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Introduction to Computing

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What is Computer Science?

- ***Computer Science*** is the scientific study of computation, theoretically and in practice, as the basis for determining what problems can be computed.

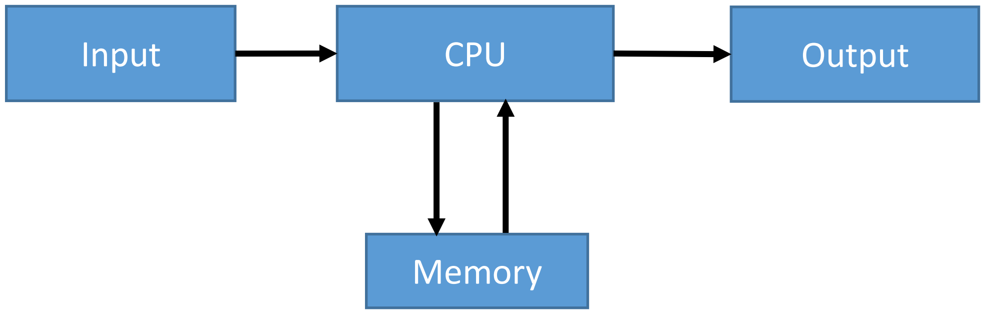
- Computer Science is **not** just the study or use of computers.
  - It’s a branch of mathematics.
  - Computers are the tools we use.

- Some things change every day (new tech) and some things never change (math and logic).
  - This course is about the things that never change.

What is a computer?

- A ***computer*** is a device or machine that is capable of performing arithmetic and/or logical operations.
  - A modern definition would include the capability of storing and processing information.

- A modern computer system is comprised of:
  - Central Processing Unit
  - Memory
  - Input
  - Output



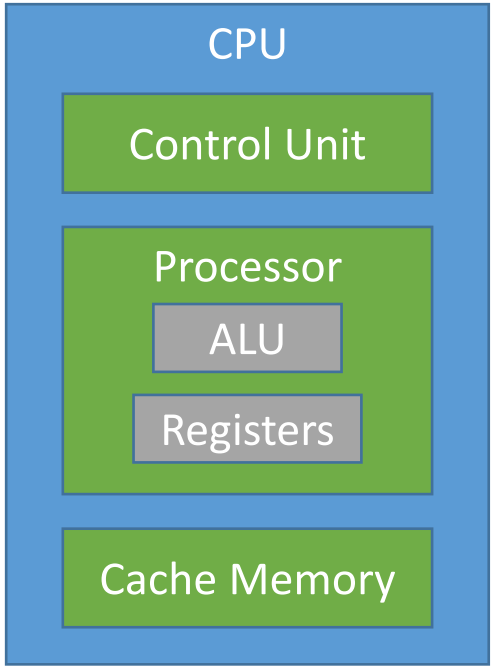
Hardware and Software

- ***Hardware*** is any component of a computer that you can physically touch.
  - Processors, disk drives, RAM, monitors, keyboards, and mice.

- ***Software*** is any intangible component of a computer.
  - Operating systems, applications, pictures, videos, and files.

Central Processing Unit (CPU)

- The Central Processing Unit is a piece of computer hardware that performs the instructions of computer programs.
  - Performs logical and arithmetic operations.
- Control Unit (CU)
  - Governs how instructions are carried out by the processor.
- Arithmetic Logic Unit (ALU)
  - Performs arithmetic and logical operations.
- Registers
  - Small amounts of memory available to the processor.
  - Single numbers and instructions.
- Cache Memory
  - Larger amount of memory available to the CPU.
  - Holds values recently sent to or retrieved from main memory for faster recall.



Memory Hierarchy

1. Registers
   - *Stores data being used right now*
2. Cache
   - *Stores data used recently*
3. Main Memory
   - *Stores data that might be needed later*
4. Secondary Storage
   - *Stores data even after the computer is powered off*
   - E.g. Hard Drives

Computer Generations

- Zeroth Generation – Mechanical Computers (1640s – 1940s)
- First Generation – Vacuum Tubes (1940s – 1950s)
- Second Generation – Transistors (1950s – 1960s)
- Third Generation – Integrated Circuits (1960s – 1980s)
- Fourth Generation – Very Large Scale Integration (1980s – Present)

Mechanical Computers

- No electricity.*
  - Operated by hand.
  - *Some used electromechanical parts near the end of the generation.

- Typically made of wood and metal.

- More sophisticated than other tools like an abacus or slide rule.

The Pascaline

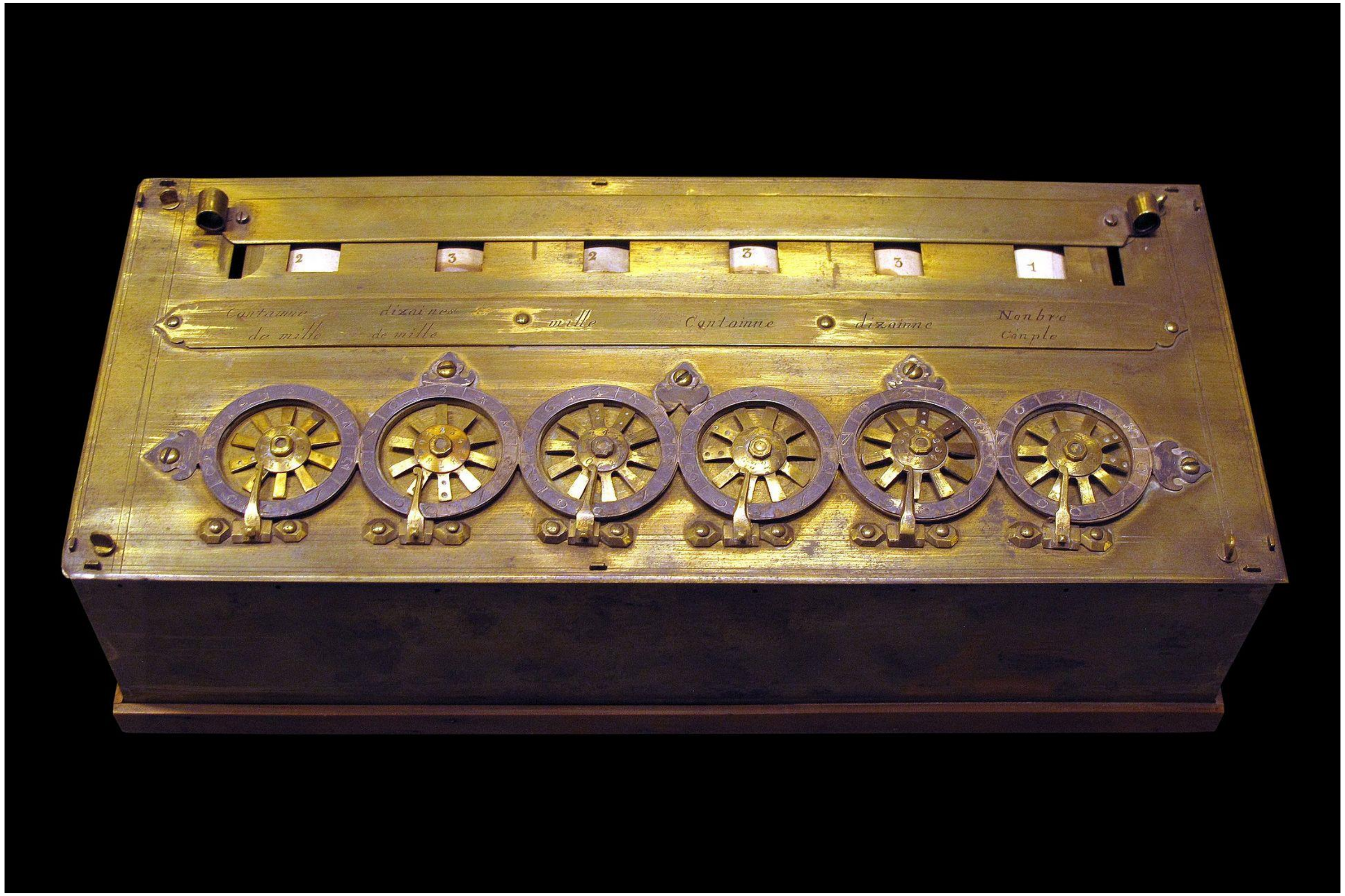
- Also known as Pascal's Calculator

- Invented by Blaise Pascal
  - French mathematician

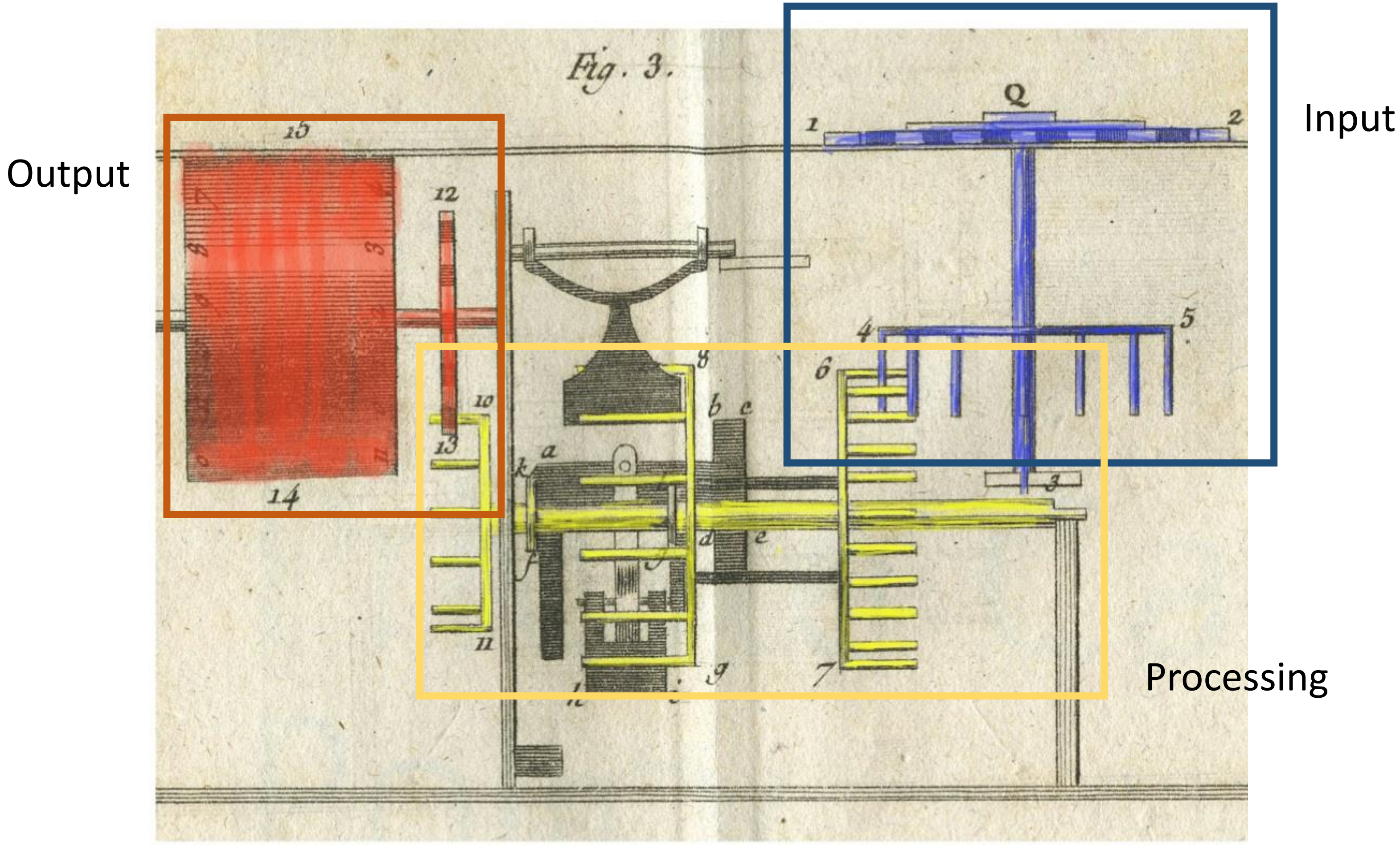
- Started work in 1642 (20 years old)
  - Finished in 1645

