
Type of Element
Material
Mesh
Constraints
Analysis Type
Solve
Postprocess





HOT and Future

Mobile Applications

Careers in Computing
计算机相关职业（自学）

Careers in Computing

- A systems analyst investigates the requirements of a business or organization, its employees, and its customers in order to plan and implement new or improved computer services
- A security specialist analyzes a computer system's vulnerability to threats from viruses, worms, unauthorized access, and physical damage
- A computer programmer designs, codes, and tests computer programs
- A quality assurance specialist participates in alpha and beta test cycles of software
- A database administrator analyzes a company's data to determine the most effective way to collect and store it

Careers in Computing (cont.)

- A network specialist/administrator plans, installs, and maintains one or more local area networks
- A computer operator typically works with minicomputers, mainframes, and supercomputers
- A computer engineer designs and tests new hardware products, such as computer chips, circuit boards, computers, and peripheral devices
- A technical support specialist provides phone or online help to customers of computer companies and software publishers

Careers in Computing (cont.)

- A technical writer creates documentation for large programming projects, and writes the online or printed user manuals that accompany computers, peripheral devices, and software
- A computer salesperson, or “sales rep,” sells computers
- A Web site designer creates, tests, posts, and modifies Web pages
- A manufacturing technician participates in the fabrication of computer chips, circuit boards, system units, or peripheral devices

Careers in Computing (cont.)

- The U.S. Bureau of Labor Statistics (BLS) projects that the number of jobs in the computer industry will substantially increase between now and 2008
- According to the BLS, the largest increases in available jobs will be for database administrators, computer support specialists, and computer engineers
- Over the next few years, economic trends may cause significant changes in the job market
- A daily look at in-demand tech skills can be viewed at: http://mshiltonj.com/sm/

IT Salaries in the USA 2023

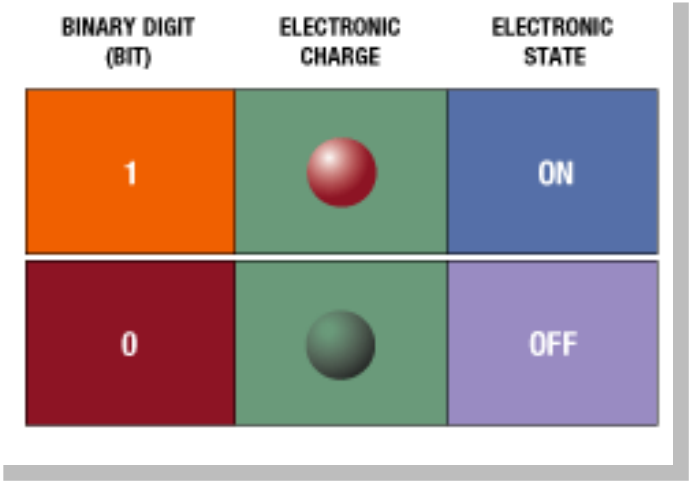
IT Role	Average Annual Salary
Information systems security manager	$157,250
Network/cloud architect	$153,750
Security architect	$143,250
Big data engineer	$141,500
Network security engineer	$131,250
Site reliability engineer	$126,750
DevOps Engineer	$125,750
Network/cloud engineer	$118,750
Systems engineer	$111,500
Database administrator	$107,750
Cloud computing analyst	$106,000
Scrum master	$104,000
Systems analyst	$99,500
Systems administrator	$88,750
Hardware analyst	$78,250
Desktop support analyst	$62,750
Product support specialist	$57,750

https://www.splunk.com/en_us/blog/learn/it-salaries.html

1.3 Data Representation
数据在计算机中的表示

Data Representation

- How do computers represent data?
- **Most computers are digital（数字）**



- Recognize only two discrete states: on or off
- Use a **binary system（二进制系统）** to recognize two states
- Use Number system with two unique digits: 0 and 1, called **bits（位）** (short for binary digits)

