Why Programming?

- To become smarter
- To solve many and huge problems
- To perform mundane repetitive tasks
- To get a good placement

You Should Learn to Program : Christian Genco at TEDxSMU

What is Programming?

- Is a process
  - Start : Analyze the problem to solve
  - End : Execute on the computer

- Involves
  - Analyze the problem
  - Develop understanding
  - Generate Algorithm
  - Verify Correctness and resource Consumption
  - Implement Algorithm in a programming language
  - Test, Debug, and Maintain the code

Amazing systems and softwares

- Google
- E-mail
- Social media
- Websites
- Mobile phone and its Apps
- Space Industry, Automobile, Defence ...
- ...

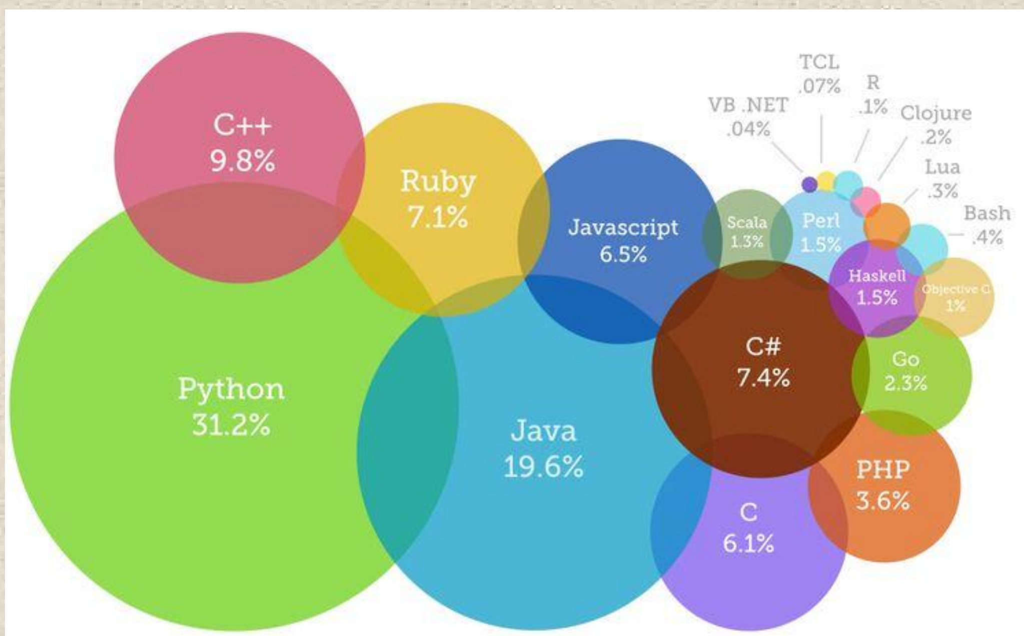
Programmer

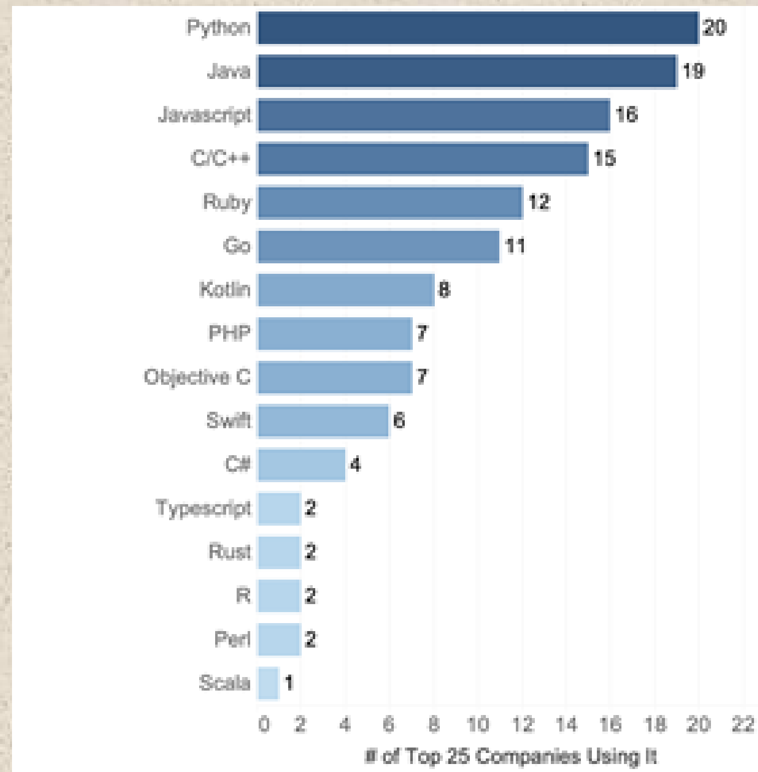
- The First Computer Programmer: **Ada Lovelace**
- Computer programmers are those who write computer software.

  Their jobs usually involve:

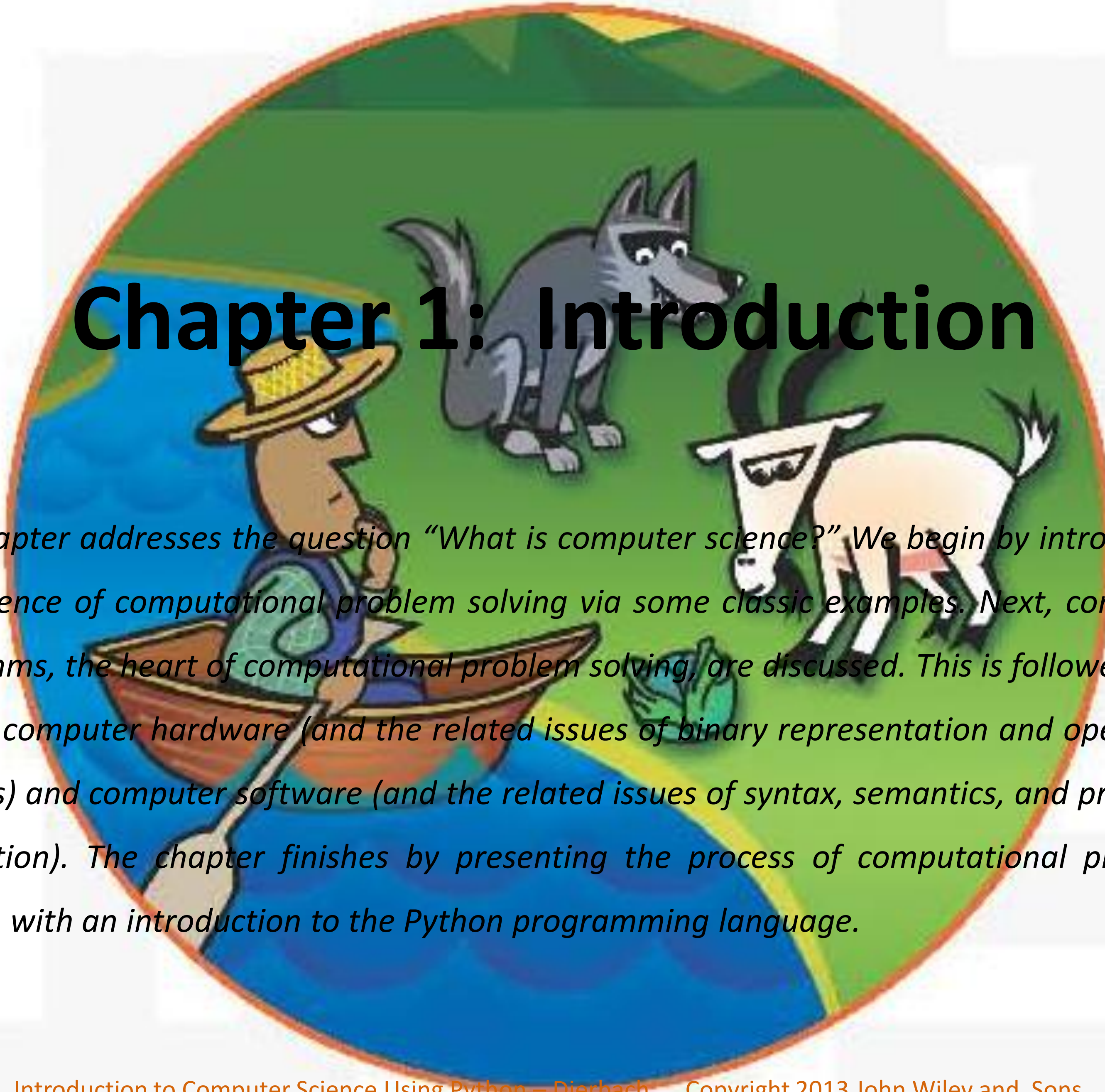
  – Coding
  – Debugging
  – Documentation
  – Integration
  – Maintenance
  – Requirements analysis
  – Software architecture
  – Software testing
  – Specification

Most Popular Coding Languages





Data was gathered May 1st, 2019 - May 10th, 2019 using information from Indeed.com job postings and technologies listed on Stackshare.io



Chapter 1: Introduction

This chapter addresses the question "What is computer science?" We begin by introducing the essence of computational problem solving via some classic examples. Next, computer algorithms, the heart of computational problem solving, are discussed. This is followed by a look at computer hardware (and the related issues of binary representation and operating systems) and computer software (and the related issues of syntax, semantics, and program translation). The chapter finishes by presenting the process of computational problem solving, with an introduction to the Python programming language.

Motivation

Computing technology has changed—and **is continuing to change—the world**. **Essentially every aspect of life has been impacted by computing.** Computing related fields in almost all areas of study are emerging.

Various Computational-Related Fields		
Computational Biology	Computational Medicine	Computational Journalism
Computational Chemistry	Computational Pharmacology	Digital Humanities
Computational Physics	Computational Economics	Computational Creativity
Computational Mathematics	Computational Textiles	Computational Music
Computational Materials Science	Computational Architecture	Computational Photography
Computer-Aided Design	Computational Social Science	Computational Advertising
Computer-Aided Manufacturing	Computational Psychology	Computational Intelligence

What is Computer Science?

Computer science is fundamentally about computational problem solving.

Programming and **computers** are only tools in the field of computing.

The computer science field has tremendous breadth and diversity.

Areas of study in computer science include:

- Programming Language Design
- Systems Programming
- Computer Architecture
- Human–Computer Interaction
- Robotics
- Artificial Intelligence
- Software Engineering
- Database Management / Data Mining
- Computer Networks
- Computer Graphics
- Computer Simulation
- Information Security
- ....

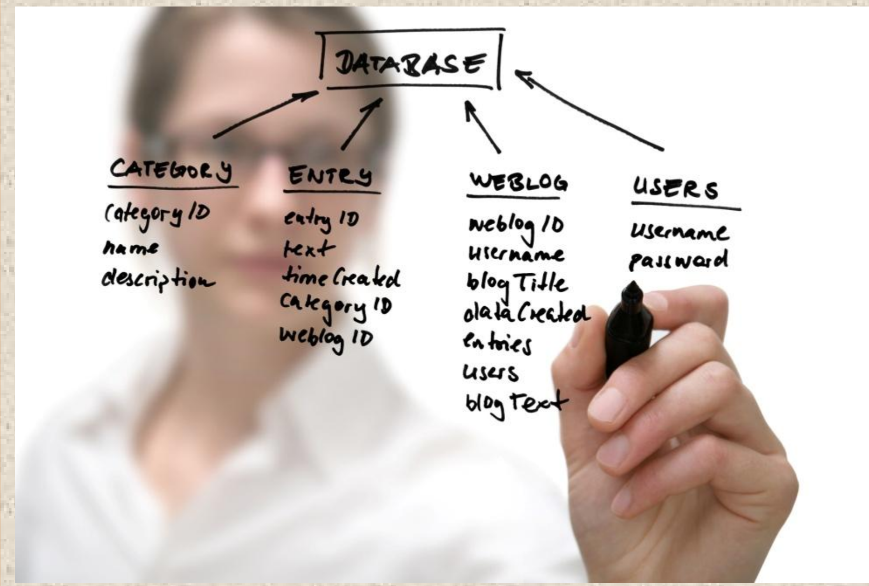
What is Computing?

Computing is a process of completing or accomplishing a task by utilizing the computer technology.

Computing may involve computer hardware and or Software, but must involve some form of a computer system.

The task or job can be either Computational or Non-Computational.

Computational Problem Solving



Two things that are needed to perform computational problem solving:

- **a representation** that captures all the relevant aspects of the problem
- **an algorithm** that solves the problem by use of the representation

Thus, computational problem solving finds a solution within a representation that translates into a solution for what is being represented.