- Only made about 2 dozen.

The Pascaline



The Pascaline



The Pascaline

- Could add and subtract.

- Could multiply and divide (using repeated addition or subtraction).

- Had a few variations:
  - Scientific
  - Accounting
  - Land Surveying

[Pascaline Simulation Video]

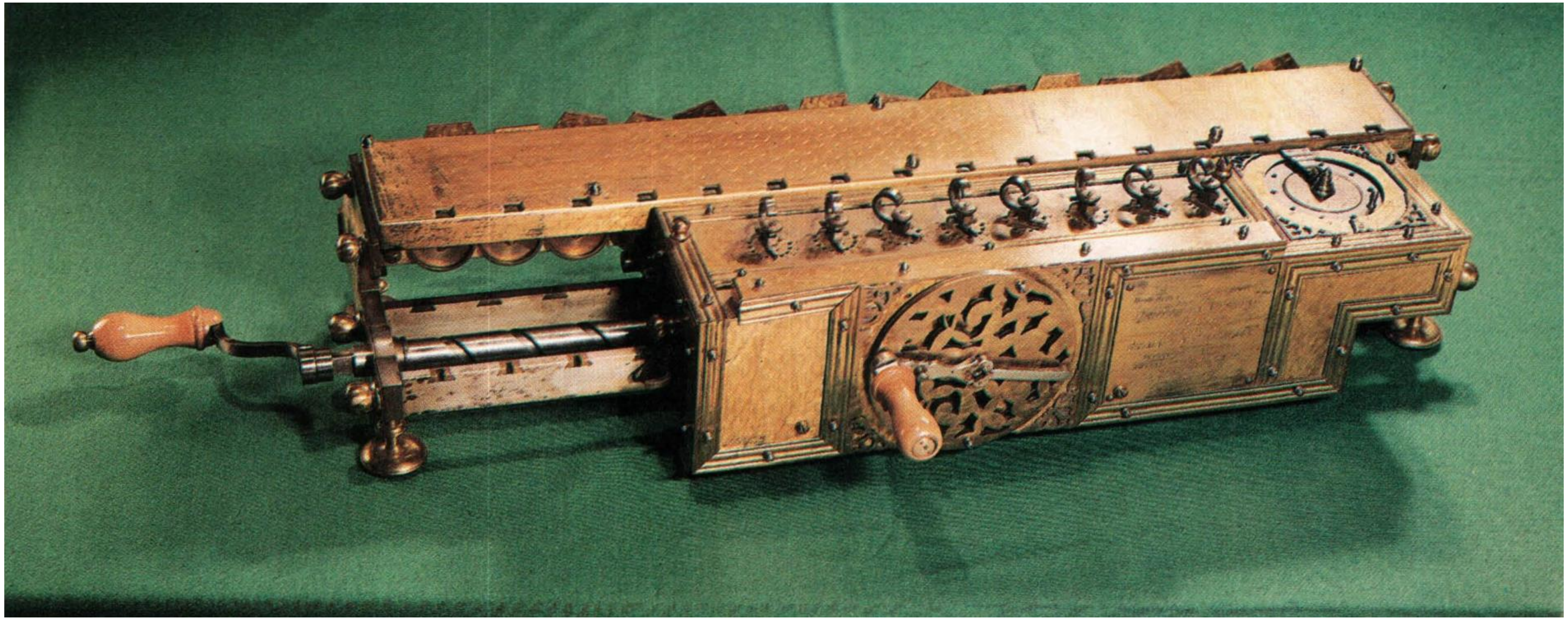
Leibniz Wheel/Stepped Drum

- Invented by Gottfried Leibniz
  - German mathematician
- Created in 1673
- Heavily influenced by the Pascaline.
  - Wanted to design a device that could add, subtract, multiply, and divide.

Stepped Reckoner

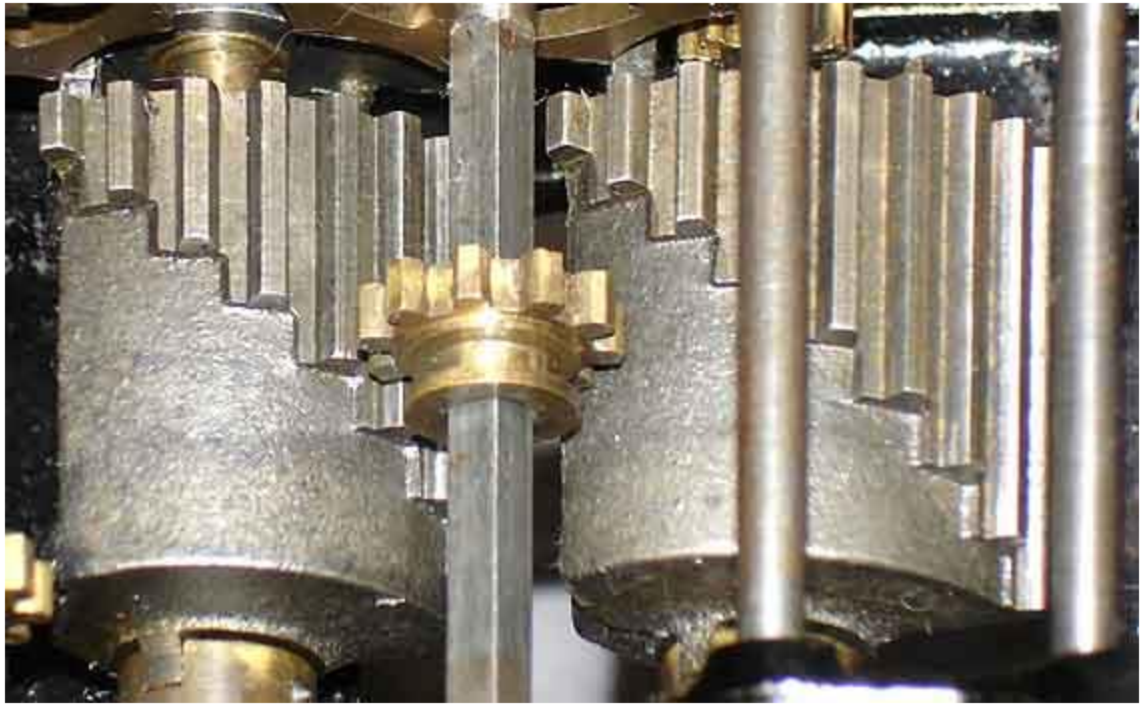
- Invented by Gottfried Leibniz
- Completed in 1694
- Could add, subtract, multiply, and divide.
- Required very precise components
  - Reliability problems

Stepped Reckoner



Leibniz Wheel/Stepped Drum

[Stepped Drum Simulation Video]



Stepped Reckoner

- Never brought to market.
  - Only two prototypes
  - Showed the potential/possibility of this concept

- The Leibniz Wheel was used in many other mechanical calculators through the 1970s.