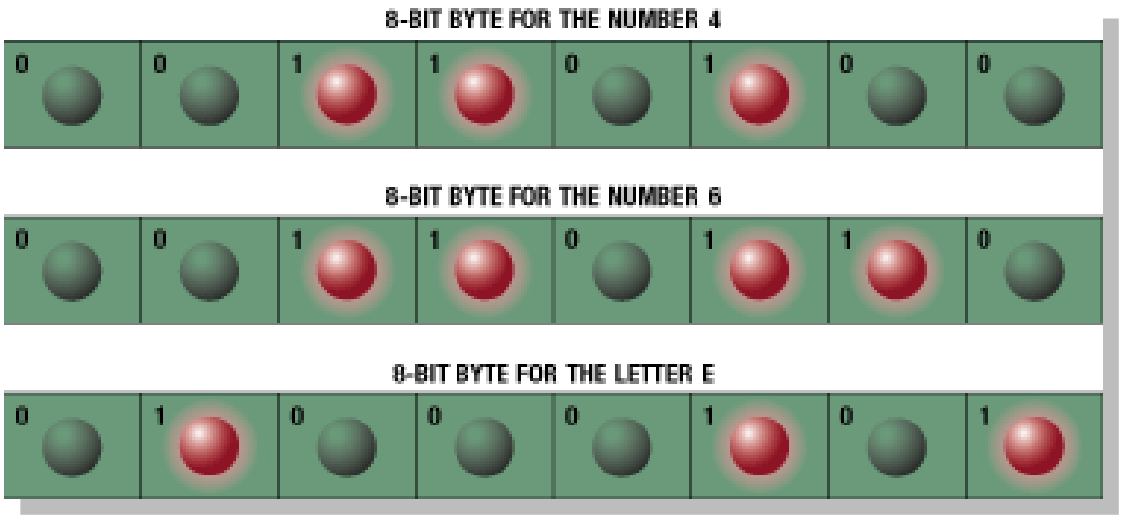
Data Representation

- What is a byte（字节）?

➢ **Eight bits grouped together as a unit**

➢ **Provides enough different combinations of 0s and 1s to represent 256 individual characters**

  - Numbers
  - Uppercase and lowercase letters
  - Punctuation marks



Data Representation: Bits and Bytes

- Recall computers are made up of electrical components
- Data can be represented electronically with electrical components being on or off.
- On and off states can be represented using digits 0s and 1s. For example:
  - 0: Off state
  - 1: On state
- Data can be represented digitally using digits 0 and 1.
  - 0 and 1 are called binary digits.
  - Each binary digit is called a bit.
  - Eight Bitsequal to one byte.

Number Systems

- Decimal（十进制）： base 10 (digits 0-9)
- Binary （二进制）： base 2 (digits 0-1)
- octal （八进制）： base 8 (digits 0-7)
- Hexadecimal （十六进制）： base16 (digits 0-9 and A-F)

