Chapter 1: Introduction to Computer Science

1. What is a computer?

A computer is an electronic device for storing and processing data, typically in binary form, according to instructions given to it in a variable program. [Oxford languages].

an electronic machine that is used for storing, organizing, and finding words, numbers, and pictures, for doing calculations, and for controlling other machines. [Cambridge dictionary]

2. What is computer science?

Computer science is the science that deals with the theory and methods of processing information in digital computers, the design of computer hardware and software, and the applications of computers. [Dictionary.com]

3. Evolution of Computing and Computers

The evolution of computing and computers has been marked by rapid advancements, from simple mechanical devices to complex, interconnected systems that are integral to modern life. Each era of computing mechanical, electromechanical, electronic, and digital has introduced technologies that built upon the previous generation, resulting in the sophisticated, powerful machines we rely on today. Looking forward, advancements in AI, quantum computing, and other emerging technologies promise to continue transforming the field of computing, shaping the future in unimaginable ways. This review will outline the key milestones in computing history, from early mechanical devices to the digital age and beyond.

Early Mechanical Computing Devices (Pre-19th Century)

The origins of computing can be traced back to ancient times, with tools like the **abacus** (2400 BCE) used to perform basic arithmetic operations. These early computational tools were manually operated and designed to assist in simple calculations.

In the 17th century, mathematicians and inventors began developing more sophisticated mechanical devices. **Blaise Pascal's Pascaline** (1642), for example, was a mechanical calculator capable of adding and subtracting. Later, **Gottfried Wilhelm Leibniz** developed the **Leibniz Wheel** (1673), which could perform all four arithmetic operations.
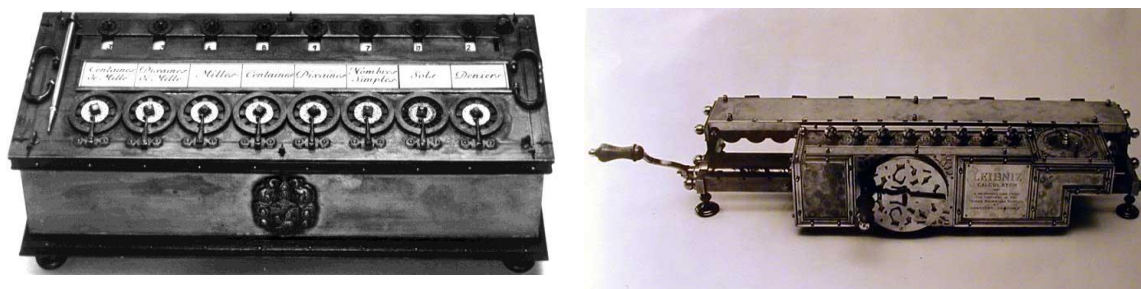
Figure 1. **by the left** The Pascaline **by the right** The Leibnitz's Wheel

These devices laid the groundwork for more advanced machines, but they remained limited in scope and application.

The Concept of Programmable Machines: Charles Babbage and Ada Lovelace (19th Century)

One of the most significant figures in the history of computing is **Charles Babbage**, an English mathematician and inventor. In the early 19th century, Babbage conceptualized and partially built the **Difference Engine**, a mechanical device designed to perform complex mathematical calculations.

His most important invention, however, was the **Analytical Engine** (1837). The Analytical Engine was never fully completed, but it introduced many concepts that would later become foundational to computing, such as:

- **Programmability**: The machine was designed to be programmable via punched cards.

- **Memory and Logic**: It had a "memory" unit and a processing unit (the "mill") that could perform a variety of calculations based on instructions.