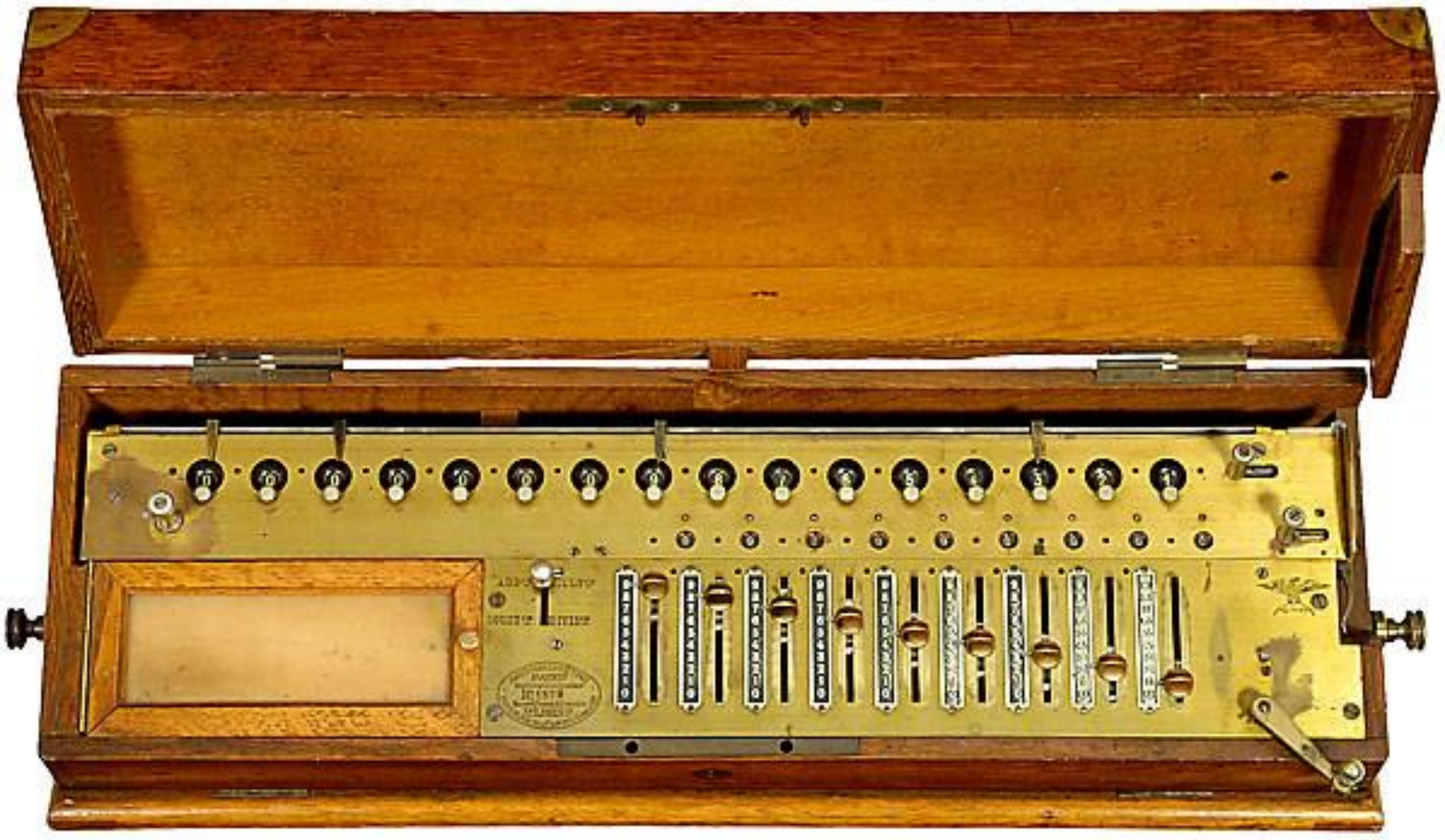
Arithmometer

- Created by Charles Thomas
  - French Inventor

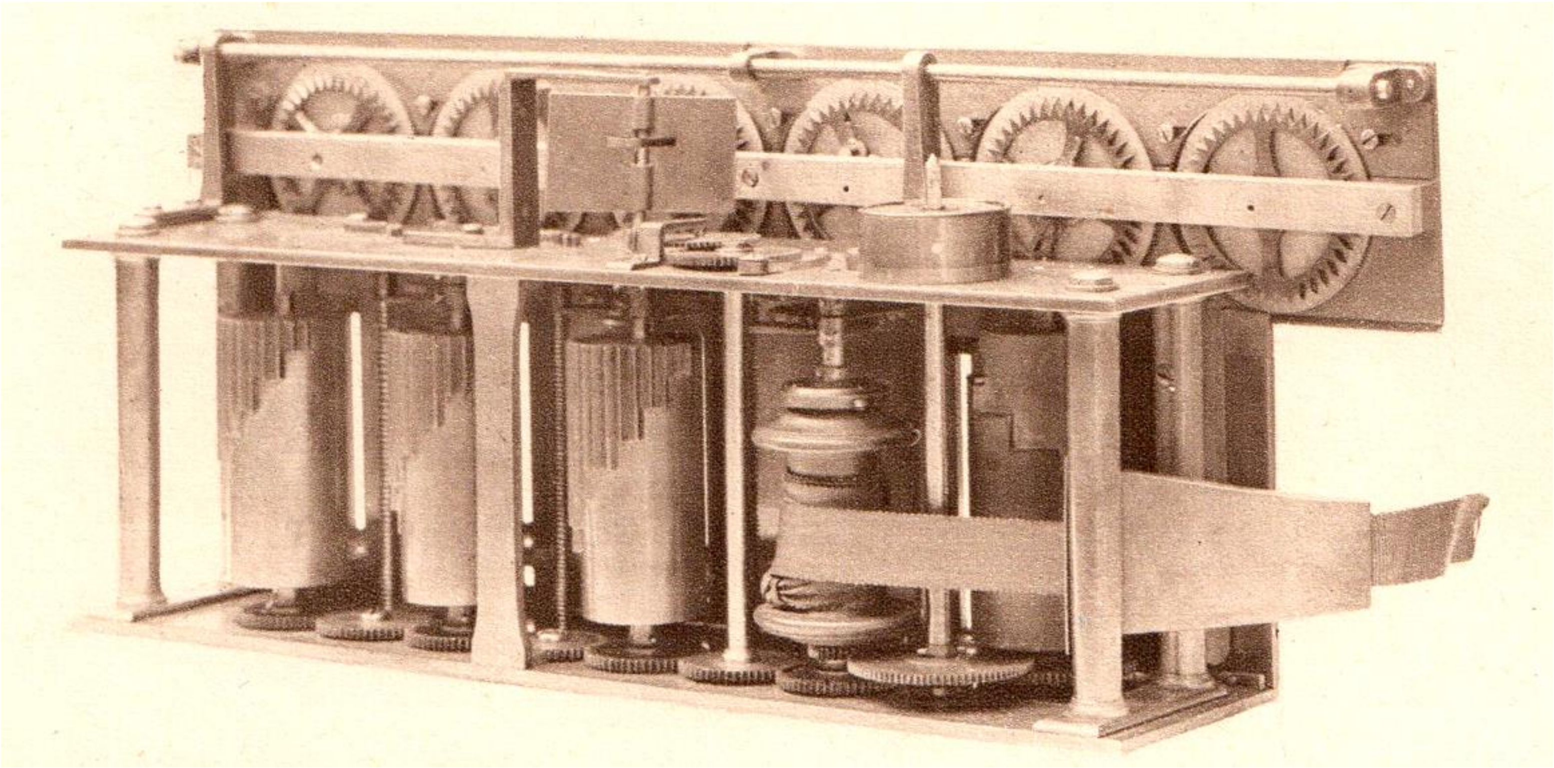
- First commercially successful mechanical calculator
  - 1850s to 1890s – only commercially available mechanical calculator.

- Utilized concepts from the Pascaline and Stepped Reckoner.

Arithmometer



Arithmometer



[Arithmometer Simulation Video]

Curta

- Created by Curt Herzstark
  - Austrian Engineer
- First successful portable calculator (1950s/1960s)
  - Up until electronic handheld calculators came out in the 1970s.
- Utilized concepts from the Stepped Reckoner and Arithmometer.

[Curta Simulation Video]

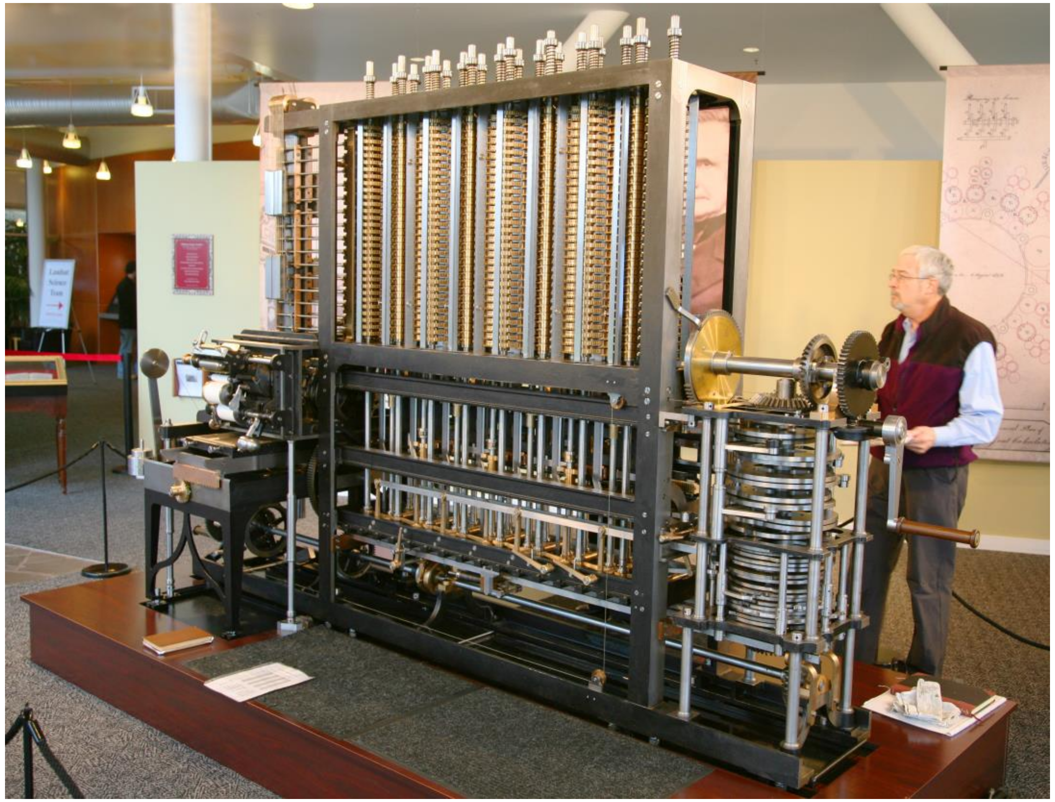
Difference Engine

- First theorized in the late 1700s.

- Could tabulate polynomial functions.

- Prototype (Difference Engine No. 0) was completed by Charles Babbage in 1822
- Difference Engine No. 1 was planned and funded but not completed.
- Difference Engine No. 2 was designed but never built.