Conversion Between Number Systems
数字系统之间的转换

Binary → Decimal

Decimal → Binary

Octal , Hexadecimal→ Binary

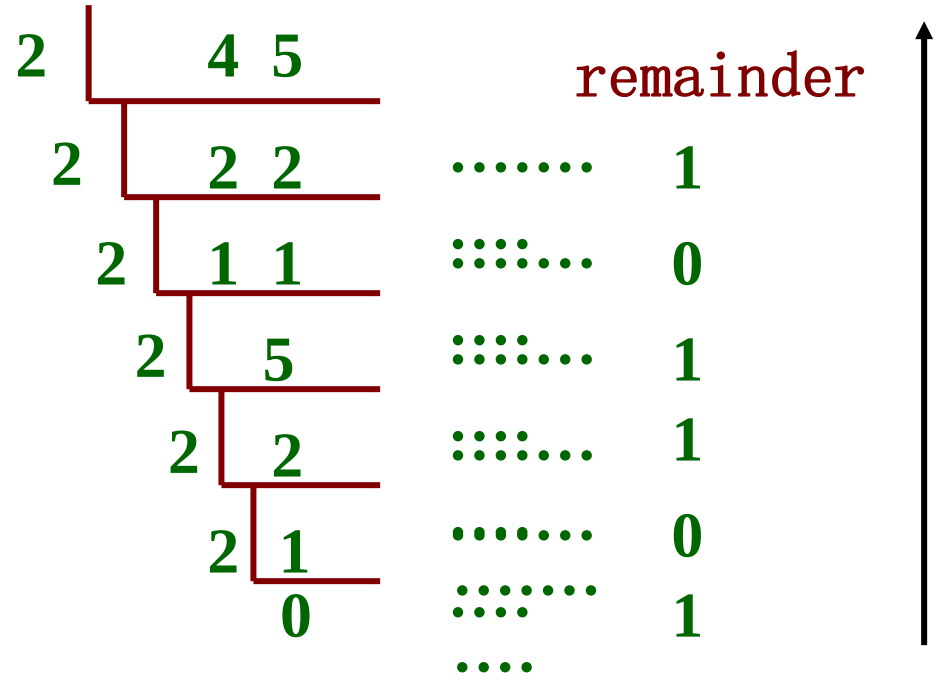
Binary → Octal , Hexadecimal

Integer → Binary

Method:

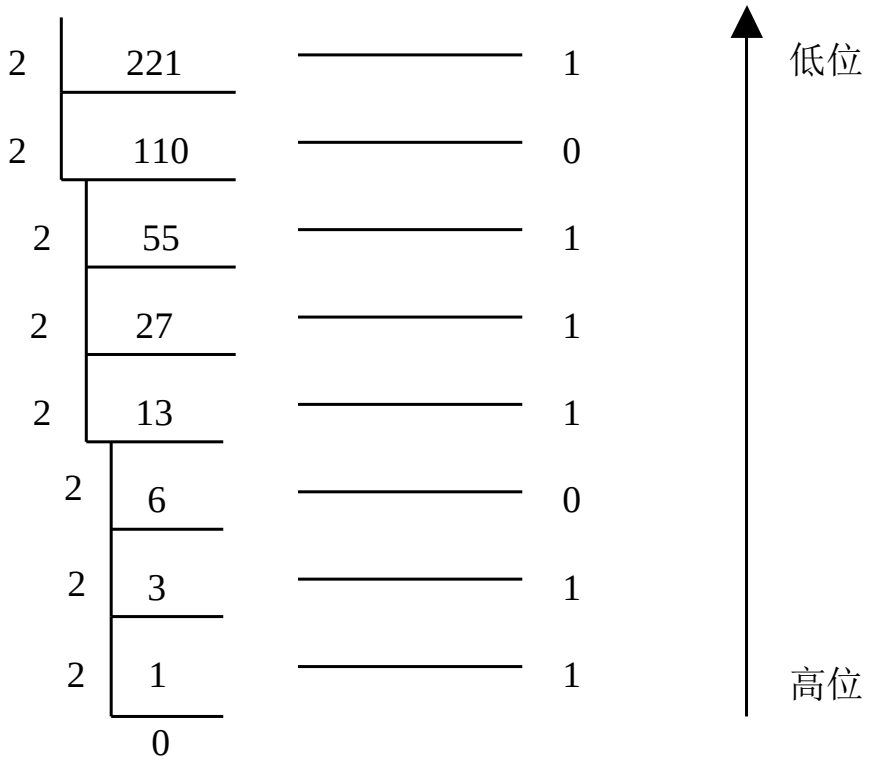
除基取余法：“除基取余，先余为低（位），后余为高（位）”。

Eg: Integer45 → Binary



Result: $(45)_{10} = (101101)_2$

Exercise：



$$(221)_{10}=(11011101)_2$$

Decimal Fraction → Binary

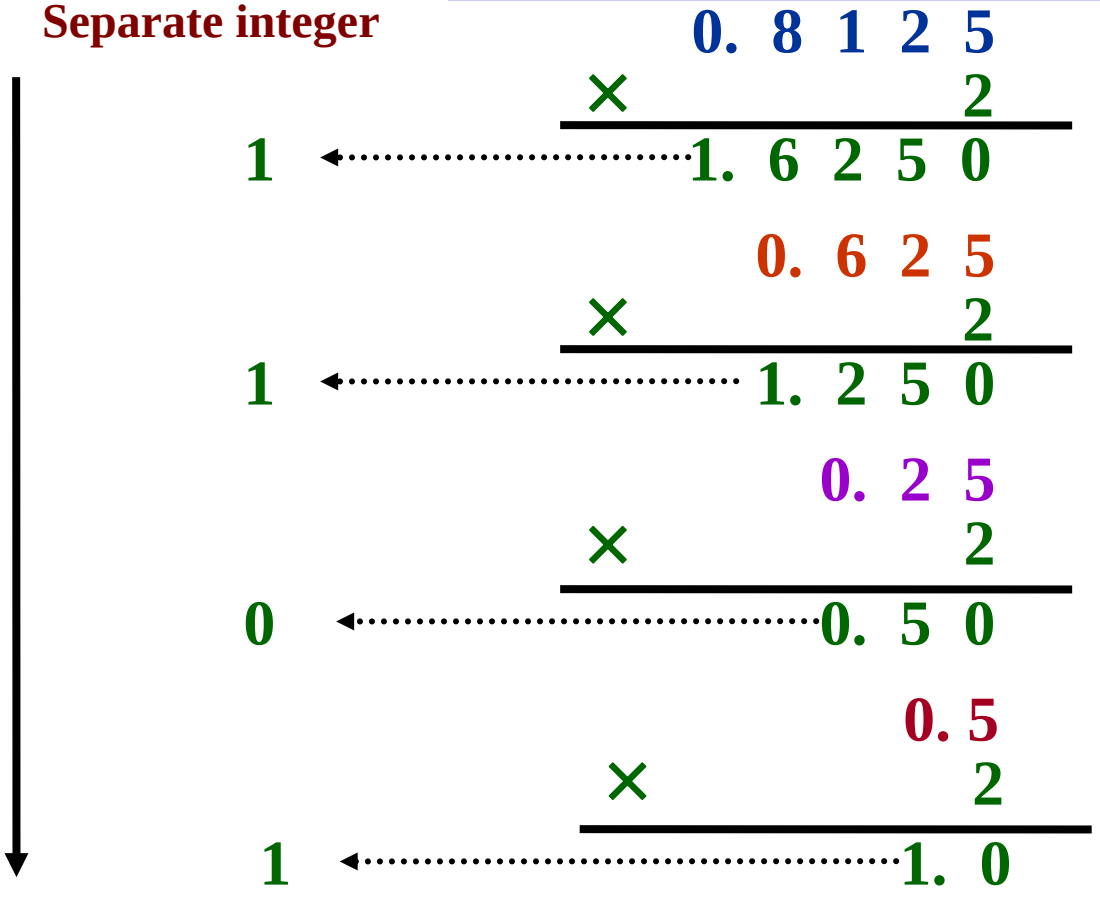
Method:

乘基取整法:“乘基取整，先整为高(位)，后整为低(位)”

Separate integer

dot.

Example:
convert decimal
0.8125 to binary



last

Result: $(0.8125)_{10} = (1101)_2$

注意：十进制小数转换为非十进制小数

- 十进制小数并不是都能够用有限位的其他进制数精确地表示，这时应根据精度要求转换到一定的位数为止，作为其近似值。
- 如果一个十进制数既有整数部分，又有小数部分，则应将整数部分和小数部分分别进行转换。

例如，将0.335转换为二进制小数，精确到0.001。

$$
\begin{array}{r}
0.335 \\
\times \quad 2 \\
\hline
0.67 \\
\times \quad 2 \\
\hline
1.34 \\
\times \quad 2 \\
\hline
0.68 \\
\times \quad 2 \\
\hline
1.536
\end{array}
$$

$$(0.335)_{10} = (0.0101\ldots)_2 \approx (0.011)_2$$

Octal , Hexadecimal→ Binary

- How to express and switch them?
  - Each hexadecimal or Octal digit represents four binary places.
  - Hexadecimal or Octal digit can be used as shorthand for binary notation
    - One Hex digit ➡ four bits
    - One byte = 8 bits ➡ two Hex digits

Octal → Binary

$2^3 = 8$　1位八进值数恰好与3位二进制数相对应　“一位拆三位

example: octal（$4675.21)_8$→binary

4	6	7	5	.2	1
↓	↓	↓	↓	↓	↓
100	110	111	101	.010	001

Process:

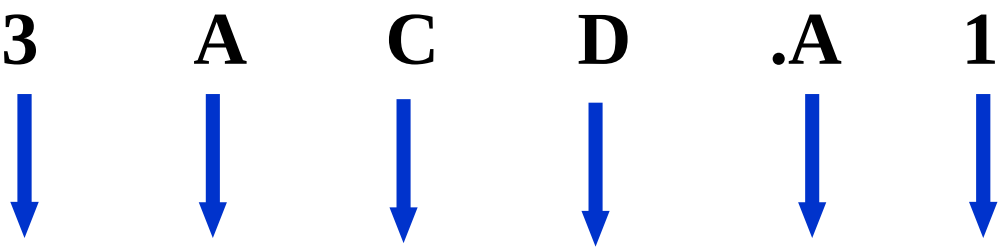
Result:　（4675.21）$_8$ =（100110111101.010001）$_2$

Hexadecimal→binary

$2^4 = 16$ **1位十六进值数恰好与4位二进制数相对应** **“一位拆四位**

example: hexadecimal（3ACD.A1)$_{16}$→binary

Process:



Result: **（3ACD.A1）$_{16}$ =（1110101100 1101.10100001）$_2$**

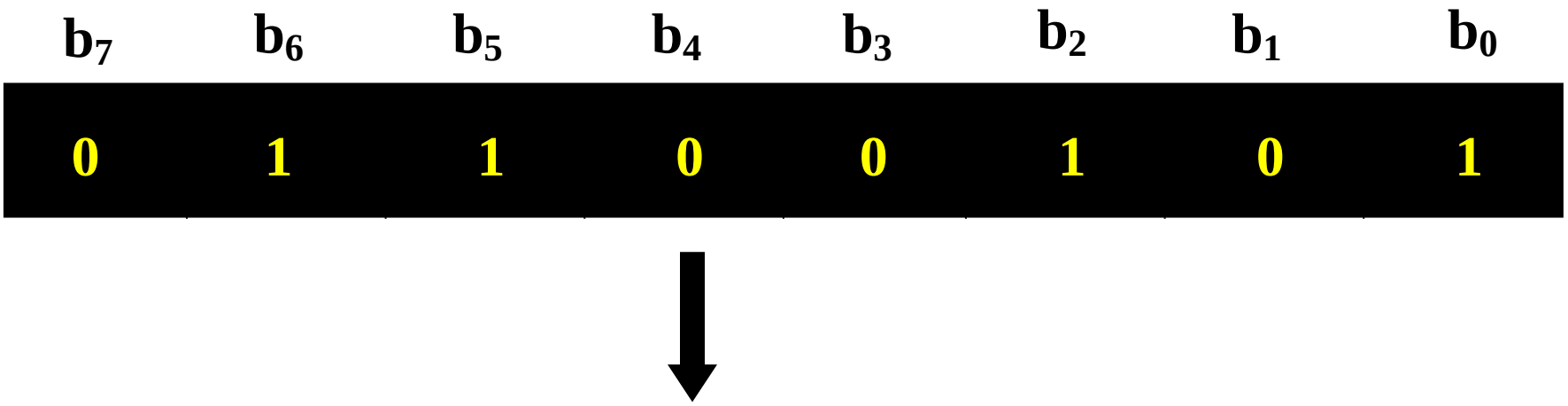
Data Representation

•What are two popular coding systems to represent data?

- **ASCII—American Standard Code for Information Interchange**
- **EBCDIC—Extended Binary Coded Decimal Interchange Code**

ASCII	Symbol	EBCDIC
00110000	0	11110000
00110001	1	11110001
00110010	2	11110010
00110011	3	11110011