Babbage's ideas were revolutionary for their time, but they were far ahead of the available technology. Nevertheless, they influenced the future of computing. **Ada Lovelace**, a mathematician and close collaborator with Babbage, is credited with writing the first algorithm intended for a machine (the Analytical Engine), making her the world's first computer programmer.
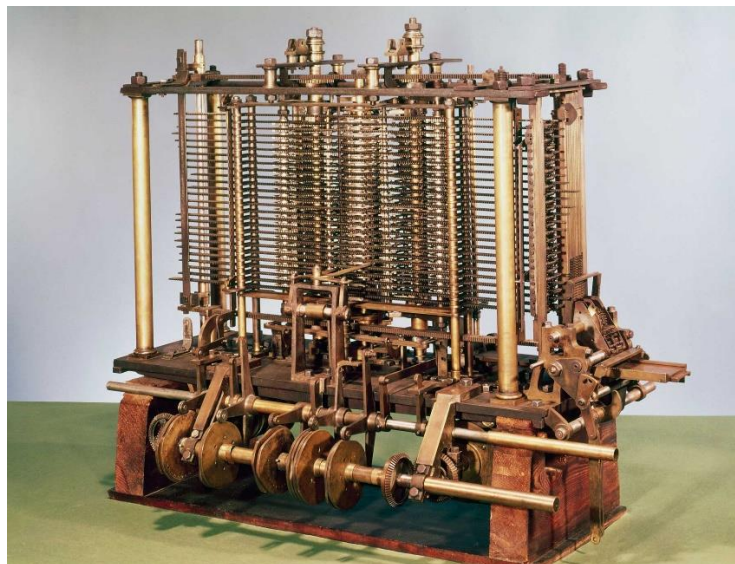

Figure 2. Analytical Engine

Electromechanical Computers and the Dawn of Digital Computing (Early 20th Century)

The 20th century saw a shift from mechanical to electromechanical computing. **Alan Turing**, often considered the father of modern computer science, developed the concept of the **Turing machine** (1936), a theoretical device capable of simulating any computer algorithm. His work provided the mathematical underpinnings of computation and algorithm theory.

During World War II, computing technology accelerated. Machines like **Konrad Zuse's Z3** (1941) and the **Colossus** (1943) were among the first working electromechanical and electronic computers. The **ENIAC** (Electronic Numerical Integrator and Computer), completed in 1945, was one of the first fully electronic general-purpose computers.
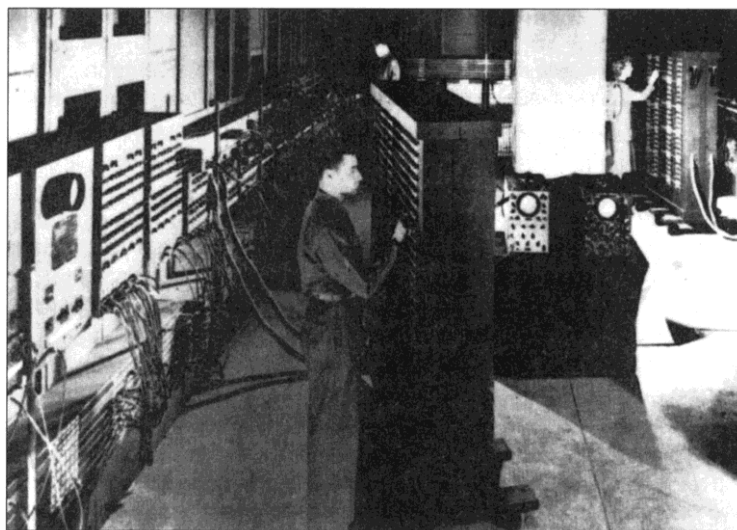
Figure 3. Photograph of the ENIAC Computer

These machines were monumental, but they were large, complex, and consumed vast amounts of power. However, they demonstrated the potential for computers to be used in practical applications such as cryptography, artillery calculations, and scientific research.

The Transistor and Integrated Circuits: Mid-20th Century Breakthroughs

One of the most pivotal moments in the evolution of computers was the invention of the **transistor** in 1947 by **John Bardeen, William Shockley, and Walter Brattain** at Bell Labs. The transistor replaced the bulky vacuum tubes that early computers relied on, allowing for smaller, faster, and more reliable machines. Transistors revolutionized computer design, making computers more energy-efficient and significantly reducing their size.

The next major development came with the invention of the **integrated circuit** (IC) in 1958 by **Jack Kilby** and **Robert Noyce**. ICs allowed multiple transistors to be placed on a single chip, further miniaturizing and improving the performance of computers. This innovation led to the development of **mainframe computers** in the 1950s and 60s, which were large, powerful machines used by businesses, governments, and research institutions.