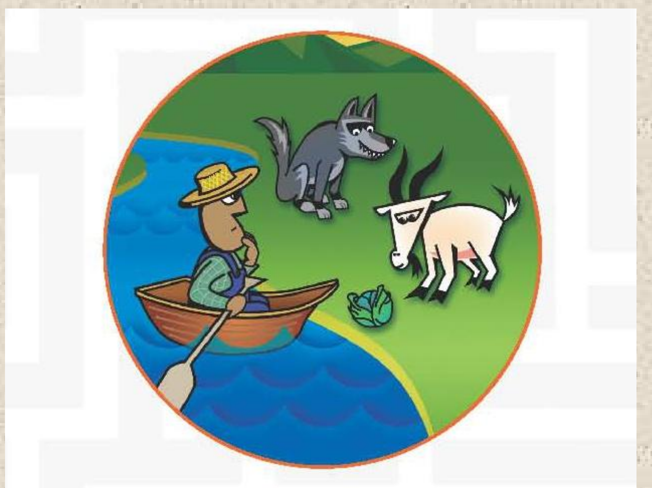
Computational Problem Solving

Two things that are needed to perform computational problem solving:

- **a representation** that captures all the relevant aspects of the problem
- **an algorithm** that solves the problem by use of the representation

Thus, computational problem solving finds a solution within a representation that translates into a solution for what is being represented.

Man, Cabbage, Goat, Wolf Problem



A man lives on the east side of a river. He wishes to bring a cabbage, a goat, and a wolf to a village on the west side of the river to sell. However, his boat is only big enough to hold himself, and either the cabbage, goat, or wolf.

In addition, the man cannot leave the goat alone with the cabbage because the goat will eat the cabbage, and he cannot leave the wolf alone with the goat because the wolf will eat the goat. How does the man solve his problem?

There is a simple algorithmic approach for solving this problem by simply **trying all possible combinations of items that may be rowed back and forth across the river.**
Trying all possible solutions is referred to as a ***brute force approach***.

What would be an appropriate representation for this problem? Whatever representation we use, only the aspects of the problem that are relevant for its solution need to be represented.

- Color of the boat?
- Name of the man?
- Width of the river?

The only information relevant for this problem is where each particular item is at each step in the problem solving. Therefore, by the use of **abstraction**, we define a representation that captures only this needed information.

For example, we could use a sequence to indicate where each of the objects currently are,

man cabbage goat wolf boat village
[east, west, east, west, east, west]

where it is understood that the first item in the sequence is the location of the man, the second the location of the cabbage, etc.

Note that the village is always on the west side of the river—it doesn't move! Its location is fixed and therefore does not need to be represented.

Also, **the boat is always in the same place as the man**. So representing the location of both the man and the boat is redundant information. The relevant, **minimal representation** is given below,

man cabbage goat wolf
[E, W, E, E]

The actual problem is to determine how the man can row objects across the river, with certain constraints on which pairs of objects cannot be left alone.

The computational problem is to find a way to convert the representation of the **start state** of the problem, when all the object are on the east side of the river,

man cabbage goat wolf
[E, E, E, E]

to the **goal state** with all objects on the west side of the river,

man cabbage goat wolf
[W, W, W, W]

with the constraint that certain **invalid states** should never be used.

Thus, in a computational problem solving approach, a problem is solved within the representation used, in which the solution within the representation must translate into a solution of the actual problem.

For example, from the start state, there are three possible moves that can be made, only one of which results in a valid state.

man cabbage goat wolf

[E, E, E, E] **START STATE**

[W, W, E, E]

Man rows cabbage across

INVALID STATE

Goat left alone with wolf

[W, E, W, E]

Man rows goat across

✓

VALID STATE

Cabbage left alone with wolf

[W, E, E, W]

Man rows wolf across

INVALID STATE

Cabbage left alone with goat

We check if the new problem state is the goal state. If true, then we solved the problem in one step! (We know that cannot be so, but the algorithmic approach that we are using does not.)

man   cabbage   goat   wolf

[E, E, E, E] **START STATE**

⇩

[W, E, W, E]

Man rows goat across ✓

Is goal state [W,W,W,W]?   **No**

Therefore we continue searching from the current state.

Since the man can only row across objects on the same side of the river, there are only two possible moves from here,

man cabbage goat wolf **INTERMEDIATE**

[W, E, W, E] **STATE**

[E, E, W, E]

Man rows back alone

✓

VALID STATE

Cabbage left alone with wolf

[E, E, E, E]

Man rows goat across

✓

VALID STATE

BUT, previously in this state. It is the start state. No progress made!

This would continue until the goal state is reached,

man cabbage goat wolf

[E, E, W, E]

.

.

[W, W, W, W] **GOAL STATE**

Thus, **the computational problem of generating the goal state from the start state translates into a solution of the actual problem since each transition between states has a corresponding action in the actual problem—**of the man rowing across the river with (or without) a particular object.

Man, Cabbage, Goat, Wolf Problem

For the Man, Cabbage, Goat, Wolf problem, assume that each state is represented by a sequence of the form **[man, cabbage, goat, wolf]**, in which a value of **0 indicates that the item is on the east side of the river**, and a value of **1 indicates that the item is on the west side**. For example, [1,0,1,0] would indicate that the cabbage and wolf are on the east side of the river, and the man and goat on the west side.

(a) Give a list of all the invalid states in this representation.
(b) Give a sequence of states that solves the problem (assuming that all items start on the east side of the river, and the village is on the west side.)

The Importance of Algorithms

MAY 2012

Sun	Mon	Tues	Wed	Thur	Fri	Sat
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

As another example computational problem, suppose that you needed to write a program that displays a calendar month for any given month and year.

The representation of this problem is rather straightforward. Only a few values are needed:

- **the month and year**
- **number of days in each month**
- **names of the days of the week**
- **day of the week that the first day of the month falls on**

The month and year, number of days in a month, names of the days of the week can be easily handled. **The less obvious part is how to determine the day of the week that a particular date falls on**.

How would you do that?

Start with a known day of the week for a given year in the past and calculate forward from there?

That would not be a very efficient way of solving the problem.

Since calendars are based on cycles, there must be a more direct method for doing this. Thus, no matter how good a programmer you may be, without knowledge of the needed algorithm, you could not write a program that solves the problem.

The Limits of Computational Problem Solving

Once an algorithm for a given problem is developed or found, an important question is "**Can a solution to the problem be found in a reasonable amount of time**?"

"But aren't computers very fast, and getting faster all the time?"

Yes, but some problems require an amount of time to compute a solution that is astronomical compared to the capabilities of current computing devices.

A classic problem in computer science that demonstrates this is the **Traveling Salesman problem**.

Self-Test Questions

1. A good definition of computer science is "the science of programming computers." (TRUE/FALSE)

2. Which of the following areas of study are included within the field of computer science?
   (a) Software engineering
   (b) Database management
   (c) Information security
   (d) All of the above

3. In order to computationally solve a problem, two things are needed: a representation of the problem, and an ______________ that solves it.

4. Leaving out detail in a given representation is a form of ______________.

5. A "brute-force" approach for solving a given problem is to:
   (a) Try all possible algorithms for solving the problem.
   (b) Try all possible solutions for solving the problem.
   (c) Try various representations of the problem.
   (d) All of the above

6. For which of the following problems is a brute-force approach practical to use?
   (a) Man, Cabbage, Goat, Wolf problem
   (b) Traveling Salesman problem
   (c) Chess-playing program
   (d) All of the above

ANSWERS:

Self-Test Questions

1. A good definition of computer science is "the science of programming computers." (TRUE/FALSE)

2. Which of the following areas of study are included within the field of computer science?
   (a) Software engineering
   (b) Database management
   (c) Information security
   (d) All of the above

3. In order to computationally solve a problem, two things are needed: a representation of the problem, and an _______________ that solves it.

4. Leaving out detail in a given representation is a form of _______________.

5. A "brute-force" approach for solving a given problem is to:
   (a) Try all possible algorithms for solving the problem.
   (b) Try all possible solutions for solving the problem.
   (c) Try various representations of the problem.
   (d) All of the above

6. For which of the following problems is a brute-force approach practical to use?
   (a) Man, Cabbage, Goat, Wolf problem
   (b) Traveling Salesman problem
   (c) Chess-playing program
   (d) All of the above

ANSWERS: 1. False,

Self-Test Questions

1. A good definition of computer science is "the science of programming computers." (TRUE/FALSE)

2. Which of the following areas of study are included within the field of computer science?
   (a) Software engineering
   (b) Database management
   (c) Information security
   (d) All of the above

3. In order to computationally solve a problem, two things are needed: a representation of the problem, and an ______________ that solves it.

4. Leaving out detail in a given representation is a form of ______________.

5. A "brute-force" approach for solving a given problem is to:
   (a) Try all possible algorithms for solving the problem.
   (b) Try all possible solutions for solving the problem.
   (c) Try various representations of the problem.
   (d) All of the above

6. For which of the following problems is a brute-force approach practical to use?
   (a) Man, Cabbage, Goat, Wolf problem
   (b) Traveling Salesman problem
   (c) Chess-playing program
   (d) All of the above

ANSWERS: 1. False 2. (d),

Self-Test Questions

1. A good definition of computer science is "the science of programming computers." (TRUE/FALSE)

2. Which of the following areas of study are included within the field of computer science?
   (a) Software engineering
   (b) Database management
   (c) Information security
   (d) All of the above

3. In order to computationally solve a problem, two things are needed: a representation of the problem, and an _______________ that solves it.

4. Leaving out detail in a given representation is a form of _______________.

5. A "brute-force" approach for solving a given problem is to:
   (a) Try all possible algorithms for solving the problem.
   (b) Try all possible solutions for solving the problem.
   (c) Try various representations of the problem.
   (d) All of the above

6. For which of the following problems is a brute-force approach practical to use?
   (a) Man, Cabbage, Goat, Wolf problem
   (b) Traveling Salesman problem
   (c) Chess-playing program
   (d) All of the above

ANSWERS: 1. False, 2. (d), 3. algorithm,

Self-Test Questions

1. A good definition of computer science is "the science of programming computers." (TRUE/FALSE)

2. Which of the following areas of study are included within the field of computer science?
   (a) Software engineering
   (b) Database management
   (c) Information security
   (d) All of the above

3. In order to computationally solve a problem, two things are needed: a representation of the problem, and an _______________ that solves it.

4. Leaving out detail in a given representation is a form of _______________.

5. A "brute-force" approach for solving a given problem is to:
   (a) Try all possible algorithms for solving the problem.
   (b) Try all possible solutions for solving the problem.
   (c) Try various representations of the problem.
   (d) All of the above

6. For which of the following problems is a brute-force approach practical to use?
   (a) Man, Cabbage, Goat, Wolf problem
   (b) Traveling Salesman problem
   (c) Chess-playing program
   (d) All of the above

ANSWERS: 1. False, 2. (d), 3. algorithm, 4. abstraction,

Self-Test Questions

1. A good definition of computer science is "the science of programming computers." (TRUE/FALSE)

2. Which of the following areas of study are included within the field of computer science?
   (a) Software engineering
   (b) Database management
   (c) Information security
   (d) All of the above

3. In order to computationally solve a problem, two things are needed: a representation of the problem, and an _______________ that solves it.

4. Leaving out detail in a given representation is a form of _______________.

5. A "brute-force" approach for solving a given problem is to:
   (a) Try all possible algorithms for solving the problem.
   (b) Try all possible solutions for solving the problem.
   (c) Try various representations of the problem.
   (d) All of the above

6. For which of the following problems is a brute-force approach practical to use?
   (a) Man, Cabbage, Goat, Wolf problem
   (b) Traveling Salesman problem
   (c) Chess-playing program
   (d) All of the above

ANSWERS: 1. False, 2. (d), 3. algorithm, 4. abstraction, 5. (b),

Self-Test Questions

1. A good definition of computer science is "the science of programming computers." (TRUE/FALSE)

2. Which of the following areas of study are included within the field of computer science?
   (a) Software engineering
   (b) Database management
   (c) Information security
   (d) All of the above

3. In order to computationally solve a problem, two things are needed: a representation of the problem, and an _______________ that solves it.

4. Leaving out detail in a given representation is a form of _______________.

5. A "brute-force" approach for solving a given problem is to:
   (a) Try all possible algorithms for solving the problem.
   (b) Try all possible solutions for solving the problem.
   (c) Try various representations of the problem.
   (d) All of the above

6. For which of the following problems is a brute-force approach practical to use?
   (a) Man, Cabbage, Goat, Wolf problem
   (b) Traveling Salesman problem
   (c) Chess-playing program
   (d) All of the above

ANSWERS: 1. False, 2. (d), 3. algorithm, 4. abstraction, 5. (b), 6. (a)

Computer Algorithms

An algorithm **is a finite number of clearly described, unambiguous "doable" steps that can be systematically followed to produce a desired result for given input in a finite amount of time** (that is, it eventually terminates).

The word "algorithm" is derived from the ninth-century Arab mathematician, **Al-Khwarizmi** who worked on "written processes to achieve some goal."

Algorithms and Computers: A Perfect Match

Computer algorithms are central to computer science. They provide step-by-step methods of computation that a machine can carry out.