Express the Data in Computer

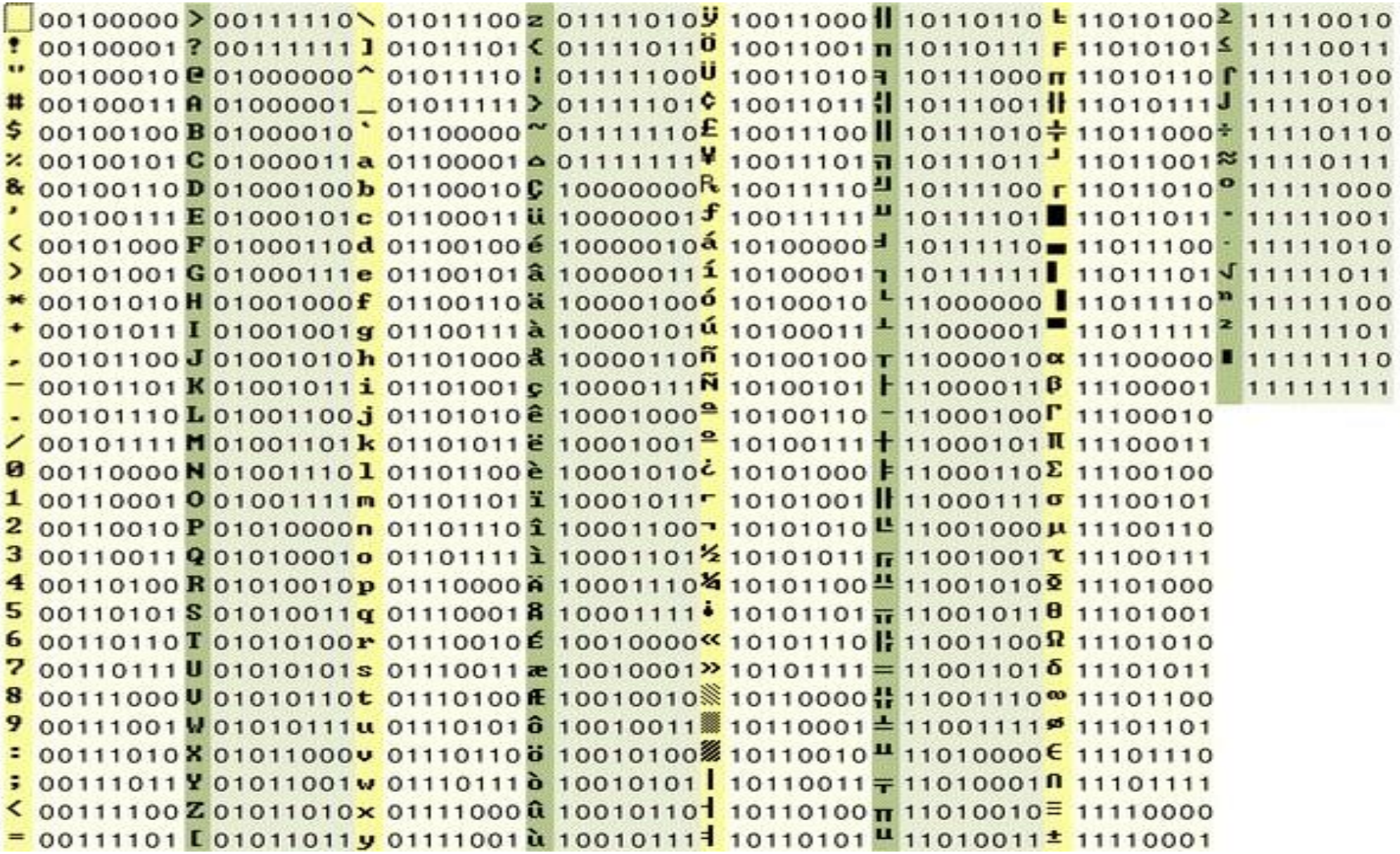


8 bits binary

ASCII Code

- ASCII stands for America Standard Code for Information Interchange
- ASCII is used to represent character data.
- For example:
  - Alphabet letter "a" can be represented as a series of eight binary digits, "01100001” using extended ASCII

Extended ASCII code



End of Unit 1

实数的表示 (补充内容)

- 实数是一个具有整数部分和小数部分的数值。例如十进制数23.7，整数部分是23，小数部分是7/10。

定点数表示法

- 在十进制系统中，假设我们使用定点数(fixed-point)表示法，两个数字在小数点右边和十四个数字在小数点左边，总共有十六个数字。在这系统中实数的精确度会不准，如果我们要表示一个十进制数例如1.00234；这系统会将此数值存成 1.00。