Programming languages also evolved during this period, with the introduction of **FORTRAN** (1957) and **COBOL** (1959), allowing computers to be used for a wider range of applications.

The Personal Computer Revolution (1970s-1980s)

The 1970s and 1980s marked a significant shift as computers became more accessible to the general public. The introduction of the **microprocessor** in 1971 by **Intel**—specifically the Intel 4004—enabled the development of smaller, cheaper computers that could be used by individuals and small businesses.

The **Altair 8800** (1975) is often credited as the first commercially successful personal computer (PC). It inspired a wave of innovation, leading to the development of the **Apple I** (1976) and later the **Apple II** (1977) by **Steve Jobs** and **Steve Wozniak**. The Apple II was one of the first PCs to gain widespread popularity.

In 1981, **IBM** entered the market with its **IBM PC**, solidifying the personal computer as a mainstream product. This era also saw the rise of software giants like **Microsoft**, which developed the **MS-DOS** operating system for IBM PCs, and later the **Windows** operating system, which became the dominant platform for personal computing.
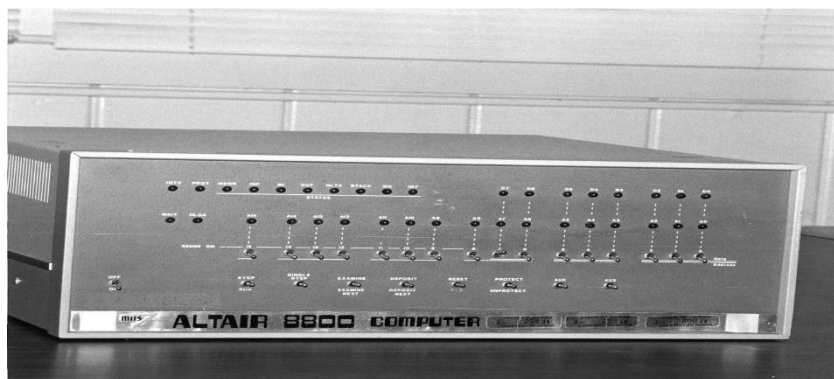
Figure 4. The Altair 8800, the World's First Microcomputer

The Internet and the Rise of Modern Computing (1990s-Present)

The 1990s ushered in the age of the **Internet**, which fundamentally transformed how computers were used. The development of the **World Wide Web** by **Tim Berners-Lee** in 1989 made the Internet accessible to everyday users and led to an explosion of web-based applications, e-commerce, and social media.

In parallel, **Moore's Law**—the observation that the number of transistors on a chip doubles approximately every two years—continued to hold, driving exponential growth in computing power. **Smartphones**, **tablets**, and **cloud computing** emerged in the 2000s, making computing even more ubiquitous.

Today, the rise of **artificial intelligence** (AI), **machine learning**, and **quantum computing** represents the cutting edge of computing technology. AI-powered systems can process vast amounts of data and perform tasks that once required human intelligence, while quantum computers promise to solve problems that are currently intractable with classical computers.

4. Number Systems and Base Conversions

a. The Decimal System

The decimal number system has the value of the base as 10. Thus, in the decimal system we have 10 different digits, which are 0; 1; 2; 3; 4; 5; 6; 7; 8; and 9.

Example:

$427=400+20+7=4*10^2 + 2 *10^1 + 7*10^0$

The decimal number system is great for calculations done by humans, but it is not a suitable system for a computer to use.

b.The Binary System

A digital computer contains elements that can be in either of two states: on or off. We sometimes even see an electrical switch with two numbers 0 and 1 where 0 means off while 1 means on.

The binary number system is also a positional notation numbering system, but in this case, the base is not ten, but is instead two. Each digit position in a binary number represents a power of two. So, when we write a binary number, each binary digit is multiplied by an appropriate power of 2 based on the position in the number.

Example:

$101101_2 = 1*2^5+ 0*2^4 +1*2^3 +1*2^2+0*2^1+1*2^0$

Conversion between Decimal and Binary numbers
Converting a number from binary to decimal is quite easy. All that is required is to find the decimal value of each binary digit position containing a 1 and add them up.