Having high-speed machines (computers) that can consistently follow a given set of instructions provides a reliable and effective means of realizing computation. However, **the computation that a given computer performs is only as good as the underlying algorithm used.**

Because **computers can execute a large number of instructions very quickly and reliably without error**, algorithms and computers are a perfect match!

Euclid's Algorithm

One of the Oldest Known Algorithms

An algorithm for computing the greatest common denominator (GCD) of two given integers. It is one of the oldest numerical algorithms still in common use.

1. Assign M the value of the larger of the two values.

2. Divide M by N, call the remainder R.

3. If R is not 0, then assign M the value of N, assign N the value of R, and
   go to step 2.

4. The greatest common divisor is N.

Example Use

Finding the GCD of 18 and 20

1. Assign M the value of the larger of the two values, and N the smaller.

   M ← 20 N ← 18

Example Use

Finding the GCD of 18 and 20

1. Assign M the value of the larger of the two values, and N the smaller.
   M ← 20   N ← 18

2. Divide M by N, call the remainder R.
   M/N = 20 / 18 = 1, with R ← 2

Example Use

Finding the GCD of 18 and 20 (**first time** through, **second time** through)

1. Assign M the value of the larger of the two values, and N the smaller.
   M ← 20 N ← 18

2. Divide M by N, call the remainder R.
   M/N = 20 / 18 = 1, with R ← 2
   M/N = 18 / 2 = 9, with R ← 0

3. If R is not 0, assign M the value of N, assign N the value of R, and go to step 2.
   R = 2. Therefore, M ← 18, N ← 2. Go to step 2.

Example Use

Finding the GCD of 18 and 20 (**first time** through, **second time** through)

1. Assign M the value of the larger of the two values, and N the smaller.
   M ← 20 N ← 18

2. Divide M by N, call the remainder R.
   M/N = 20 / 18 = 1, with R ← 2
   M/N = 18 / 2 = 9, with R ← 0

3. If R is not 0, assign M the value of N, assign N the value of R, and go to step 2.
   R = 2. Therefore, M ← 18, N ← 2. Go to step 2.
   R is 0. Therefore, proceed to step 4.

Example Use

Finding the GCD of 18 and 20 (**first time** through, **second time** through)

1. Assign M the value of the larger of the two values, and N the smaller.

   M ← 20   N ← 18

2. Divide M by N, call the remainder R.

   M/N = 20 / 18 = 1, with R ← 2

   M/N = 18 / 2 = 9, with R ← 0

3. If R is not 0, assign M the value of N, assign N the value of R, and go to step 2.

   R = 2. Therefore, M ← 18, N ← 2. Go to step 2.

   R is 0. Therefore, proceed to step 4.

4. The greatest common divisor is N.

   GCD = N = 2

Animation of Euclid's Algorithm

Self-Test Questions

1. Which of the following are true of an algorithm?
(a) Has a finite number of steps
(b) Produces a result in a finite amount of time
(c) Solves a general problem
(d) All of the above

2. Algorithms were first developed in the 1930–1940s when the first computing machines appeared. (TRUE/FALSE)

3. Algorithms and computers are a "perfect match" because: (Select all that apply.)
(a) Computers can execute a large number of instructions very quickly.
(b) Computers can execute instructions reliably without error.
(c) Computers can determine which algorithms are the best to use for a given problem.

4. Given that the year 2016 is a leap year, what day of the week does April 15th of that year fall on? Use the algorithm in Figure 1-8 for this.

5. Which of the following is an example of an algorithm? (Select all that apply.)
(a) A means of sorting any list of numbers
(b) Directions for getting from your home to a friend's house
(c) A means of finding the shortest route from your house to a friend's house.

ANSWERS:

Self-Test Questions

1. Which of the following are true of an algorithm?
   (a) Has a finite number of steps
   (b) Produces a result in a finite amount of time
   (c) Solves a general problem
   (d) All of the above

2. Algorithms were first developed in the 1930–1940s when the first computing machines appeared. (TRUE/FALSE)

3. Algorithms and computers are a "perfect match" because: (Select all that apply.)
   (a) Computers can execute a large number of instructions very quickly.
   (b) Computers can execute instructions reliably without error.
   (c) Computers can determine which algorithms are the best to use for a given problem.

4. Given that the year 2016 is a leap year, what day of the week does April 15th of that year fall on? Use the algorithm in Figure 1-8 for this.

5. Which of the following is an example of an algorithm? (Select all that apply.)
   (a) A means of sorting any list of numbers
   (b) Directions for getting from your home to a friend's house
   (c) A means of finding the shortest route from your house to a friend's house.

ANSWERS: 1. (d),

Self-Test Questions

1. Which of the following are true of an algorithm?
   (a) Has a finite number of steps
   (b) Produces a result in a finite amount of time
   (c) Solves a general problem
   (d) All of the above

2. Algorithms were first developed in the 1930–1940s when the first computing machines appeared. (TRUE/FALSE)

3. Algorithms and computers are a "perfect match" because: (Select all that apply.)
   (a) Computers can execute a large number of instructions very quickly.
   (b) Computers can execute instructions reliably without error.
   (c) Computers can determine which algorithms are the best to use for a given problem.

4. Given that the year 2016 is a leap year, what day of the week does April 15th of that year fall on? Use the algorithm in Figure 1-8 for this.

5. Which of the following is an example of an algorithm? (Select all that apply.)
   (a) A means of sorting any list of numbers
   (b) Directions for getting from your home to a friend's house
   (c) A means of finding the shortest route from your house to a friend's house.

ANSWERS: 1. (d) 2. False,

Self-Test Questions

1. Which of the following are true of an algorithm?
   (a) Has a finite number of steps
   (b) Produces a result in a finite amount of time
   (c) Solves a general problem
   (d) All of the above

2. Algorithms were first developed in the 1930–1940s when the first computing machines appeared. (TRUE/FALSE)

3. Algorithms and computers are a "perfect match" because: (Select all that apply.)
   (a) Computers can execute a large number of instructions very quickly.
   (b) Computers can execute instructions reliably without error.
   (c) Computers can determine which algorithms are the best to use for a given problem.

4. Given that the year 2016 is a leap year, what day of the week does April 15th of that year fall on? Use the algorithm in Figure 1-8 for this.

5. Which of the following is an example of an algorithm? (Select all that apply.)
   (a) A means of sorting any list of numbers
   (b) Directions for getting from your home to a friend's house
   (c) A means of finding the shortest route from your house to a friend's house.

ANSWERS: 1. (d), 2. False, 3. (a,b)

Self-Test Questions

1. Which of the following are true of an algorithm?
   (a) Has a finite number of steps
   (b) Produces a result in a finite amount of time
   (c) Solves a general problem
   (d) All of the above

2. Algorithms were first developed in the 1930–1940s when the first computing machines appeared. (TRUE/FALSE)

3. Algorithms and computers are a "perfect match" because: (Select all that apply.)
   (a) Computers can execute a large number of instructions very quickly.
   (b) Computers can execute instructions reliably without error.
   (c) Computers can determine which algorithms are the best to use for a given problem.

4. Given that the year 2016 is a leap year, what day of the week does April 15th of that year fall on? Use the algorithm in Figure 1-8 for this.

5. Which of the following is an example of an algorithm? (Select all that apply.)
   (a) A means of sorting any list of numbers
   (b) Directions for getting from your home to a friend's house
   (c) A means of finding the shortest route from your house to a friend's house.

ANSWERS: 1. (d), 2. False, 3. (a,b) 4. Friday

Self-Test Questions

1. Which of the following are true of an algorithm?
   (a) Has a finite number of steps
   (b) Produces a result in a finite amount of time
   (c) Solves a general problem
   (d) All of the above

2. Algorithms were first developed in the 1930–1940s when the first computing machines appeared. (TRUE/FALSE)

3. Algorithms and computers are a "perfect match" because: (Select all that apply.)
   (a) Computers can execute a large number of instructions very quickly.
   (b) Computers can execute instructions reliably without error.
   (c) Computers can determine which algorithms are the best to use for a given problem.

4. Given that the year 2016 is a leap year, what day of the week does April 15th of that year fall on? Use the algorithm in Figure 1-8 for this.

5. Which of the following is an example of an algorithm? (Select all that apply.)
   (a) A means of sorting any list of numbers
   (b) Directions for getting from your home to a friend's house
   (c) A means of finding the shortest route from your house to a friend's house.

ANSWERS: 1. (d), 2. False, 3. (a,b) 4. Friday $\boxed{\text{5. (a,c)}}$

Computer Hardware

Computer hardware comprises the **physical part of a computer system**. It includes the all-important components of the **central processing unit** (CPU) and **main memory**. It also includes **peripheral components** such as a keyboard, monitor, mouse, and printer.

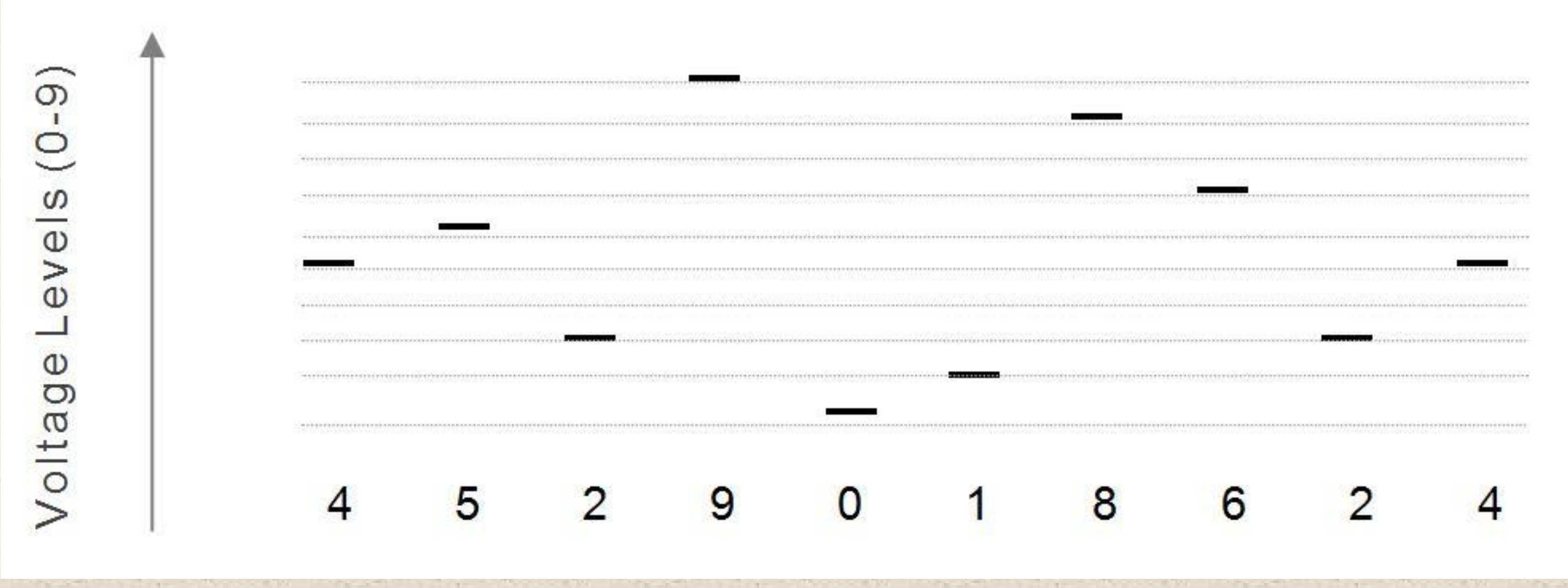
Digital Computing: It's All About Switches

It is essential that computer hardware be reliable and error free. If the hardware gives incorrect results, then any program run on that hardware may give incorrect results as well.