Difference Engine



Difference Engine Simulation Video (Part 1)

Difference Engine Simulation Video (Part 2)

Difference Engine Simulation Video (Part 3)

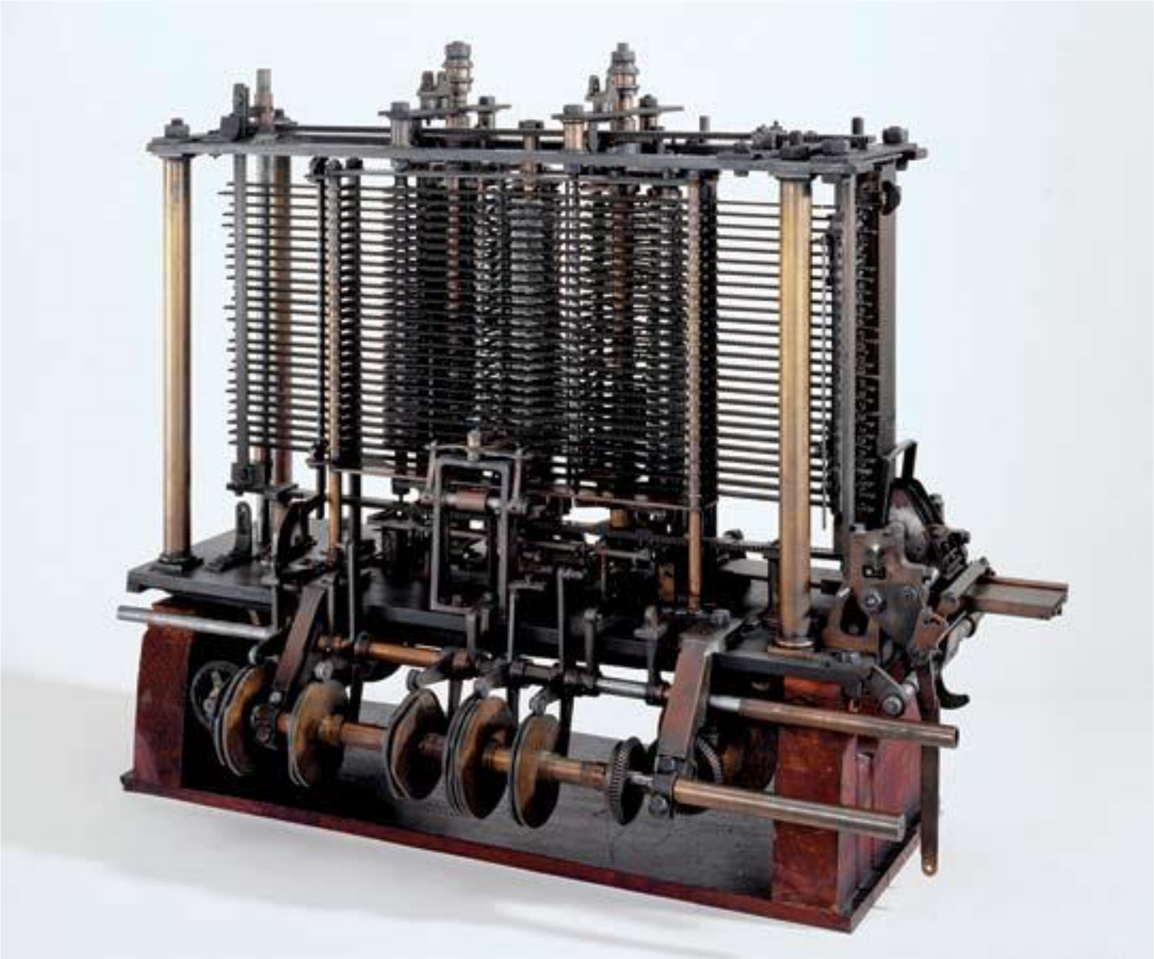
Difference Engine Simulation Video (Part 4)

Difference Engine Simulation Video (Part 5)

Analytical Engine

- Babbage's next project.
  - Started in the 1830s
- Designed to be general-purpose and programmable.
  - Programmed using cards with holes in them (***punched cards***)
- Construction was never completed.
  - It was ahead of its time.
  - The first working general-purpose computers wouldn't come around for another 100 years.

Analytical Engine

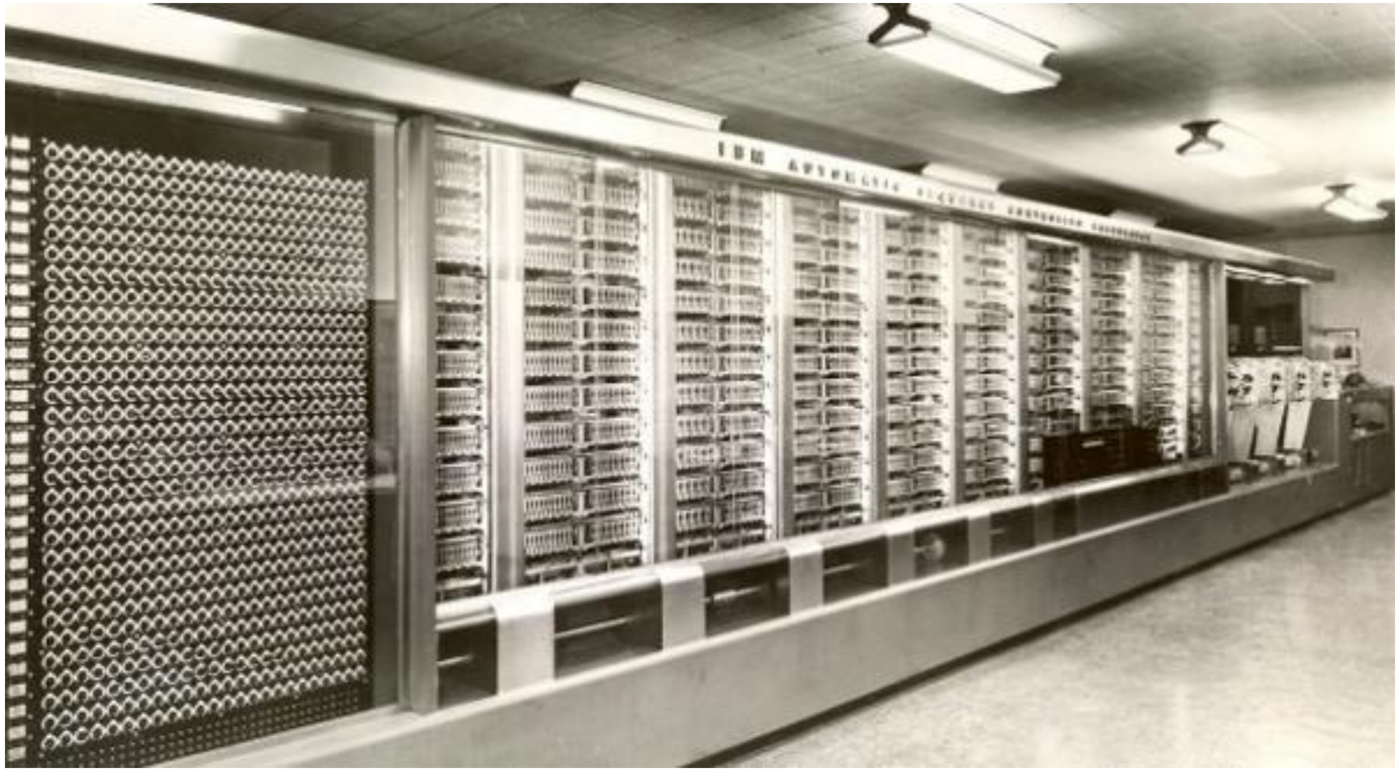


[Analytical Engine Simulation Video]

Harvard Mark I

- Designed by Howard Aiken/IBM
  - 1930s – 1940s
- Automatic, general-purpose and programmable.
- Among the first to use electromechanical parts
- Computed and printed mathematical tables.
  - Influenced by the Analytical Engine.

Harvard Mark I



Harvard Mark 1 Video

Harvard Mark 1 Video 2

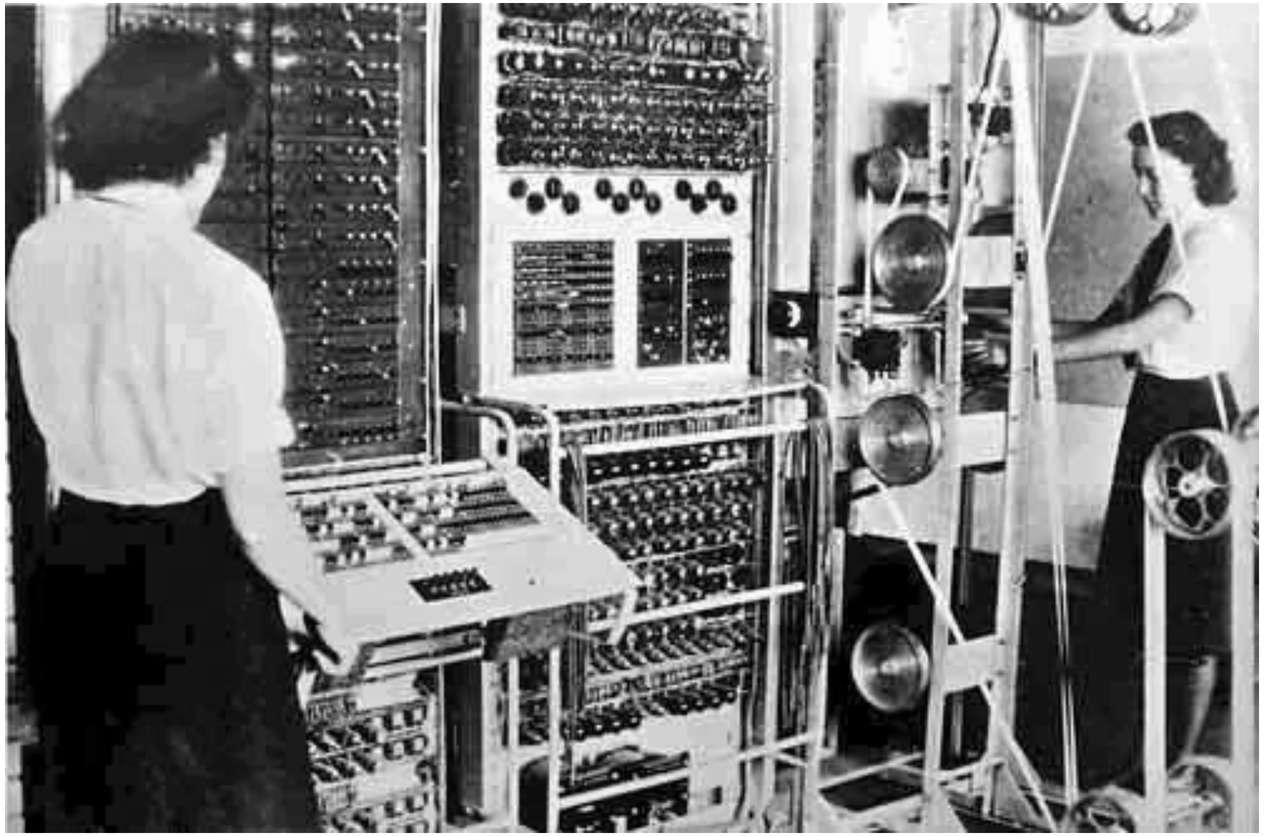
Vacuum Tubes

- Replaced the slower electromagnetic relays in early electronic computers.
  - Also used in radios and televisions.
- Controlled electrical flow, like a switch.
- There is a good description of how vacuum tubes work in the transistors video shown later in the lecture.