Example:

$10110_2=1*2^4 +0*2^3 +1*2^2+1*2^1+0*2^0$

$= 16+4+2$

$= 22$

Conversion between Decimal and Binary numbers
The method for converting a decimal number to binary is one that can be used to convert from decimal to any number base.

It involves using successive division by the base until the dividend reaches 0. At each division, the remainder provides a digit of the converted number, starting with the least significant digit.

Example:

$37/2 = 18$ remainder 1

18/2=9 remainder 0

9/2=4 remainder 1

4/2=2 remainder 0

2/2=1 remainder 0

1/2= 0 remainder 1

The resulting binary number is *100101*

c.Octal Number System

The octal numeral system is the base 8 number system, and uses the digits 0, 1, 2…, 7.

Conversion From Binary to Octal
Octal numerals can be made from binary numerals by grouping consecutive binary digits into groups of three (starting from the right) and add zeros on the left as needed. For example:

1001010= (001)(001)(010)

Thus

1001010_2= (001)(001)(010)=112_8

In the octal system each place is a power of eight. For examples:

$112_8 = 1*8^2+1*8^1+2*8^0=64+8+2=74$

Conversion From Octal to Binary
Replace each octal digit with the corresponding 3-bit binary string. For examples:

213_8=(010)(001)(011)=10001011_2

Conversion From Octal to Decimal
The conversion can be performed in the conventional mathematical way, by showing each digit place as an increasing power of 8. For example:

*345_8 =$(3*8^2)+(4*8^1)+(5*8^0)$=(3*64)+(4*8)+(5*1) = 229_{10}*

Conversion of decimal to octal (base 10 to base 8)
Example:

177/8=22 remainder 1

22/8=2 remainder 6

2/8=0 remainder 2

Thus

$177_{10} = 261_8$

d.Hexadecimal number system

Another number system often used in computer. The hexadecimal numbers are also called Hex in short. This number system has 16 symbols. Those are: 0 , 1 , 2 , 3 , 4 , 5 , 6 , 7, 8, 9, A, B, C, D, E, F.

Conversion of hex to decimal (base 16 to base 10)
Example:

$FAC_{16} = (F*16^2) + (4*16^1)+(C*16^0)= (15*256)+(4*16)+(12*1) =$

Conversion of decimal to hex (base 10 to base 16)
Example:

$4768/16=298$ remainder 0

$298/16 = 18$ remainder 10=A

$8/16=1$ remainder 2

$1/16=0$ remainder 1

Thus

$4768_{10} = 12A0_{16}$

5. A Brief Review of Computer Components

A computer is a complex system made up of various components, each playing a crucial role in its functionality. These components can be categorized into two main types: **hardware** (the physical parts) and **software** (the programs and data).

a.Hardware:

Each component of a computer plays a vital role in its overall performance. The CPU processes instructions, the RAM and storage manage data, and the motherboard connects everything. Devices like GPUs, power supplies, and cooling systems ensure that the computer runs efficiently, while input and output devices facilitate user interaction. Together, these components make modern computing possible.

Below is a summary of the essential hardware components that make up a computer.

1. Central Processing Unit (CPU)

The **CPU** is often referred to as the "brain" of the computer. It performs all the calculations and processes instructions from software applications. The CPU consists of two main parts:

- **Control Unit (CU)**: Directs the operation of the processor by interpreting instructions.

- **Arithmetic Logic Unit (ALU)**: Handles all arithmetic and logical operations.

Modern CPUs are multi-core, meaning they can process multiple tasks simultaneously, improving performance.

2. Memory (RAM)

Random Access Memory (RAM) is the computer's short-term memory. It temporarily stores data that the CPU needs to access quickly while running applications. The more RAM a computer has, the better it can handle multiple tasks simultaneously. RAM is volatile, meaning it loses its data when the computer is turned off.

3. Storage (HDD/SSD)

Storage devices are used for long-term data retention. There are two primary types:

- **Hard Disk Drives (HDDs)**: Traditional storage devices that use spinning disks to read and write data. They offer large storage capacities but are slower than SSDs.

- **Solid-State Drives (SSDs)**: Modern storage devices that use flash memory, providing faster data access and better reliability compared to HDDs. SSDs have become the preferred choice in most new computers due to their speed.