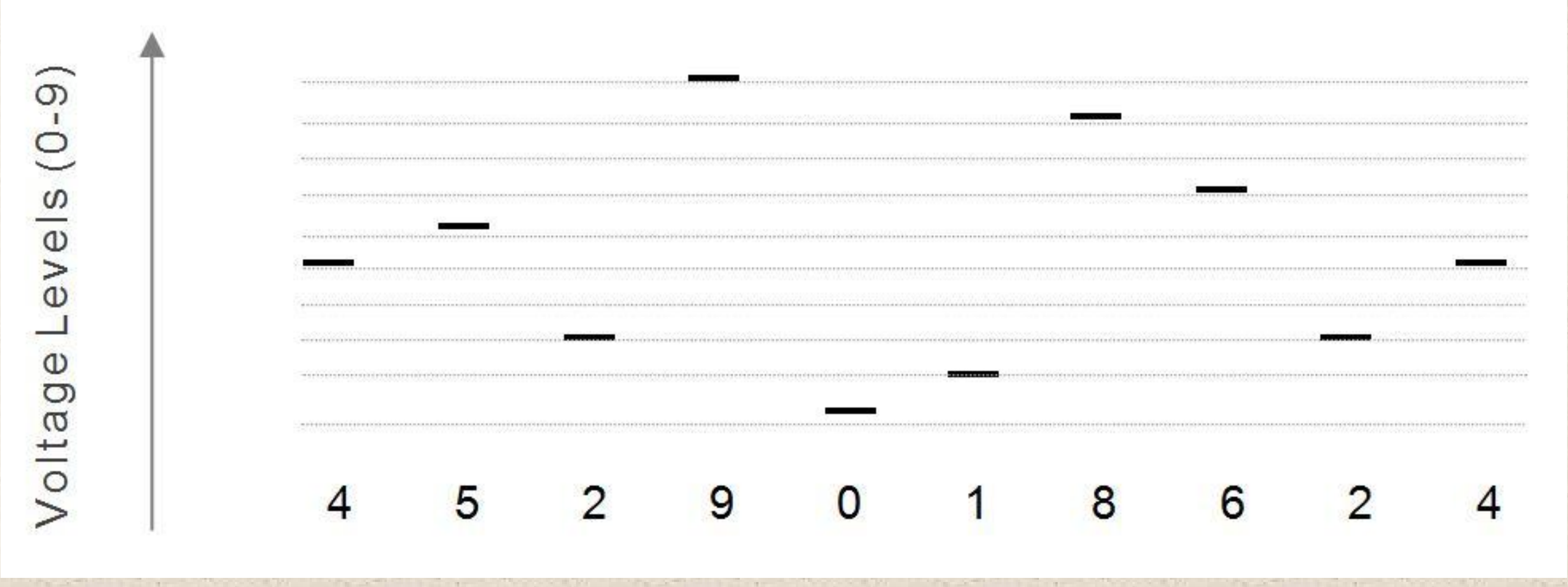
The key to developing reliable systems is to keep the design as simple as possible. In digital computing, all information is represented as a series of digits.

Decimal Digitalization

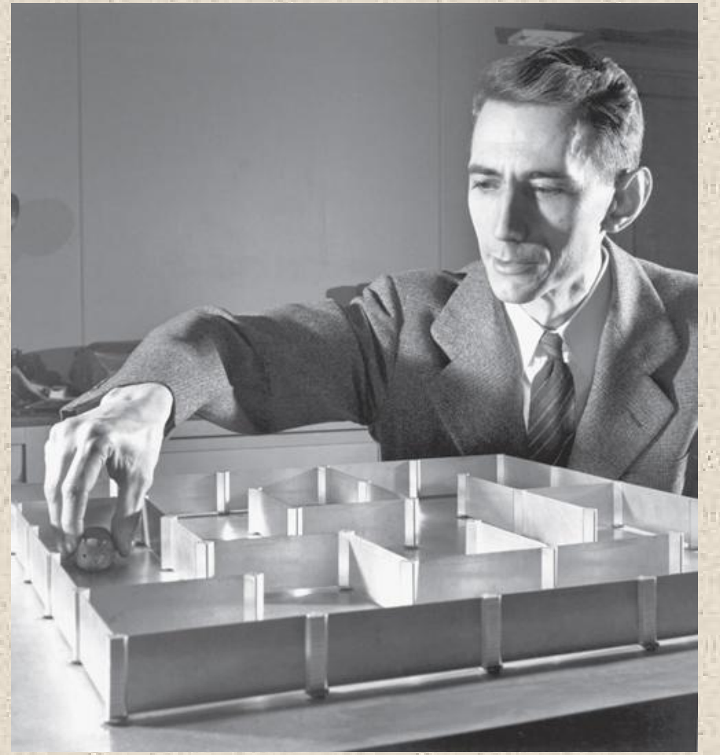
In electronic computing, values are represented by discrete voltage levels. Suppose that the computer represented numbers as we are used to, in base ten.



Each digit is represented by a different voltage level. The **more voltage levels (digits)** that the hardware must utilize and distinguish, the **more complex the hardware becomes to design**. This results in greater chance of hardware design errors.



Information Theory



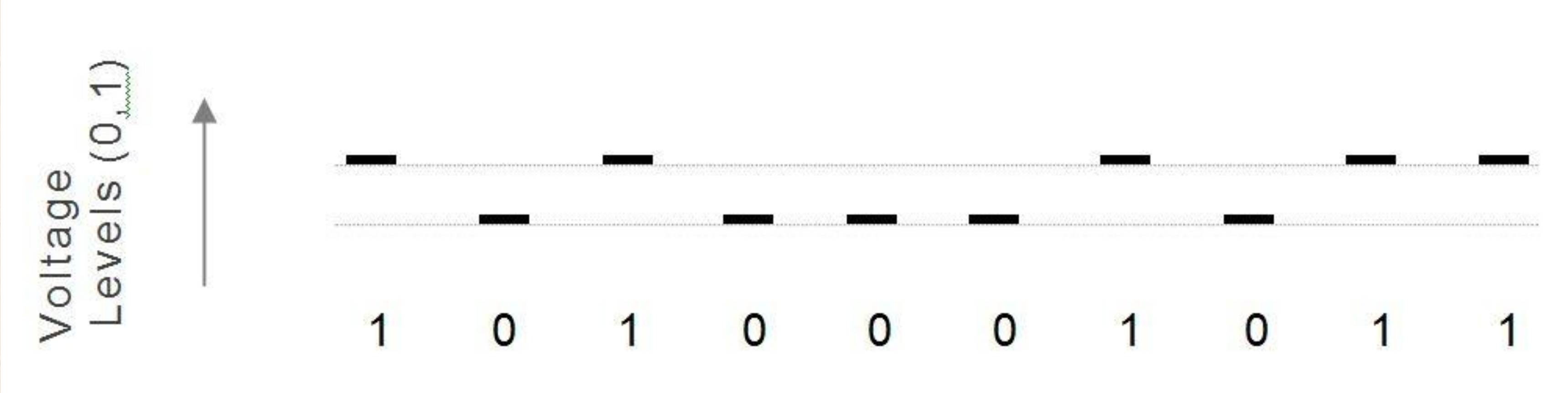
The **Fundamental Theorem of Information Science** of **Claude Shannon** states that all information can be represented by the use of only two symbols, 0 and 1. This is referred to as **binary representation.**

Shannon is known as the **"Father of Information Theory."**

Binary Digitalization

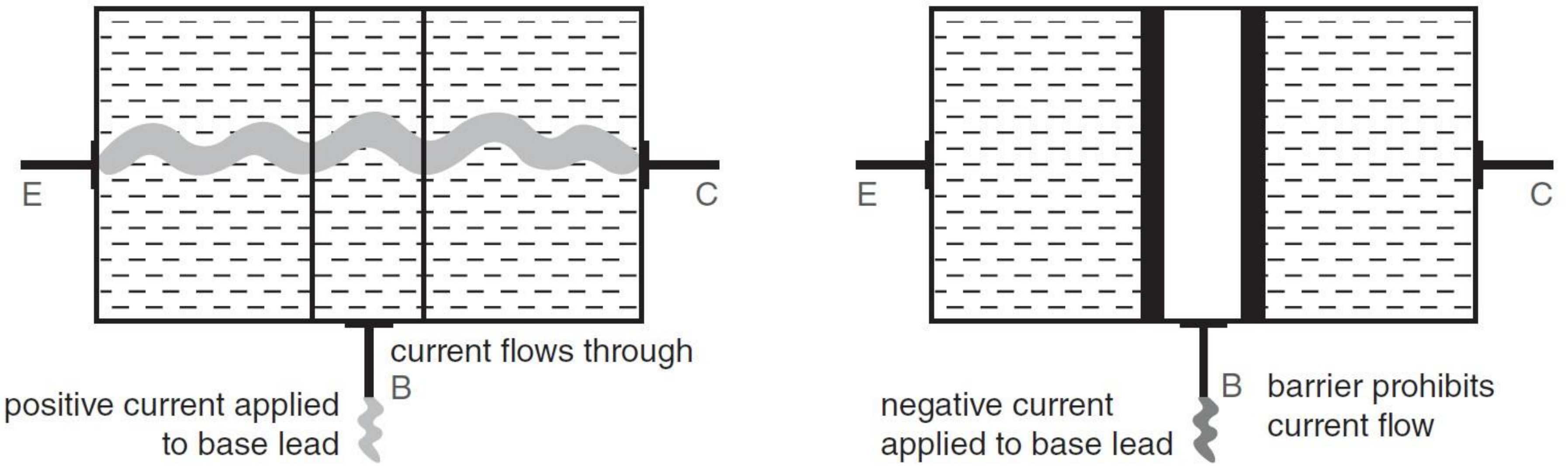
In this representation, each digit can be one of only two possible values, similar to a light switch that can be either on or off.

Computer hardware, therefore, is based on the use of simple **electronic on/off switches** called **transistors** that can switched at essentially the speed of light.



The Transistor

The transistor, developed in 1947, revolutionized electronics. Its invention is what has allowed for all of the dramatic advances in computing technology that we continue to see today.

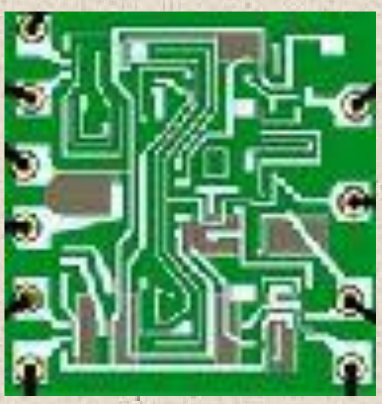


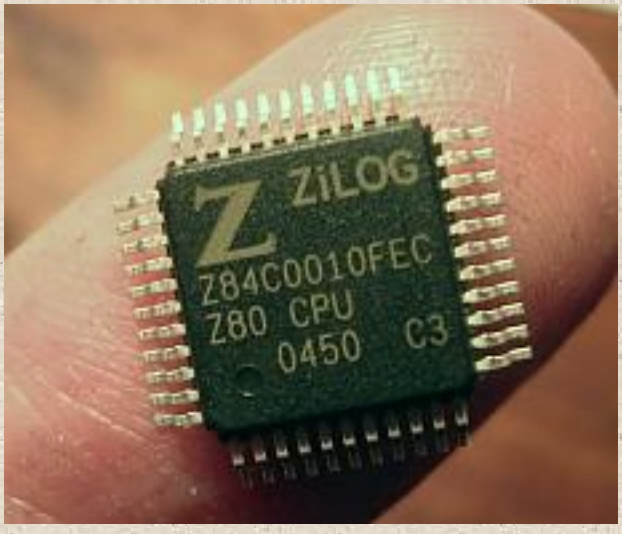
Transistor Switched On
(E – emitter C – collector B – base lead)

Transistor Switched Off
(E – emitter C – collector B – base lead)

Integrated Circuits

Integrated circuits (chips), the building blocks of computer hardware, are comprised of millions or even billions of transistors.





The Binary Number System

For representing numbers, any base (radix) can be used. For example, in **base 10**, there are ten possible digits (0, 1, ..., 9), in which each column value is a power of ten:

10,000,000	1,000,000	100,000	10,000	1,000	100	10	1
10^7	10^6	10^5	10^4	10^3	10^2	10^1	10^0
						9	9 = **99**

For representing numbers in **base 2**, there are two possible digits (0, 1) in which each column value is a power of two:

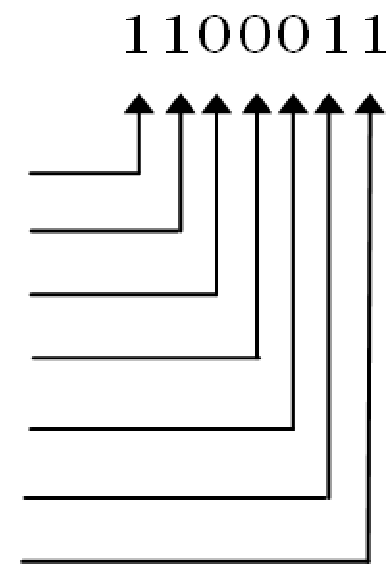
128	64	32	16	8	4	2	1
2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
0	1	1	0	0	0	1	1
0 +	64 +	32 +	0 +	0 +	0 +	2 +	1 = **99**

Although values represented in base 2 are significantly longer than those in base 10, **binary representation is used in digital computing because of the resulting simplicity of hardware design**.