Colossus

- Designed by Tommy Flowers at Bletchley Park in the 1940s
- Used for codebreaking, specifically the Lorenz cipher, during World War II.
- First electronic, digital, programmable computer.
  - Did not store programs in memory.
  - Was not general-purpose.
- Was not public knowledge until the 1970s.

Colossus



[Colossus Video]

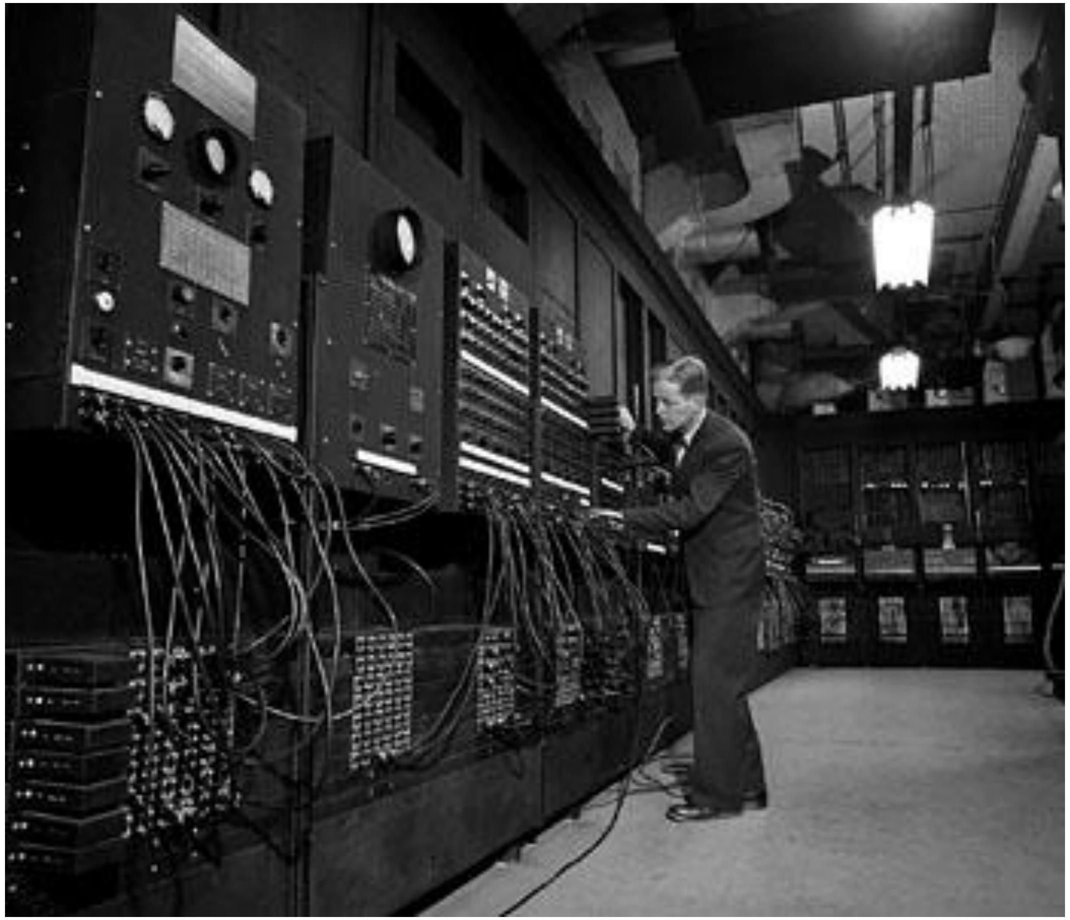
ENIAC

- Electronic Numerical Integrator And Computer

- Created by John Mauchly and John Presper Eckert (1940s)
  - Built at the University of Pennsylvania
  - February 15^{th} was declared “ENIAC Day” in Philadelphia in 2011.

- Electronic, digital, general-purpose, programmable with stored programs.
  - Wasn’t a secret or undiscovered like Colossus or other electronic computers at that time.

ENIAC



[ENIAC Video]

UNIVAC

- A family of Universal Automatic Computers

- Created by John Mauchly and John Presper Eckert (also in the 1940s)
  - Formed their own company
  - Later bought by Remington-Rand.

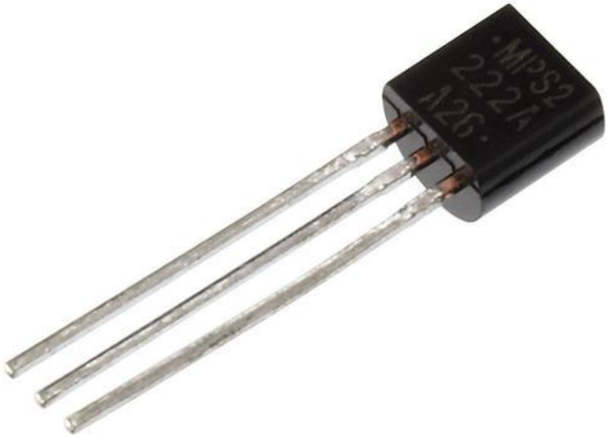
- First commercially successful electronic, digital, general-purpose, and programmable computers.
  - Originally intended for the Census Bureau.
  - Produced through the 1970s

- Used magnetic tape for memory.
  - Could read punched cards to tape.

UNIVAC

Transistors

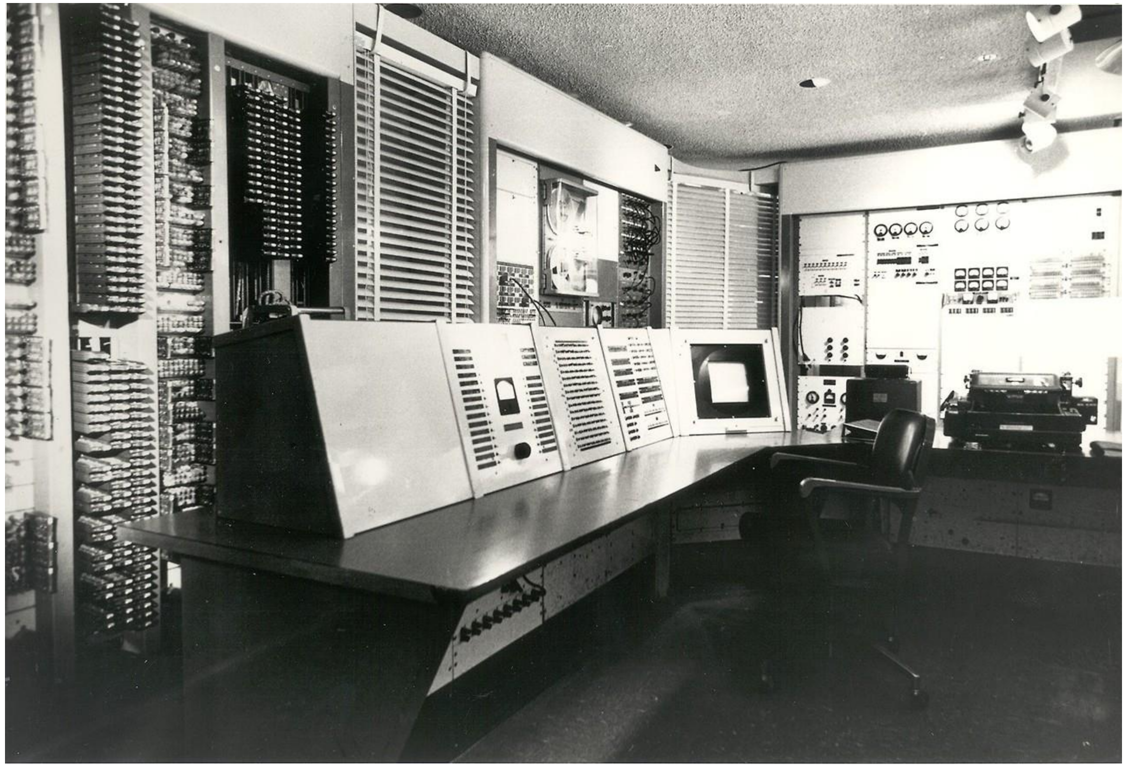
- Replaced vacuum tubes.
- Can control the amount of current or voltage, amplification/modulation or switching of an electronic signal.
- The transistor became the primary building block of computing and electronic equipment as we know it today.
- Magnetic System Memory



[Transistors Video]

TX-0

- Fully transistorized computer.
  - Created at MIT (1956)
- Experimental



DEC and the PDP

- Digital Equipment Corporation (1950s – 1990s)
- Created a transistorized line of computers, starting in 1961.
- Programmed Data Processor (PDP)
    - Commercially available

PDP-1

- First of DEC's PDP series.

- A lot of software firsts
  - First computer games
  - First text editor
  - First word processor
  - First debugger
  - First computerized music

- Focused on the user

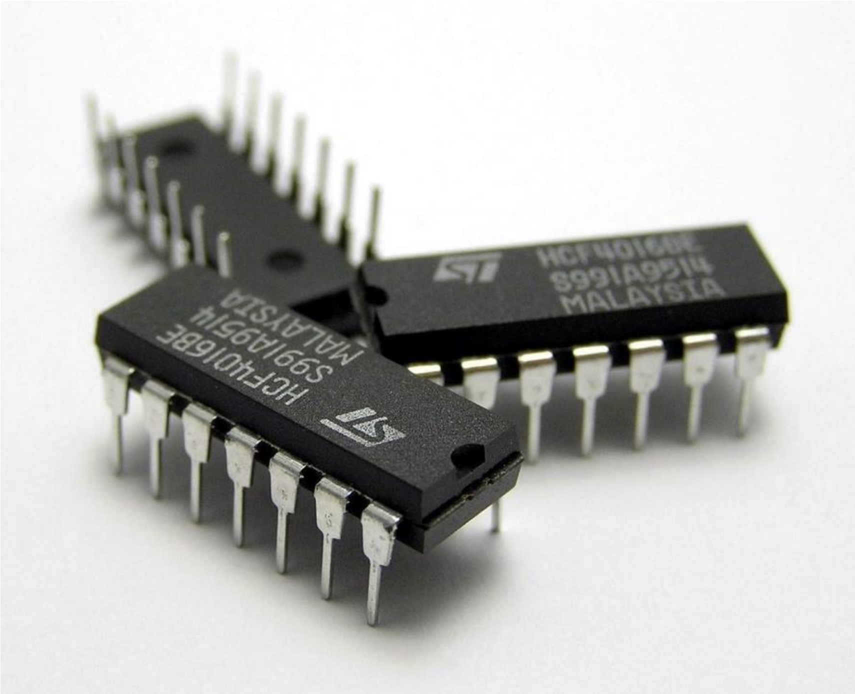
[PDP-1 Video]

PDP-8

- First commercially successful minicomputer.
  - 1965
- Affordable and accessible to new businesses.
- Focused on the value.