4. Motherboard

The **motherboard** is the main circuit board that connects all the computer's components. It houses the CPU, RAM, storage interfaces, and other key components. The motherboard also contains expansion slots for additional hardware like graphic cards or sound cards and provides connectivity for input and output devices.

5. Power Supply Unit (PSU)

The **Power Supply Unit** converts electricity from an outlet into usable power for the computer's components. It supplies the necessary voltage and current to ensure that all parts of the computer can function properly. A reliable PSU is critical for the stability and performance of a system.

6. Graphics Processing Unit (GPU)

The **GPU** is responsible for rendering images, videos, and animations. While the CPU can handle graphical tasks, a dedicated GPU is more efficient for rendering high-quality graphics and handling intensive tasks like video editing and gaming. GPUs are essential for tasks that require parallel processing, such as machine learning.

7. Input/Output Devices

These devices allow the user to interact with the computer and receive information from it:

- **Input Devices**: Devices like keyboards, mice, and microphones that allow users to provide data to the computer.

- **Output Devices**: Devices like monitors, printers, and speakers that display or output data from the computer.

8. Cooling System

Computers generate heat as they operate, especially during intensive tasks. **Cooling systems**, including fans and heat sinks, are essential for dissipating this heat and ensuring the components remain at an optimal temperature. High-end systems may also use liquid cooling for more effective temperature management.

b.Software:

Computer software refers to the set of instructions, programs, and data that direct a computer on how to perform specific tasks. Unlike hardware, which is the physical part of a computer, software is intangible and operates in the background or as visible applications to users. There are two primary categories of computer software: **system software** (which manages hardware and system resources) and **application software** (which allows users to complete tasks) forms the core structure of how computers operate. Together, these layers of software enable computers to be functional, versatile, and user-friendly tools for various applications.

 Here's a brief overview of each:

1. System Software

System software manages the hardware and provides a platform for running application software. It acts as an intermediary between the user and the computer's hardware. The main types of system software include:

- **Operating System (OS)**: The OS is the most critical system software, managing all hardware resources, running applications, and providing an interface for users. Examples of popular operating systems include:
    - **Windows** (by Microsoft)
    - **macOS** (by Apple)
    - **Linux** (open-source)
- **Device Drivers**: Device drivers are specialized programs that allow the operating system to communicate with hardware components like printers, network cards, and graphics cards. Each hardware device needs a driver for the OS to manage its functions.
- **Utility Programs**: These programs perform maintenance tasks to ensure the smooth functioning of a computer, such as disk cleanup, virus scanning, file management, and system backups. Examples include **antivirus software**, **disk defragmenters**, and **file compressors**.

2. Application Software

Application software refers to programs designed to help users perform specific tasks beyond the basic functions of the computer. These can range from productivity tools to entertainment software. The most common types of application software include:

- **Productivity Software**: These are programs used for office work and productivity tasks such as word processing, spreadsheets, presentations, and database management. Examples include:

    o **Microsoft Office Suite** (Word, Excel, PowerPoint)

    o **Google Workspace** (Docs, Sheets, Slides)

- **Web Browsers**: Software used to access and navigate the internet. Popular browsers include **Google Chrome**, **Mozilla Firefox**, and **Safari**.

- **Media Players**: These programs allow users to play audio and video files. Examples include **VLC Media Player**, **Windows Media Player**, and **iTunes**.

- **Graphics and Design Software**: These programs are used for editing photos, creating illustrations, or designing graphics. Examples include **Adobe Photoshop**, **CorelDRAW**, and **GIMP**.

- **Games**: Gaming software ranges from simple, casual games to complex, high-performance titles. Examples include **Fortnite**, **Minecraft**, and **Call of Duty**.

3. Programming Software

Programming software consists of tools and environments used by developers to write, test, and debug computer programs. This category includes:

- **Text Editors**: Basic tools like **Notepad++** or **Visual Studio Code** for writing code.

- **Integrated Development Environments (IDEs)**: Advanced environments that combine code writing, debugging, and compiling into one tool (e.g., **Eclipse**, **IntelliJ IDEA**, **Visual Studio**).

- **Compilers/Interpreters**: Software that translates programming languages into machine-readable code so the computer can execute the program.