Bits and Bytes

Each **bi**nary **d**igit is referred to as a **bit**. A group of (usually) eight bits is called a **byte**. Converting a base ten number to base two involves the successive division of the number by 2.

```
99/2  =  49, with remainder 1
49/2  =  24, with remainder 1
24/2  =  12, with remainder 0
12/2  =  6,  with remainder 0
6/2   =  3,  with remainder 0
3/2   =  1,  with remainder 1
1/2   =  0,  with remainder 1
```



Fundamental Hardware Components

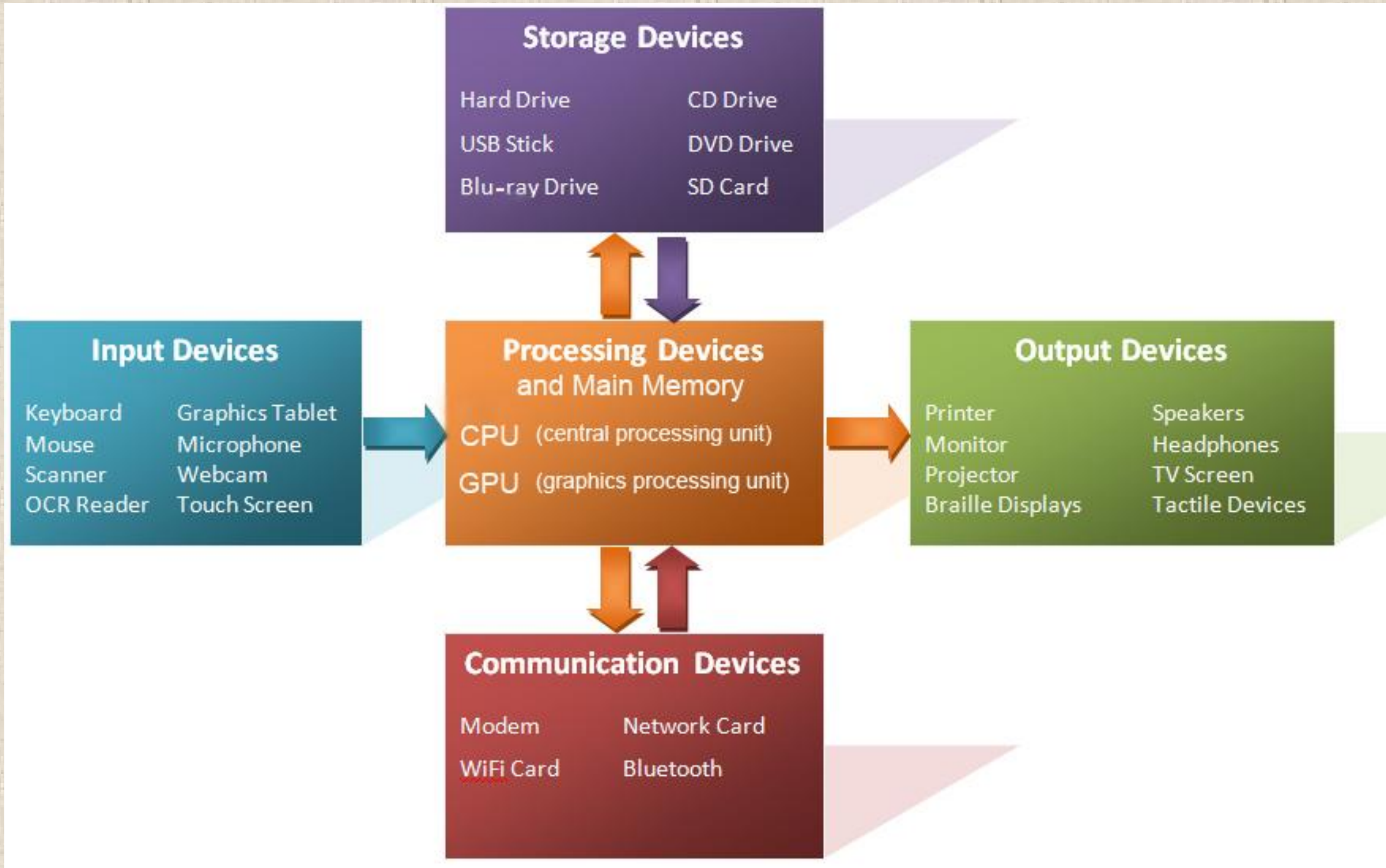
Central processing unit (CPU) – the "brain" of a computer system. Interprets and executes instructions.

Main memory – is where currently executing programs reside. It is *volatile*, the contents are lost when the power is turned off.

Secondary memory – provides long-term storage of programs and data. N*onvolatile*, the contents are retained when power is turned off. Can be magnetic (hard drive), optical (CD or DVD), or flash memory (USB drive).

Input/output devices – mouse, keyboard, monitor, printer, etc.

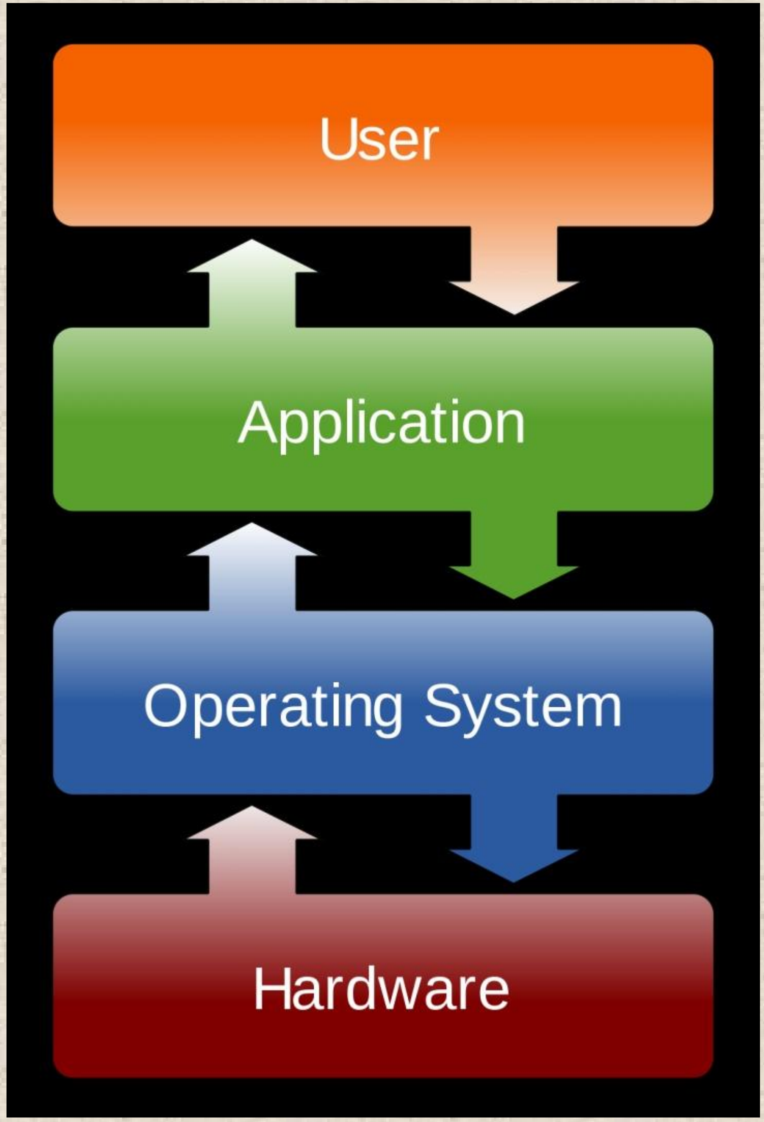
Buses – transfer data between components within a computer system. System bus (between CPU and main memory).


Storage Devices
Hard Drive
CD Drive
USB Stick
DVD Drive
Blu-ray Drive
SD Card
Input Devices
Keyboard
Graphics Tablet
Mouse
Microphone
Scanner
Webcam
OCR Reader
Touch Screen
Processing Devices
and Main Memory
CPU (central processing unit)
GPU (graphics processing unit)
Output Devices
Printer
Speakers
Monitor
Headphones
Projector
TV Screen
Braille Displays
Tactile Devices
Communication Devices
Modem
Network Card
WiFi Card
Bluetooth

Operating Systems

An **operating system** is software that manages and interacts with the hardware resources of a computer.

Because an operating system is intrinsic to the operation of a computer, it is referred to as **system software**.


User
Application
Operating System
Hardware

Operating systems also provide a particular **user interface**.

It is the operating system installed on a given computer that determines the **"look and feel"** of the user interface and how the user interacts with the system, and not the particular model computer.

Limits of Integrated Circuits Technology: Moore's Law

In 1965, **Gordon E. Moore**, one of the pioneers in the development of integrated circuits and cofounder of Intel Corporation, **predicted that the number of transistors that would be able to be put on a silicon chip would double roughly every two years**, allowing the complexity and therefore the capabilities of integrated circuits to grow exponentially. This prediction became known as **Moore's Law**.

Amazingly, to this day that prediction has held true. While this doubling of performance cannot go on indefinitely, it has not yet reached its limit.

Self-Test Questions

1. All information in a computer system is in binary representation. (TRUE/FALSE)

2. Computer hardware is based on the use of electronic switches called ______________.

3. How many of these electronic switches can be placed on a single integrated circuit, or "chip"?
   (a) Thousands
   (b) Millions
   (c) Billions

4. The term "bit" stands for ______________.

5. A bit is generally a group of eight bytes. (TRUE/FALSE)

6. What is the value of the binary representation 0110.
   (a) 12
   (b) 3
   (c) 6

7. The ______________ interprets and executes instructions in a computer system.

8. An operating system manages the hardware resources of a computer system, as well as provides a particular user interface. (TRUE/FALSE)

9. Moore's Law predicts that the number of transistors that can fit on a chip doubles about every ten years. (TRUE/FALSE)

ANSWERS:

Self-Test Questions

1. All information in a computer system is in binary representation. (TRUE/FALSE)

2. Computer hardware is based on the use of electronic switches called ______________.

3. How many of these electronic switches can be placed on a single integrated circuit, or "chip"?
   (a) Thousands
   (b) Millions
   (c) Billions

4. The term "bit" stands for ______________.

5. A bit is generally a group of eight bytes. (TRUE/FALSE)

6. What is the value of the binary representation 0110.
   (a) 12
   (b) 3
   (c) 6

7. The ______________ interprets and executes instructions in a computer system.

8. An operating system manages the hardware resources of a computer system, as well as provides a particular user interface. (TRUE/FALSE)

9. Moore's Law predicts that the number of transistors that can fit on a chip doubles about every ten years. (TRUE/FALSE)

ANSWERS 1. True,

Self-Test Questions

1. All information in a computer system is in binary representation. (TRUE/FALSE)
2. Computer hardware is based on the use of electronic switches called ______________.
3. How many of these electronic switches can be placed on a single integrated circuit, or "chip"?
   (a) Thousands
   (b) Millions
   (c) Billions
4. The term "bit" stands for ______________.
5. A bit is generally a group of eight bytes. (TRUE/FALSE)
6. What is the value of the binary representation 0110.
   (a) 12
   (b) 3
   (c) 6
7. The ______________ interprets and executes instructions in a computer system.
8. An operating system manages the hardware resources of a computer system, as well as provides a particular user interface. (TRUE/FALSE)
9. Moore's Law predicts that the number of transistors that can fit on a chip doubles about every ten years. (TRUE/FALSE)

ANSWERS: 1. True 2. transistors,

Self-Test Questions

1. All information in a computer system is in binary representation. (TRUE/FALSE)

2. Computer hardware is based on the use of electronic switches called ______________.

3. How many of these electronic switches can be placed on a single integrated circuit, or "chip"?
   (a) Thousands
   (b) Millions
   (c) Billions

4. The term "bit" stands for ______________.

5. A bit is generally a group of eight bytes. (TRUE/FALSE)

6. What is the value of the binary representation 0110.
   (a) 12
   (b) 3
   (c) 6

7. The ______________ interprets and executes instructions in a computer system.

8. An operating system manages the hardware resources of a computer system, as well as provides a particular user interface. (TRUE/FALSE)

9. Moore's Law predicts that the number of transistors that can fit on a chip doubles about every ten years. (TRUE/FALSE)

ANSWERS: 1. True, 2. transistors, 3. (c),

Self-Test Questions

1. All information in a computer system is in binary representation. (TRUE/FALSE)
2. Computer hardware is based on the use of electronic switches called ________________.
3. How many of these electronic switches can be placed on a single integrated circuit, or "chip"?
   (a) Thousands
   (b) Millions
   (c) Billions
4. The term "bit" stands for ________________.
5. A bit is generally a group of eight bytes. (TRUE/FALSE)
6. What is the value of the binary representation 0110.
   (a) 12
   (b) 3
   (c) 6
7. The ________________ interprets and executes instructions in a computer system.
8. An operating system manages the hardware resources of a computer system, as well as provides a particular user interface. (TRUE/FALSE)
9. Moore's Law predicts that the number of transistors that can fit on a chip doubles about every ten years. (TRUE/FALSE)

ANSWERS: 1. True, 2. transistors, 3. (c), 4. binary digit, 5. False,

Self-Test Questions

1. All information in a computer system is in binary representation. (TRUE/FALSE)

2. Computer hardware is based on the use of electronic switches called ______________.

3. How many of these electronic switches can be placed on a single integrated circuit, or "chip"?
   (a) Thousands
   (b) Millions
   (c) Billions