Integrated Circuits

- Holds a large number of transistors on a single “chip”.



[Integrated Circuits Video]

IBM 360

- Designed for commercial and scientific applications.
    - 1960s – 1970s

- Scalable
    - Add or remove components

- Software written for one could be run on others.

- Several programs in memory at once.

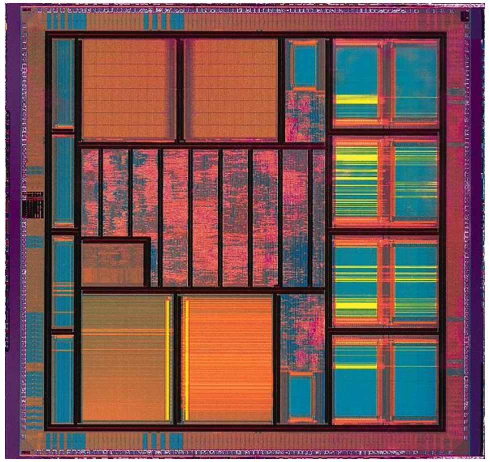
IBM 360 Video

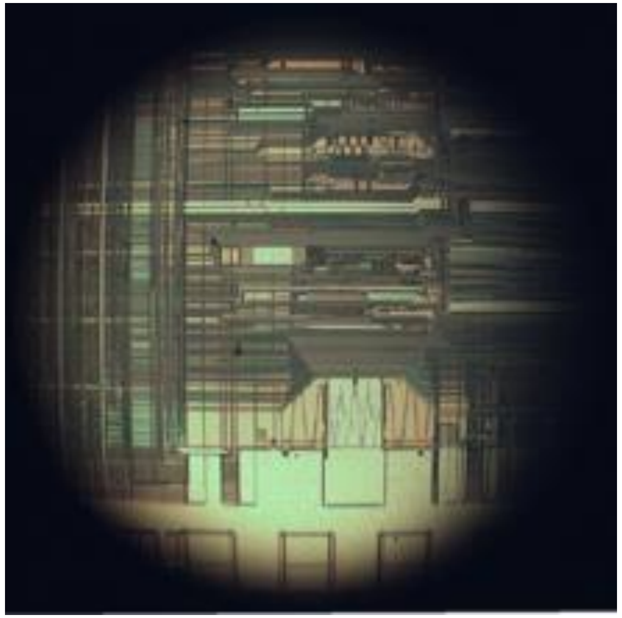
PDP-11

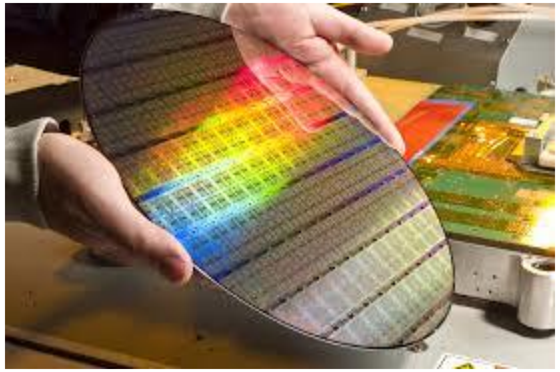
- DEC’s most successful minicomputer.
  - 1970s to 1990s
- Large number of peripheral devices.
- Could be upgraded/scaled as needed.

Microprocessors and VLSI

- Billions of nanoscale transistors and multiple integrated circuits in one device.
  - This process is mentioned at the end of the Integrated Circuits Video.







Personal Computers

Major Types of Software

- Application Software
  - Programs that make your computer useful.
  - Word processors, Internet browsers, video games and mobile apps

- System Software
  - Programs that control the computer.
  - Operating Systems, device drivers, utility programs and software development tools.

What is a computer programming language?

- A ***programming language*** is a formal language that consists of a set of instructions that cause a computer to execute a series of operations or tasks.
  - A group of instructions that completes some task is a ***computer program***.

- There are, in general, two major types of programming languages: low-level and high-level.

What is a low-level programming language?

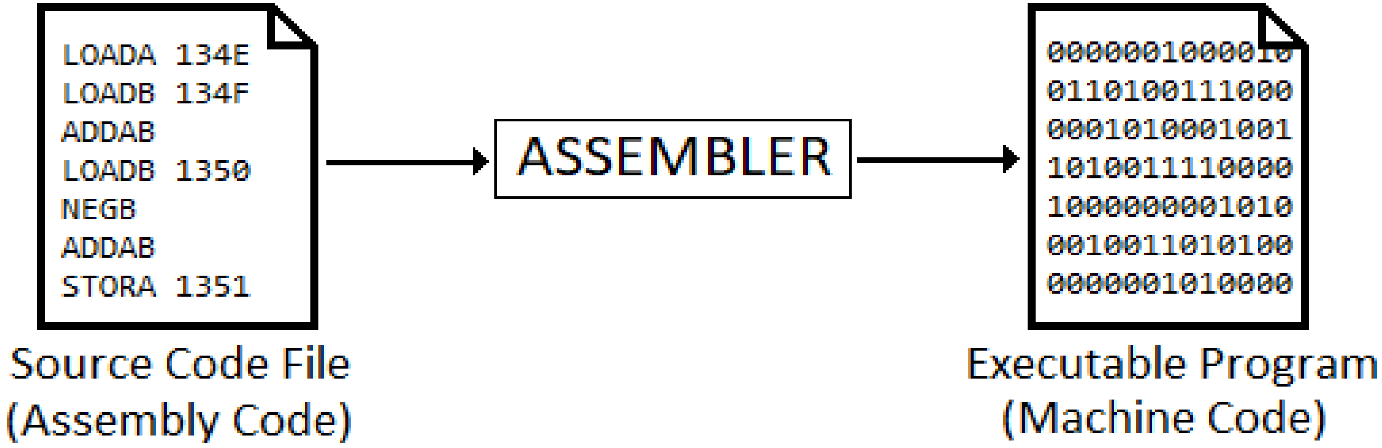
- A ***low-level programming language*** is one where the instructions are (or closely related to) the instructions for the processor/CPU.
  - The language may only work for a specific processor or other hardware.

- Usually refers to assembly language or machine code.

- Difficult to program with.
  - With machine code, it's typically done in binary.
  - Assembly language maps the binary instructions to somewhat less vague instructions. An *assembler* translates those instructions back to binary.

```
; Global declarations
STATUS     equ   3       ; Status register is File 3
C          equ   0       ; Carry/Not Borrow flag is bit0
           cblock 20h
            NUM:2        ; Number: high byte, low byte
           endc
MAIN       goto   SQR_ROOT
; **************************************************************
; * FUNCTION: Calculates the square root of a 16-bit integer *
; * EXAMPLE : Number = FFFFh (65,535d), Root = FFh (255d)    *
; * ENTRY   : Number in File NUM:NUM+1                       *
; * EXIT    : Root in W. NUM:NUM+1; I:I+1 and COUNT altered  *
; **************************************************************
; Local declarations
         cblock
          I:2, COUNT     ; Magic number hi:lo byte & loop count
         endc
         org    200h     ; Code to begin @ 200h in Program store
SQR_ROOT clrf   COUNT    ; Task 1: Zero loop count
         clrf   I        ; Task 2: Set magic number I to one
         clrf   I+1
         incf   I+1,f
; Task 3: DO
SQR_LOOP movf   I+1,w    ; Task 3(a): Number - I
         subwf  NUM+1,f  ; Subtract lo byte I from lo byte Num
         movf   I,w      ; Get high byte magic number
         btfss  STATUS,C ; Skip if No Borrow out
          addlw 1        ; Return borrow
         subwf  NUM,f    ; Subtract high bytes
; Task 3(b): IF underflow THEN exit
         btfss  STATUS,C ; IF No Borrow THEN continue
          goto  SQR_END  ; ELSE the process is complete
         incf   COUNT,f  ; Task 3(c): ELSE inc loop count
         movf   I+1,w    ; Task 3(d): Add 2 to the magic number
         addlw  2
         btfsc  STATUS,C ; IF no carry THEN done
          incf  I,f      ; ELSE add carry to upper byte I
         movwf  I+1
         goto   SQR_LOOP
SQR_END  movf   COUNT,w  ; Task 4: Return loop count as the root
         return
         end
```

Assembly Language

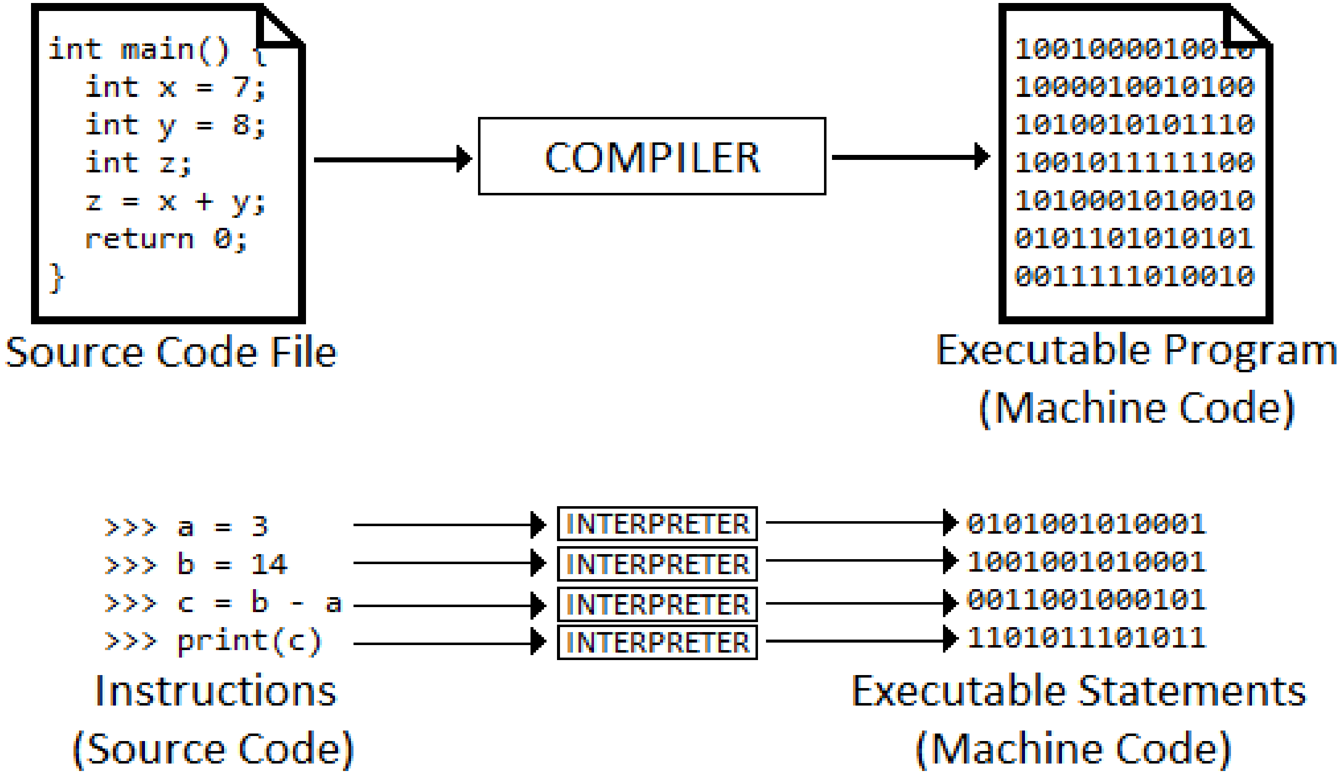


What is a high-level programming language?