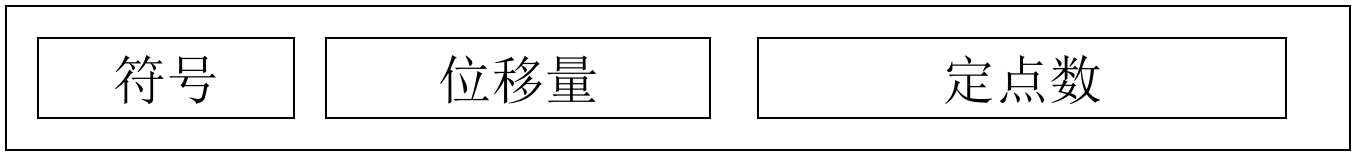
定点数表示法

- 在十进制系统中，假设我们使用定点数表示法，六个数字在小数点右边和十个数字在小数点左边，总共有十六个数字。在这个系统中实数的精确度也会不准，如果我们要表示一个十进制数例如236154302345.00，这系统会将此数值存成 6154302345.00，整数部分远小於其应有的大小。

浮点数表示法

- 保持正确性或精确度的解决方法是使用浮点数表示法(floating-point)。

- 在浮点数表示法中，一个数值是由三部分组成。第一个部分是符号，不是正就是负。第二个部分显示小数点应该从实际数值往右或往左位移多少位置。第三个部分是定点数表示法，其小数点位置是固定的。



科学计数法

- 在十进制系统中，定点数只有一个数字在小数点左边，而位移量是 10 的次方，称为科学计数法(scientific notation)。

- 例如，十进制数值 7,425,000,000,000,000,000,000.00的科学计数法表示为：

→ + 7,425,000,000,000,000,000,000.00

→ + 7.425×10^{21}

- 例如，十进制数值–0.0000000000000232的科学计数法表示为：

→ – 0.0000000000000232

→ – 2.32×10^{-14}

二进制浮点数表示

- 在二进制系统中，我们以同样的想法保持只有一个非零数字在小数点的左边。

- 例如， $-(0.000000000000000000000101)_2$的浮点数表示为：

$$\rightarrow \quad - \quad (0.000000000000000000000101)_2$$

$$\rightarrow \quad - \quad 1.01 \times 2^{-24}$$

浮点数的规范化

- 为了使表示法的定点数部分一致，科学计数法(十进制系统)和浮点数方法(二进制系统)使用在小数点左边只有一个非零数字，这称为规范化(normalization)。

→	±	d.xxxxxxxxxxxxx
→	±	1.yyyyyyyyyyyyy

注意：d取值范围是1到9而x是0到9，每个y取值范围是0或1。

- 一个二进制数值规范化之后，由符号(Sign)、位移量(指数，阶码 Exponent)和定点数(尾数，Mantissa; 有效数字, Significand)三个部分来表示例如，+1000111.0101 变成：

+	2^6	×	1.0001110101
+	6		0001110101
↑	↑		↑

注意：在二进制浮点数表示中小数点和定点数左边的位元 1 并没有被存储，它们是隐含的。

超码系统(Excess System)

- 指数有正有负，可以使用Excess System表示法，将右移的正整数和左移的负整数都表示为无符号整数。

- 要表示一个正或负整数，有一个正整数(称为偏差值 bias)要加到每一个数值以便将它们一律移动到非负数值的那一边。这个偏差值为 $2^{m-1} - 1$，其中 m 是存储指数的位数大小。

- 例如， 用4bit位元配置的数值系统来表达16个整数。使用一个位置表示 0 并且平分其余15个，可表达范围为 -7到8的数值，如图所示。如果此范围的每一个整数都加上7，我们可以将所有的整数一律往右移动并且让它们成为正数，而不必改变这些整数彼此间相关的位置。这新系统称为超7(Excess-7)系统，或偏差值为7(Bias-7)的偏移表示法。

IEEE浮点数

- 电子电气工程师协会(Institute of Electrical and Electronics Engineers；IEEE)为浮点数定义了几种标准。此处我们讨论两种最常用的标准，单精度(32-bit)和双精度(64-bit) 。

IEEE 单精度浮点数

符号 Sign	指数 Exponent	尾数 Mantissa
1 bit	8 bits	23 bits

IEEE 双精度浮点数

符号 Sign	指数 Exponent	尾数 Mantissa
1 bit	11 bits	52 bits

8 位的指数为可以表达 0 到 255 之间的 256 个指数值，偏差值为 $127=(2^{(8-1)}-1)$；指数值的实际取值范围为 -127 到 128 之间。

11位的指数为可以表达 0 到 2047 之间的 2048 个指数值，偏差值为 1023；指数值的实际取值范围为 -1023 到 1024 之间。