4. The term "bit" stands for ______________.

5. A bit is generally a group of eight bytes. (TRUE/FALSE)

6. What is the value of the binary representation 0110.
   (a) 12
   (b) 3
   (c) 6

7. The ______________ interprets and executes instructions in a computer system.

8. An operating system manages the hardware resources of a computer system, as well as provides a particular user interface. (TRUE/FALSE)

9. Moore's Law predicts that the number of transistors that can fit on a chip doubles about every ten years. (TRUE/FALSE)

ANSWERS: 1. True, 2. transistors, 3. (c), 4. binary digit, 5. False, 6. (c),

Self-Test Questions

1. All information in a computer system is in binary representation. (TRUE/FALSE)
2. Computer hardware is based on the use of electronic switches called ______________.
3. How many of these electronic switches can be placed on a single integrated circuit, or "chip"?
   (a) Thousands
   (b) Millions
   (c) Billions
4. The term "bit" stands for ______________.
5. A bit is generally a group of eight bytes. (TRUE/FALSE)
6. What is the value of the binary representation 0110.
   (a) 12
   (b) 3
   (c) 6
7. The ______________ interprets and executes instructions in a computer system.
8. An operating system manages the hardware resources of a computer system, as well as provides a particular user interface. (TRUE/FALSE)
9. Moore's Law predicts that the number of transistors that can fit on a chip doubles about every ten years. (TRUE/FALSE)

ANSWERS: 1. True, 2. transistors, 3. (c), 4. binary digit, 5. False, 6. (c), 7. CPU,

Self-Test Questions

1. All information in a computer system is in binary representation. (TRUE/FALSE)
2. Computer hardware is based on the use of electronic switches called ______________.
3. How many of these electronic switches can be placed on a single integrated circuit, or "chip"?
   (a) Thousands
   (b) Millions
   (c) Billions
4. The term "bit" stands for ______________.
5. A bit is generally a group of eight bytes. (TRUE/FALSE)
6. What is the value of the binary representation 0110.
   (a) 12
   (b) 3
   (c) 6
7. The ______________ interprets and executes instructions in a computer system.
8. An operating system manages the hardware resources of a computer system, as well as provides a particular user interface. (TRUE/FALSE)
9. Moore's Law predicts that the number of transistors that can fit on a chip doubles about every ten years. (TRUE/FALSE)

ANSWERS: 1. True, 2. transistors, 3. (c), 4. binary digit, 5. False, 6. (c), 7. CPU, 8. True,

Self-Test Questions

1. All information in a computer system is in binary representation. (TRUE/FALSE)
2. Computer hardware is based on the use of electronic switches called ______________.
3. How many of these electronic switches can be placed on a single integrated circuit, or "chip"?
   (a) Thousands
   (b) Millions
   (c) Billions
4. The term "bit" stands for ______________.
5. A bit is generally a group of eight bytes. (TRUE/FALSE)
6. What is the value of the binary representation 0110.
   (a) 12
   (b) 3
   (c) 6
7. The ______________ interprets and executes instructions in a computer system.
8. An operating system manages the hardware resources of a computer system, as well as provides a particular user interface. (TRUE/FALSE)
9. Moore's Law predicts that the number of transistors that can fit on a chip doubles about every ten years. (TRUE/FALSE)

ANSWERS: 1. True, 2. transistors, 3. (c), 4. binary digit, 5. False, 6. (c), 7. CPU, 8. True, $\boxed{\text{9. False}}$

Computer Software

What is computer software?

Computer software is a set of program instructions, including related data and documentation, that can be executed by computer. This can be in the form of instructions on paper, or in digital form.

While **system software** is intrinsic to a computer system, **application software** fulfills users' needs, such as a photo-editing program.

The First Computer Programmer

The first computer programs ever written were for a mechanical computer designed by **Charles Babbage** in the mid-1800s. The person who wrote these programs was a woman, **Ada Lovelace**, who was a talented mathematician. Thus, she is referred to as **"the first computer programmer."**

Syntax, Semantics and Program Translation

Programming languages (called **"artificial languages"**) are languages just as **"natural languages"** such as English and Mandarin (Chinese).

Syntax and ***semantics*** are important concepts that apply to all languages.

Syntax

The **syntax** of a language is a set of characters and the acceptable sequences (arrangements) of those characters.

English, for example, includes the letters of the alphabet, punctuation, and properly spelled words and properly punctuated sentences. The following is a syntactically correct sentence in English,

"Hello there, how are you?"

The following, however, is not syntactically correct,

"Hello there, hao are you?"

The sequence of letters "hao" is not a word in the English language.

Semantics

The **semantics** of a language is the meaning associated with each syntactically correct sequence of characters.

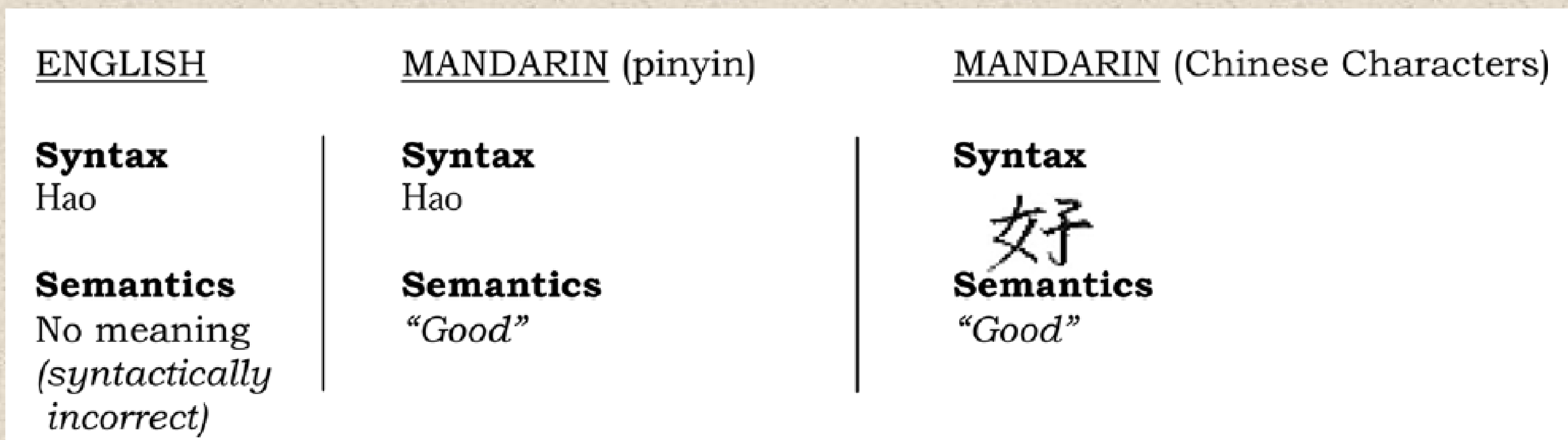
Consider the following sentence:

"Colorless green ideas sleep furiously."

This sentence is syntactically correct, but has no meaning. Thus, it is *semantically incorrect.*

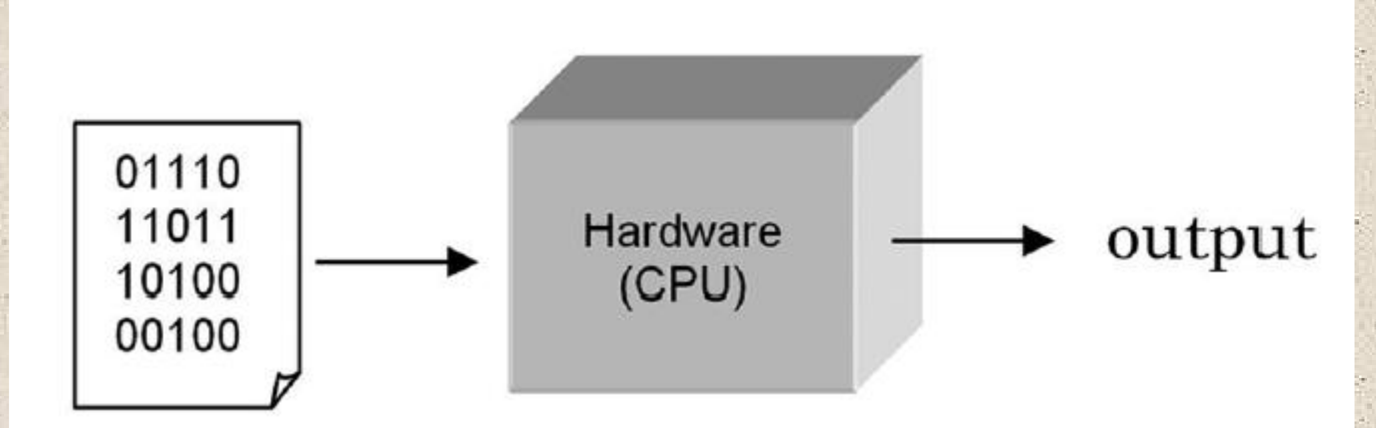
Every language has its own syntax and semantics.

For example, in English “Hao” is syntactically incorrect. In Mandarin (Chinese), however, “Hao” is a valid word meaning “good.” (“Hao” is from a system called pinyin, which uses the Roman alphabet rather than Chinese characters for writing Mandarin.)



Program Translation

A central processing unit (CPU) is designed to interpret and execute a specific set of instructions represented in binary form (i.e., 1s and 0s) called **machine code**. Only programs in machine code can be executed by a CPU.



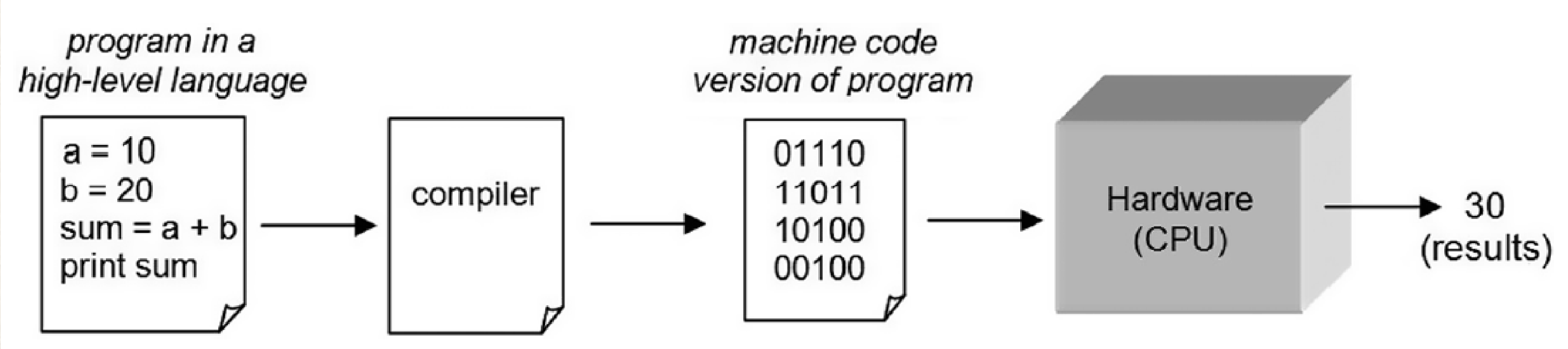
Writing programs at this "low level" is tedious and error-prone. Therefore, most programs are written in a "high-level" programming language such as Python. Since the instructions of such programs are not in machine code that a CPU can execute, a translator program must be used.

There are two fundamental types of translators:

- **Compiler** translates programs into machine code to be executed by the CPU

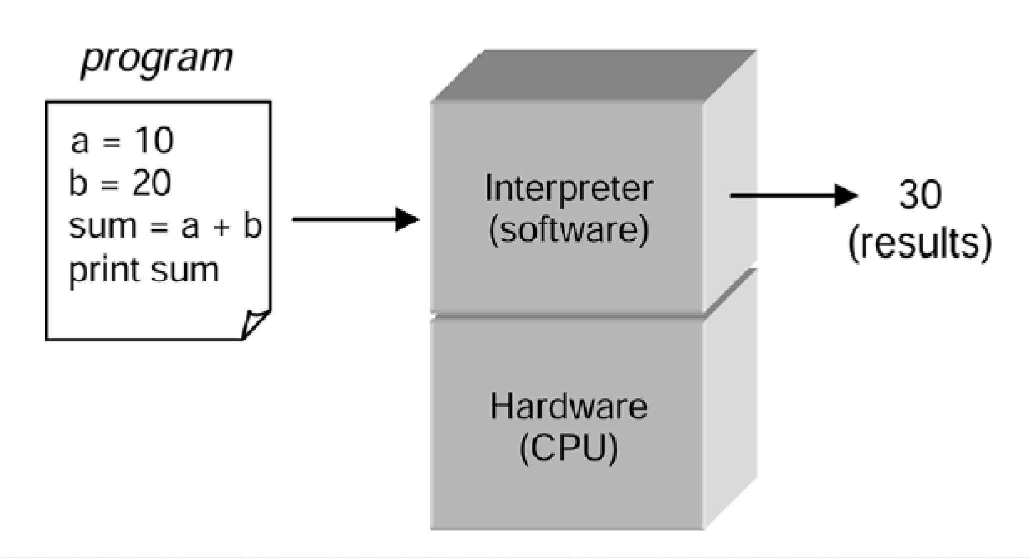
- **Interpreter** executes instructions in place of the CPU

Compiler



Compiled programs generally execute faster than interpreted programs.