- A ***high-level programming language*** is one where the instructions read more closely to a human language.
  - Normally, the language will work for a variety of different platforms/processors.

- Programs in high-level languages are easier to read, write and update when compared to programs written in a low-level language.

Compilers and Interpreters



How are programming languages classified?

- Most programming languages follow a *paradigm* or style of how instructions are written.
- The two most common types are:
  - ***Procedural Programming*** which seeks to break computer programs into separate routines or *procedures* that are sent to the processor to be executed.
  - ***Object-Oriented Programming*** which seeks to break computer programs into self-contained objects that use fields and methods to manipulate the program's data.
- Some languages, like Python and Java, are multi-paradigm.

What are Python and Java?

- Both are high-level, object-oriented programming languages.
- Both languages are widely used.

Who makes/made Python?

- Created by Guido van Rossum of the Netherlands.
  - Started development in 1989 as a hobby.
  - Released in 1991.

- Maintained and developed by the Python Software Foundation.
  - Non-profit organization devoted to Python's continued development.

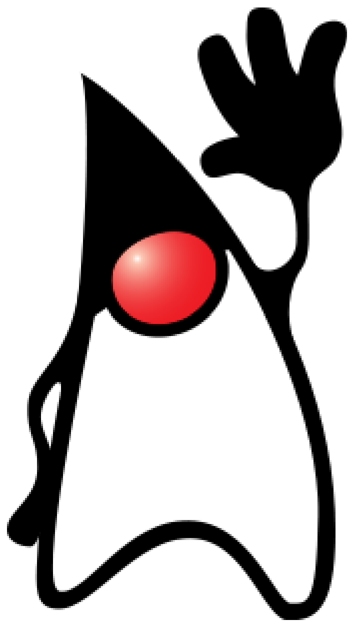
- van Rossum remains the principal author of Python.

Who makes/made Java?

- Created by a team led by James Gosling at Sun Microsystems
  - Started development in 1991.
  - Released in 1995.

- Originally called Oak, then Green, then finally Java.

- Sun Microsystems (and Java) was purchased by Oracle in 2010.



How does Python work?

- Python source code is written by a programmer.
  - ***Source code*** is the human-readable text file written in a programming language that contains executable statements and instructions.

- The Python code is interpreted to machine code by the Python interpreter.

- Python code *can* be compiled, but it isn't required.

How does Java work?

- Java source code is written by a programmer.

- Java source code is compiled to bytecode.

- The compiled bytecode is executed in a virtual machine.
  - The ***Java Virtual Machine (JVM)*** interprets the bytecode to machine code.

What is a Virtual Machine?

- A ***virtual machine*** (or ***VM***) is a software application implemented in such a way that it functions like a physical computer.

- Two types: System VM or Process VM
  - System VMs: Acts like a complete physical computer; the system's hardware is emulated by software.
    - Some popular System VMs are VMWare and VirtualBox.

  - Process VMs: A VM that only runs a single program.
    - Both Java and Python utilize Process VMs

Why Use Virtual Machines?

- The use of a virtual machine allows Python and Java applications to function across a variety of hardware platforms and operating systems.

- There is no need to rewrite or recompile programs for, say, Windows and OSX.

- The virtual machine (for each platform) interprets the Python code or Java bytecode for that platform.

What do I need to develop Python programs?

- In order to run Python programs, you'll need to have the Python interpreter installed on your computer.

- The interpreter can be used in two ways:
  - Interactive mode: You type Python statements and they are executed.
  - Script mode: You write a source code file containing Python statements. Then, the interpreter reads the source code and interprets the statements contained in it.

- Python scripts can be written using a simple text editor, like Notepad.
  - Better tools exist to simplify the development process.

What do I need to develop Python programs?

- Python 3 comes with IDLE
  - **I**ntegrated **D**evelopment and **L**earning **E**nvironment
  - Allows writing and executing Python source code files.

- Appropriate for new Python developers.

- More powerful IDEs exist for developing Python applications.

What do I need to run Java programs?

- Java Runtime Environment (JRE)
  - Includes the JVM for running Java programs.

- Downloadable for free.

What do I need to develop Java programs?

- Java Development Kit (JDK)
  - Includes all features of the JRE and includes the Java compiler.
  - We can’t create executable Java programs without the compiler.

- Java source code can be written in a text editor, like Notepad.
  - Better tools exist to simplify the development process.

- More powerful IDEs exist for developing Java applications.
  - IntelliJ – We will be using this.
  - Eclipse

What are the different versions of Python?

- Python 2
  - Last release (version 2.7) was in 2010.
  - Still widely used as not all of Python 2's libraries have been updated for Python 3.

- Python 3
  - Initially released in 2008; Current version (3.7.1)
  - Not all of Python 2's libraries are included yet.

How much does it cost to develop Java or Python programs? Do I need a developer's license?

- Nothing and No!
- The JDK and Python interpreter is available for free.
  - Anyone can develop Java or Python programs.
- IntelliJ is also free.

What are the different editions of Java?

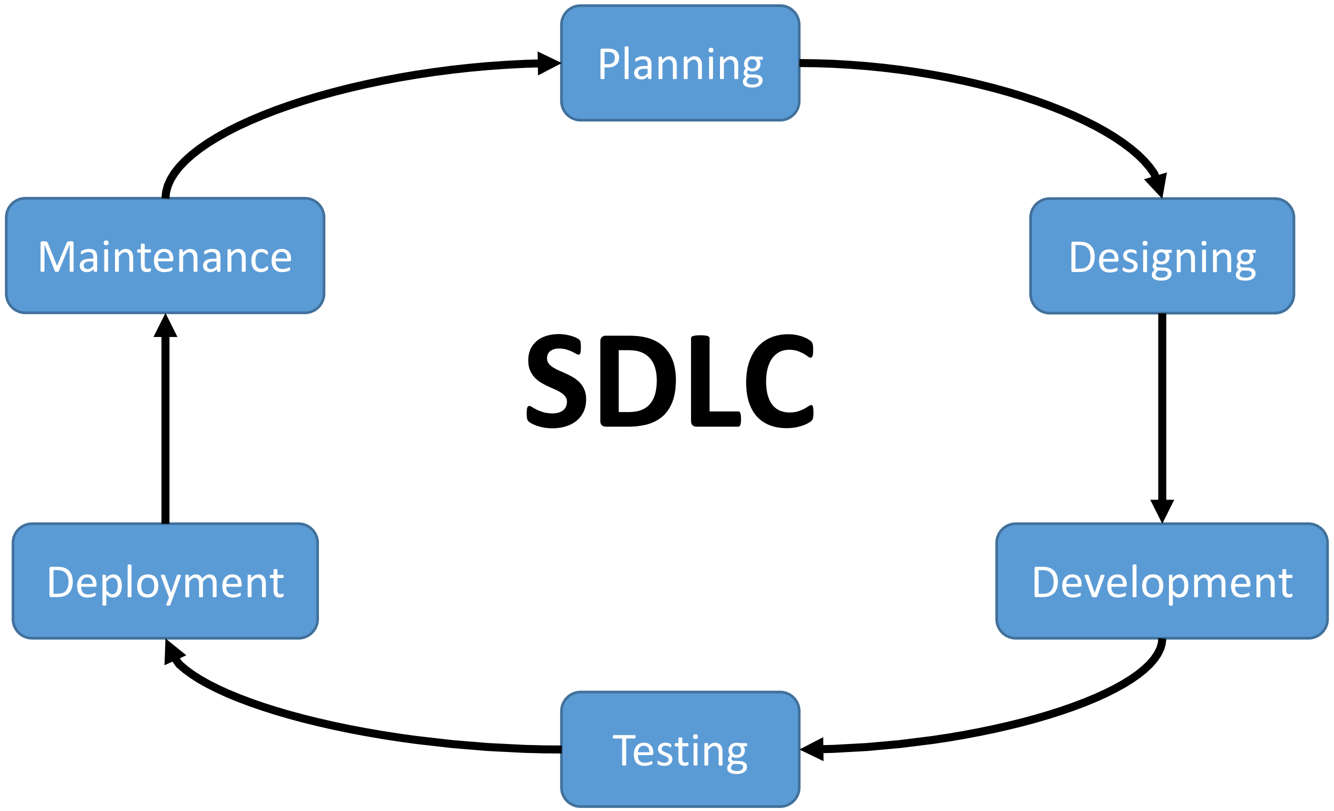
- JavaSE – Standard Edition (What we will be using)
- JavaEE – Enterprise Edition (Enterprise Environments)
- JavaME – Micro Edition (Embedded Systems)

The Software Development Life Cycle

- The ***Software Development Life Cycle*** (SDLC) is a process to produce computer software.
  - Highest Quality
  - Lowest Cost
  - Shortest Time

- Consists of (normally) six stages.

The Software Development Life Cycle



SDLC Stage 1 – Planning

- The Planning Stage involves input from all project stakeholders to determine the project's objective.
  - The Customer
  - Senior Management
  - Sales/Marketing
  - Technical Experts

- This is also when an estimate of resources and costs is determined.
  - Equipment, labor, etc.