Interpreter



An interpreter can immediately execute instructions as they are entered. This is referred to as **interactive mode**. This is a very useful feature for program development. Python, as we shall see, is executed by an interpreter.

Program Debugging:
Syntax Errors vs. Semantic Errors

Program debugging is the process of finding and correcting errors ("bugs") in a computer program. Programming errors are inevitable during program development.

Syntax errors are caused by invalid syntax (for example, entering `prnt` instead of `print`).

Since a translator cannot understand instructions containing syntax errors, translators terminate when encountering such errors indicating where in the program the problem occurred.

In contrast, **semantic errors** (generally called logic errors) **are errors in program logic**. Such errors cannot be automatically detected, since translators cannot understand the intent of a given computation.

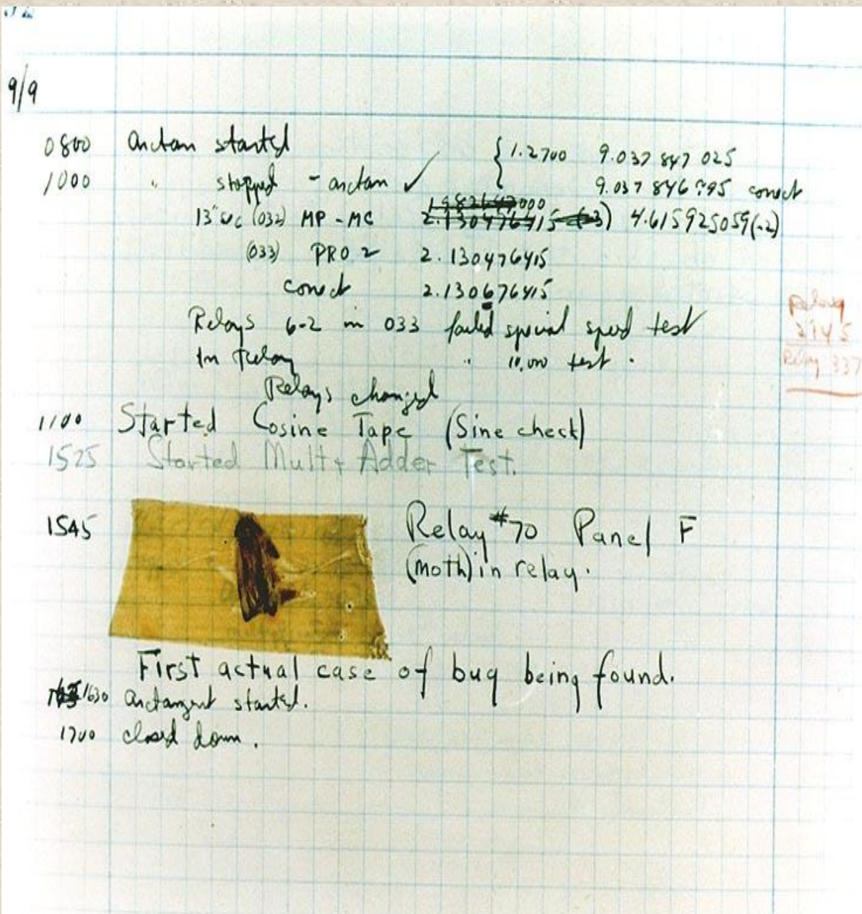
For example, if a program computed the average of three numbers as follows,

```
(num1 + num2 + num3) / 2.0
```

a translator would have no means of determining that the divisor should be 3 and not 2. **Computers do not understand what a program is meant to do, they only follow the instructions given**. It is up to the programmer to detect such errors.

Program debugging is not a trivial task, and constitutes much of the time of program development.

The First Actual Computer "Bug"



In 1947, engineers working on the **Mark II computer at Harvard University** found a moth stuck in one of the components, causing the machine to malfunction. They taped the insect in their logbook and labeled it "**first actual case of bug being found**." It has become a standard part of the language of computer programmers. The log book, complete with the attached bug, is on display at the Smithsonian Institution in Washington, D.C.

Procedural vs. Object-Oriented Programming

Programming languages fall into a number of programming paradigms. **The two major programming paradigms in use today are procedural (imperative) programming and object-oriented programming**. Each provides a different way of thinking about computation. While most programming languages only support one paradigm, **Python supports both procedural and object-oriented programming**. We will start with the procedural aspects of Python.

Self-Test Questions

1. Two general types of software are system software and ______________ software.

2. The syntax of a given language is,
   (a) the set of symbols in the language.
   (b) the acceptable arrangement of symbols.
   (c) both of the above

3. The semantics of a given language is the meaning associated with any arrangement of symbols in the language. (TRUE/FALSE)

4. CPUs can only execute instructions that are in binary form called ______________.

5. The two fundamental types of translation programs for the execution of computer programs are ______________ and ______________.

6. The process of finding and correcting errors in a computer program is called ______________.

7. Which kinds of errors can a translator program detect?
   (a) Syntax errors
   (b) Semantic errors
   (c) Neither of the above

8. Two major programming paradigms in use today are ______________ programming and ______________ programming.

ANSWERS:

Self-Test Questions

1. Two general types of software are system software and ______________ software.

2. The syntax of a given language is,
   (a) the set of symbols in the language.
   (b) the acceptable arrangement of symbols.
   (c) both of the above

3. The semantics of a given language is the meaning associated with any arrangement of symbols in the language. (TRUE/FALSE)

4. CPUs can only execute instructions that are in binary form called ______________.

5. The two fundamental types of translation programs for the execution of computer programs are ______________ and ______________.

6. The process of finding and correcting errors in a computer program is called ______________.

7. Which kinds of errors can a translator program detect?
   (a) Syntax errors
   (b) Semantic errors
   (c) Neither of the above

8. Two major programming paradigms in use today are ______________ programming and ______________ programming.

ANSWERS: 1. application,

Self-Test Questions

1. Two general types of software are system software and ______________ software.

2. The syntax of a given language is,
   (a) the set of symbols in the language.
   (b) the acceptable arrangement of symbols.
   (c) both of the above

3. The semantics of a given language is the meaning associated with any arrangement of symbols in the language. (TRUE/FALSE)

4. CPUs can only execute instructions that are in binary form called ______________.

5. The two fundamental types of translation programs for the execution of computer programs are ______________ and ______________.

6. The process of finding and correcting errors in a computer program is called ______________.

7. Which kinds of errors can a translator program detect?
   (a) Syntax errors
   (b) Semantic errors
   (c) Neither of the above

8. Two major programming paradigms in use today are ______________ programming and ______________ programming.

ANSWERS: 1. application, 2. (c), [redacted]

Self-Test Questions

1. Two general types of software are system software and ______________ software.
2. The syntax of a given language is,
   (a) the set of symbols in the language.
   (b) the acceptable arrangement of symbols.
   (c) both of the above
3. The semantics of a given language is the meaning associated with any arrangement of symbols in the language. (TRUE/FALSE)
4. CPUs can only execute instructions that are in binary form called ______________.
5. The two fundamental types of translation programs for the execution of computer programs are ______________ and ______________.
6. The process of finding and correcting errors in a computer program is called ______________.
7. Which kinds of errors can a translator program detect?
   (a) Syntax errors
   (b) Semantic errors
   (c) Neither of the above
8. Two major programming paradigms in use today are ______________ programming and ______________ programming.

ANSWERS: 1. application, 2. (c), 3. False,

Self-Test Questions

1. Two general types of software are system software and ______________ software.
2. The syntax of a given language is,
   (a) the set of symbols in the language.
   (b) the acceptable arrangement of symbols.
   (c) both of the above
3. The semantics of a given language is the meaning associated with any arrangement of symbols in the language. (TRUE/FALSE)
4. CPUs can only execute instructions that are in binary form called ______________.
5. The two fundamental types of translation programs for the execution of computer programs are ______________ and ______________.
6. The process of finding and correcting errors in a computer program is called ______________.
7. Which kinds of errors can a translator program detect?
   (a) Syntax errors
   (b) Semantic errors
   (c) Neither of the above
8. Two major programming paradigms in use today are ______________ programming and ______________ programming.

ANSWERS: 1. application, 2. (c), 3. False, 4. machine code,

Self-Test Questions

1. Two general types of software are system software and ______________ software.
2. The syntax of a given language is,
   (a) the set of symbols in the language.
   (b) the acceptable arrangement of symbols.
   (c) both of the above
3. The semantics of a given language is the meaning associated with any arrangement of symbols in the language. (TRUE/FALSE)
4. CPUs can only execute instructions that are in binary form called ______________.
5. The two fundamental types of translation programs for the execution of computer programs are ______________ and ______________.
6. The process of finding and correcting errors in a computer program is called ______________.
7. Which kinds of errors can a translator program detect?
   (a) Syntax errors
   (b) Semantic errors
   (c) Neither of the above
8. Two major programming paradigms in use today are ______________ programming and ______________ programming.

ANSWERS: 1. application, 2. (c), 3. False, 4. machine code, 5. compilers, interpreters,

Self-Test Questions

1. Two general types of software are system software and _______________ software.

2. The syntax of a given language is,
   (a) the set of symbols in the language.
   (b) the acceptable arrangement of symbols.
   (c) both of the above

3. The semantics of a given language is the meaning associated with any arrangement of symbols in the language. (TRUE/FALSE)

4. CPUs can only execute instructions that are in binary form called _______________.

5. The two fundamental types of translation programs for the execution of computer programs are _______________ and _______________.

6. The process of finding and correcting errors in a computer program is called _______________.

7. Which kinds of errors can a translator program detect?
   (a) Syntax errors
   (b) Semantic errors
   (c) Neither of the above

8. Two major programming paradigms in use today are _______________ programming and _______________ programming.

ANSWERS: 1. application, 2. (c), 3. False, 4. machine code, 5. compilers, interpreters, 6. program debugging,

Self-Test Questions

1. Two general types of software are system software and ______________ software.
2. The syntax of a given language is,
   (a) the set of symbols in the language.
   (b) the acceptable arrangement of symbols.
   (c) both of the above
3. The semantics of a given language is the meaning associated with any arrangement of symbols in the language. (TRUE/FALSE)
4. CPUs can only execute instructions that are in binary form called ______________.
5. The two fundamental types of translation programs for the execution of computer programs are ______________ and ______________.
6. The process of finding and correcting errors in a computer program is called ______________.
7. Which kinds of errors can a translator program detect?
   (a) Syntax errors
   (b) Semantic errors
   (c) Neither of the above
8. Two major programming paradigms in use today are ______________ programming and ______________ programming.

ANSWERS: 1. application, 2. (c), 3. False, 4. machine code, 5. compilers, interpreters, 6. program debugging 7. (a),

Self-Test Questions

1. Two general types of software are system software and ______________ software.
2. The syntax of a given language is,
   (a) the set of symbols in the language.
   (b) the acceptable arrangement of symbols.
   (c) both of the above
3. The semantics of a given language is the meaning associated with any arrangement of symbols in the language. (TRUE/FALSE)
4. CPUs can only execute instructions that are in binary form called ______________.
5. The two fundamental types of translation programs for the execution of computer programs are ______________ and ______________.
6. The process of finding and correcting errors in a computer program is called ______________.
7. Which kinds of errors can a translator program detect?
   (a) Syntax errors
   (b) Semantic errors
   (c) Neither of the above
8. Two major programming paradigms in use today are ______________ programming and ______________ programming.

ANSWERS: 1. application, 2. (c), 3. False, 4. machine code, 5. compilers, interpreters, 6. program debugging, 7. (a) 8. procedural, object-oriented

The Process of Computational Problem Solving

Computational problem solving does not simply involve the act of computer programming. It is a *process*, with programming being only one of the steps.

Before a program is written, a design for the program must be developed. And before a design can be developed, the problem to be solved must be well understood. Once written, the program must be thoroughly tested.