SDLC Stage 1 – Planning

- The Planning Stage is sometimes called a ***requirement analysis***.
  - What do we want?
  - What don't we want?

- Risks
  - Is the project's timeline feasible?
  - Does the technology exist?
  - Is the cost too high?
  - **Minimize Risk**

SDLC Stage 1 – Planning

- Near the end of the Planning Stage, the requirements of the product will need to be formalized.

- A **Software Requirement Specification** (SRS) document will outline what functionality the product should have.
  - Requirements should not be ambiguous.
    - “Good User Interface”
  - This document should be reviewed and approved by stakeholders.

SDLC Stage 2 – Designing

- The Designing Stage involves creating the overall architecture of the application.

- **Design Document Specification** (DDS) documents will contain different design approaches for the architecture.
  - Is based on the SRS
  - With input from stakeholders, the best design approach is selected.

- Each approach should:
  - Identify the separate components of the architecture.
  - Identify how the components will work together.
  - Ensure the application’s requirements are met.

SDLC Stage 2 – Designing

- The DDS should also contain a list of milestones
  - What will be completed in certain timeframes?
- Functionality of the application should be detailed.
  - User Interfaces
  - Failure
  - Limitations
- Misunderstandings will cause problems later.

SDLC Stage 3 – Development

- With the requirement analysis and design document complete, software development can begin.
  - The better requirements were defined in the previous stages, the easier it will be for the programmers to create the actual product.

SDLC Stage 4 – Testing

- After development is complete, the product needs to be tested.
- While testing is performed by programmers as they develop, a formal test procedure or test plan must be created.
  - The test plan should incorporate testing the features and functions described in the DDS.

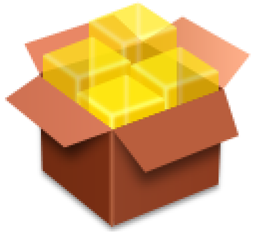
SDLC Stage 4 – Testing

- Some organizations have entire departments (***Quality Assurance*** or ***QA***) devoted to testing.

- QA testers follow the test plans to ensure the product works as intended.
  - Programming teams are notified if the testers discover issues.

- QA testers will also try to find and report any odd or abnormal behavior (*glitches*) in the product/application.

SDLC Stage 5 – Deployment



- After the product has passed all tests and is determined to function as designed, the product is ready to be delivered to the customer.

- Often, the deployment stage will involve teams who visit the customer on-site to install and configure hardware/software.
  - Will work closely with the customer's IT staff.
  - Ensures the product was delivered and is working correctly.

SDLC Stage 6 – Maintenance

- Problems may arise after deployment.
  - Issues not anticipated or discovered during testing.
- The customer will often be provided with an update or ***software patch*** that fixes the problem.
- Customer Support services may be offered.
  - Product support may have ***end-of-life*** terms.

What next?

- If this was a one-time software solution, the product and SDLC is complete.

- Normally, this isn't the end.
  - After getting customer feedback and patching problems, work for the next version of the software can be started.
  - The cycle begins again at the Planning Stage.

Developing Software

- During the Development stage (Stage 3) of the SDLC, the programming team will begin by reviewing and understanding the DDS.
  - Sometimes, this is the responsibility of a software development manager.

- Different parts of the application will be assigned to different team members.
  - Usually matched with their ability/expertise.

Developing Software

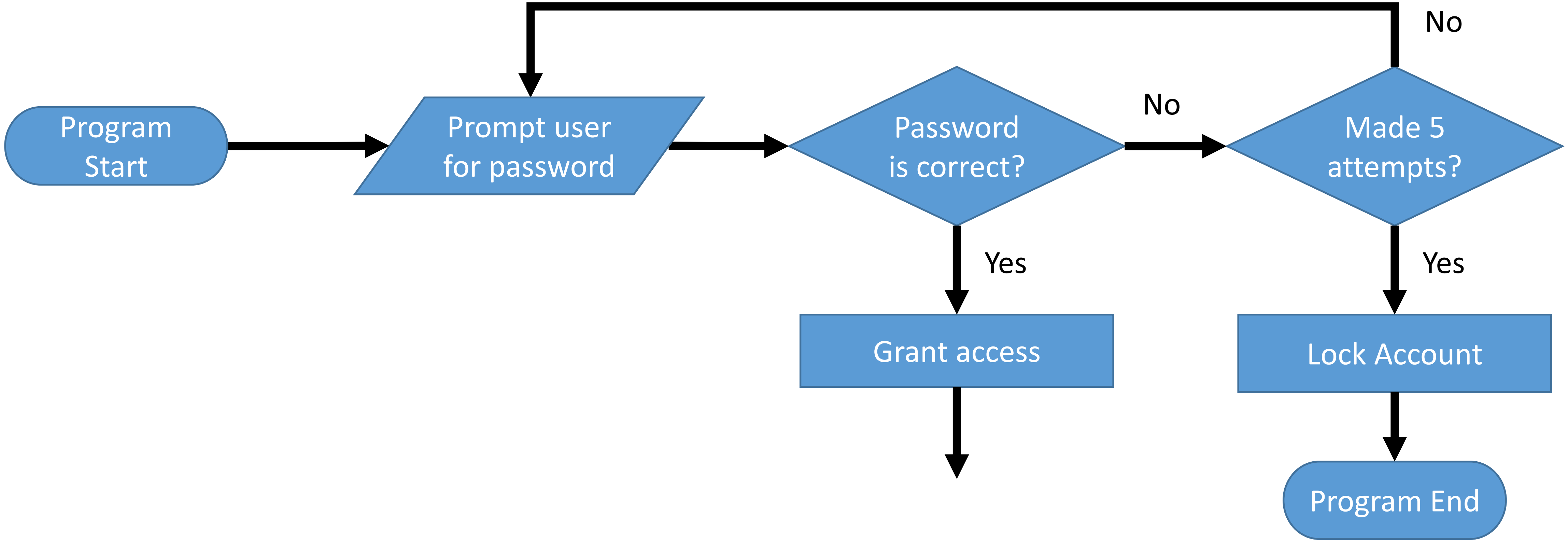
- Programmers use a variety of non-programming techniques when developing software.

- A programmer must have a plan **before** they write a single line of code.

"Plans are worthless, but planning is everything."
- Dwight Eisenhower

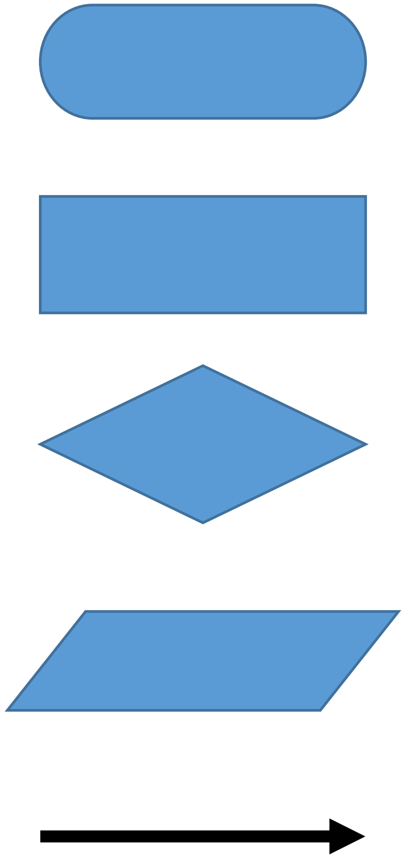
Developing Software – Flowcharts

- Drawing flowcharts is a great way to aid in your planning by visualizing processes.



Developing Software – Flowchart Symbols

- Oval – Program start or stop
- Rectangle – Process
- Diamond – Decision
- Input/Output – Parallelogram
- Arrows – Direction of Flow



Developing Software – Pseudocode

- Based on the programmer’s notes and flowcharts, a “script” of how the program should work can be written.
  - The script will contain the step-by-step processes completed by the program.
  - The processes are often written in plain text, mixed with actual programming code.

- This is referred to as ***pseudocode***.
  - It’s not really valid, working code; Serves as a guide for how the actual code will be written.

```
Ask user for password
while user_guess != password :
    Print error message
    attempts += 1
    Check if too many attempts
        Print error message / Stop program
    Ask for password again
...
```

Developing Software – Programming

- With the completed flowcharts and pseudocode scripts, the programmer can begin to write the actual program.
  - You’ve already drawn/written out exactly (or pretty close, at least) how the program should function.
  - The flowcharts and pseudocode act as a road map of all the steps the program needs to take to complete its task.

```
Ask user for password
while user_guess != password :
    Print error message
    attempts += 1
    Check if too many attempts
        Print error message / Stop program
    Ask for password again
...
```

```
user_guess = input("Enter password: ")
while user_guess != password :
    print("Invalid Password.")
    attempts += 1
    if attempts == 5 :
        print("Login attempts exceeded.")
        exit()
    user_guess = input("Try Again: ")
```

Developing Software – Documentation

- Programmers will document their code using ***comments***.
  - Comments are notes that explains the "why's" and "what's" of the code.
- Other programmers may not understand what certain statements are doing, why they are there, and/or why they are important.
  - YOU might even forget why you have certain statements in the program.
- Properly documented code makes debugging, maintenance, and working as a team easier.
  - It also shows me that you understand what your statements are doing and why you wrote those statements.

Developing Software – Testing

- As the programmer develops the program, he or she must test that the functionality works correctly.
  - Many programmers will develop iteratively- create or change code and test it, create or change more code and test it, and so on.

- A programmer may encounter a few types of errors during the development process.
  - A ***compile-time error*** is an error that occurs when the program is compiled into machine code.

Developing Software – Testing

- A ***run-time error*** is an error that occurs while the program is running, causing the program to crash.
  - When a program crashes, the program will stop executing its statements.

- The source of a run-time error can sometimes be difficult to pinpoint and can require considerable time to solve.
  - When a run-time error occurs, it will often provide some details to help track down the cause.

Developing Software – Testing

- You may, during testing, discover your program exhibit unintentional behaviors or glitches.

- A ***bug*** is a colloquial term for some erroneous code, logic, or unexpected behavior in a program.
  - ***Debugging*** is the term used to describe the process of searching for the cause of an error or unexpected behaviors.

Developing Software – Best Practices

- Always start a program with a pencil and paper.
  - Draw flowcharts
  - Write a pseudocode script.

- Test, Test, Test.
  - Validate your program works as designed and there are no bugs.

- Manage your time effectively.
  - Expect to spend time planning, programming, and testing/debugging.