Computational Problem Solving Steps

ANALYSIS

Analyze Problem

- Clearly understand the problem
- Know what constitutes a solution

DESIGN

Describe Data & Algorithms

- Determine what type of data is needed
- Determine how data is to be structured
- Find and/or design appropriate algorithms

IMPLEMENTATION

Implement Program

- Represent data within programming language
- Implement algorithms in programming language

TESTING

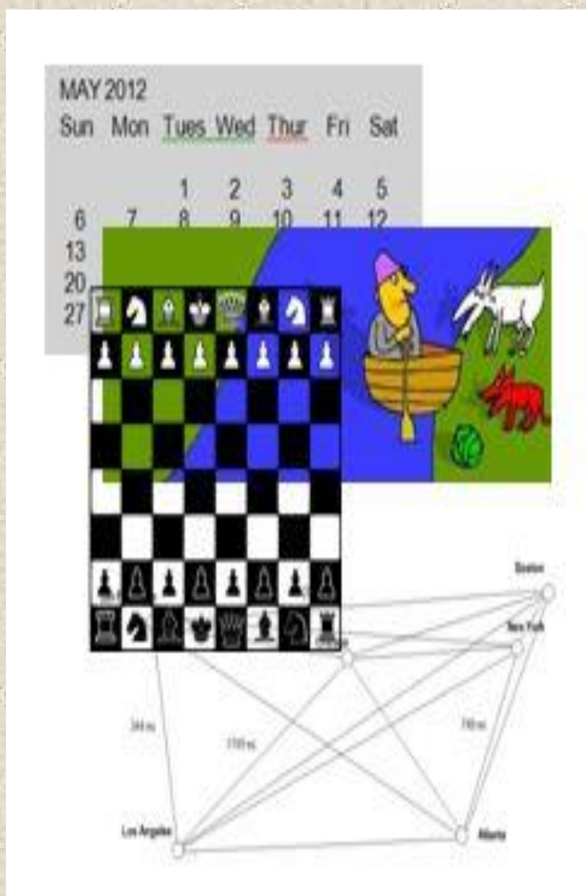
Test and Debug

- Test the program on a selected set of problem instances
- Correct and understand the causes of any errors found

Problem Analysis

Understanding the Problem

Once a problem is clearly understood, the fundamental **computational issues** for solving it can be determined. For each of the problems discussed earlier, the representation is straightforward.



For **calendar month problem**, can use direct calculation for determining the day of the week for a given date

For **MCGW problem**, can use brute-force approach of trying all of the possible rowing actions that may be taken

For the **Traveling Salesman** and **Chess playing problems**, a brute-force approach is infeasible.
Therefore, other more clever approaches need to be tried

Problem Analysis

Knowing what constitutes a solution.

For some problems, there is only one solution. For others, there may be a number (or infinite number) of solutions. Thus, a problem may be stated as finding,

- **A solution** (calendar month, chess playing)
- **An approximate solution**
- **A best solution** (MCGW, Traveling Salesman Problem)
- **All solutions**

Problem Design

Describe the Data Needed

- For **calendar month problem**, need to store the month and year, the number of days in each month, and the names of the days of the week

- For the **MCGW problem**, need to store the current state of the problem (as earlier shown)

- For **Traveling Salesman** need to store the distance between every pair of cities

- For the **chess playing problem**, need to store the configuration of pieces on a chess board

Table Representation of Data for the Traveling Salesman Problem

	Atlanta	Boston	Chicago	Los Angeles	New York City	San Francisco
Atlanta	-	1110	718	2175	888	2473
Boston	1110	-	992	2991	215	3106
Chicago	718	992	-	2015	791	2131
Los Angeles	2175	2991	2015	-	2790	381
New York City	888	215	791	2790	-	2901
San Francisco	2473	3106	2131	381	2901	-

Note that only half of the table need be stored

Representation for Chess Playing Program

R	N	B	Q	K	B	N	R
P	P	P	P	P	P	P	P
P	P	P	P	P	P	P	P
R	N	B	Q	K	B	N	R

4	2	3	4	5	3	2	4
1	1	1	1	1	1	1	1
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
-4	-2	-3	-4	-5	-3	-2	-4
-1	-1	-1	-1	-1	-1	-1	-1

Although the representation on the left is intuitive, the one on the right is more appropriate for computational problem solving.

Describing the Algorithms Needed

When solving a computational problem, either suitable existing algorithms may be found, or new algorithms must be developed.

For the MCGW problem, there are **standard search algorithms** that can be used.

For the calendar month problem, **a day of the week algorithm already exists**.

For the Traveling Salesman problem, **there are various (nontrivial) algorithms that can be utilized** for solving problems with tens of thousands of cities.

Finally, for the chess playing, since it is infeasible to look ahead at the final outcomes of every possible move, **there are algorithms that make a best guess at which moves to make**. Algorithms that work well in general but are not guaranteed to give the correct result for each specific problem are called ***heuristic algorithms***.

Program Implementation

Design decisions provide general details of the data representation and the algorithmic approaches for solving a problem. The details, however, do not specify which programming language to use, or how to implement the program. That is a decision for the implementation phase.

Since we are programming in Python, the implementation needs to be expressed in a syntactically correct and appropriate way, using the instructions and features available in Python.

Program Testing

Writing computer programs is difficult and challenging. As a result, **programming errors are pervasive, persistent and inevitable**.

Given this fact, **software testing is a crucial part of software development**. Testing is done incrementally as a program is being developed, when the program is complete, and when the program needs to be updated.

Truisms of Software Development

1. Programming errors are pervasive, persistent, and inevitable.

1. Software testing is an essential part of software development.

1. Any changes made in correcting a programming error should be fully understood as to why the changes correct the detected error.

The Python Programming Language

The Python Programming Language was created by **Guido van Rossum**. It was first released in the early 1990s.

Its name comes from a 1970s British comedy sketch show called Monty Python's Flying Circus (The Argument Clinic).

Python has a simple syntax. Python programs are clear and easy to read. At the same time, Python provides powerful programming features, and is widely used.

Companies and organizations that use Python include YouTube, Google, Yahoo and NASA.

Python is well supported and freely available at www.python.org.

Python Features

- **Simple Syntax**
  Python programs are clear and easy to read

- **Interpreted Language**
  Python instructions can be executed interactively

- **Powerful Programming Features**
  Can accomplish significant computation with few instructions

- **Numerous Python Modules Provide Additional Capabilities**
  Capabilities that can be incorporated into a Python program

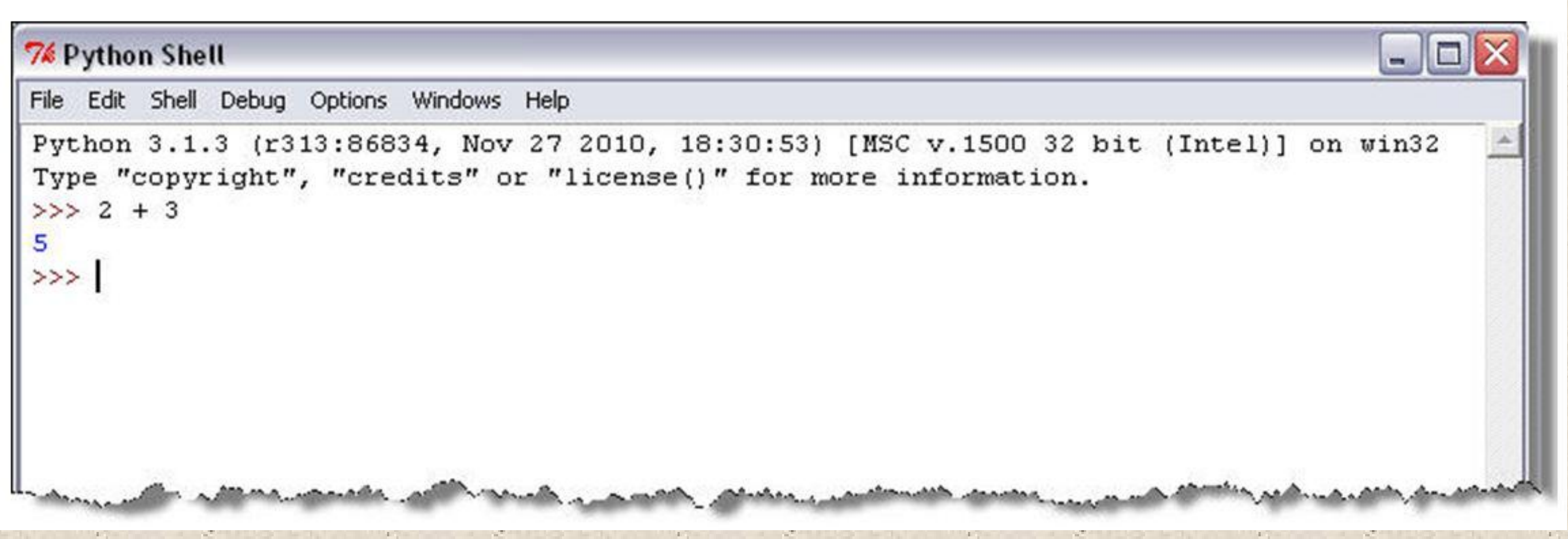
The IDLE Python Development Environment

IDLE is an integrated development environment (IDE). An **IDE** is a bundled set of software tools for program development. This typically includes,

- **an editor**
  for creating and modifying programs
- **a translator**
  for executing programs, and
- **a program debugger**
- for taking control of the execution of a program
  to aid in finding program errors

The Python Shell

Python can be executed interactively in the **Python shell**. **In this mode, executing Python is similar to using a calculator**.



The **>>> symbol is the shell prompt**. Here, typing 2 + 3 at prompt outputs the result 5, again displaying the prompt in wait of another instruction.

The Python Standard Library

The **Python Standard Library** is a collection of **built-in modules**, *each providing specific functionality* beyond what is included in the “core” part of Python.

For example, the **math module** provides additional mathematical functions. The random module provides the ability to generate random numbers, useful in programming, as we shall see.

Other Python modules are described in the Python 3 Programmers’ Reference.
https://docs.python.org/3/py-modindex.html

Importing a Library Module

In order to utilize the capabilities of modules in a specific program, an **import statement** is used as shown.

Python Shell

File Edit Shell Debug Options Windows Help

```
Python 3.1.3 (r313:86834, Nov 27 2010, 18:30:53) [MSC v.1500 32 bit (Intel)] on
win32
Type "copyright", "credits" or "license()" for more information.
>>> import math
>>> math.factorial(4)
24
>>> math.factorial(10)
3628800
>>> math.factorial(20)
2432902008176640000
>>> math.factorial(50)
30414093201713378043612608166064768844377641568960512000000000000
>>> |
```

```
Python Shell
File  Edit  Shell  Debug  Options  Windows  Help
Python 3.1.3 (r313:86834, Nov 27 2010, 18:30:53) [MSC v.1500 32 bit (Intel)] on
win32
Type "copyright", "credits" or "license()" for more information.
>>> import math
>>> math.factorial(4)
24
>>> math.factorial(10)
3628800
>>> math.factorial(20)
2432902008176640000
>>> math.factorial(50)
30414093201713378043612608166064768844377641568960512000000000000
>>> 
```

Because the factorial function is from the math module, the function is called with the name of the module prepended:

e.g., **`math.factorial(20)`**

A Bit of Python

We introduce a bit of Python, just enough to begin writing some simple programs.

Since all computer programs,

- input data (Countabaly finite, ...)
- process the data
- output results

we look at the notion of a **variable**, how to perform some simple arithmetic calculations, and how to do simple input and output.

Variables

One of the most fundamental concepts in programming is that of a **variable**.

A variable is "**a name that is assigned to a value**," as shown below,

```
n = 5
```
variable `n` is assigned the value 5

Thus, whenever variable `n` appears in a calculation, it is the current value of n is that is used, as in the following,

```
n + 20
```
(5 + 20)

If variable `n` is assigned a new value, then the same expression will produce a different result,

```
n = 10
n + 20
```
(10 + 20)

In programming, a variable is a value that can change, depending on conditions or on information passed to the program.

Some Basic Arithmetic Operators

The **common arithmetic operators** in Python are,

+ (**addition**) * (**multiplication**) ** (**exponentiation**)
− (**subtraction**) / (**division**)

Addition, subtraction, and division use standard mathematical notation,

`10 + 20`   `25 - 15`   `20 / 10`
(Also, // for truncated division, discussed later)

For multiplication and exponentiation, the asterisk (*) is used,

`5 * 10` (5 times 10)   `2 ** 4` (2 to the 4th power)

Multiplication is never denoted by the use of parentheses,

`10 * (20 + 5)` CORRECT   `10(20 + 5)` INCORRECT

Note that parentheses may be used to denote subexpressions.

Basic Input

The programs that we will write request and get information from the user. In Python, the **input function** is used for this purpose,

```
name = input('What is your name?: ')
```

Characters within quotes are called strings. This particular use of a string, for requesting input from the user, is called a **prompt**.

The input function displays the string on the screen to prompt the user for input,

```
What is your name?: Charles
```

The underline is used here to indicate the user's input.

Basic Output

The print function is used to display information on the screen in Python. This may be used to display a message (string),

```
>>> print('Welcome to My First Program!')
Welcome to My First Program!
```

or used to output the value of a variable,

```
>>> n = 10
>>> print(n)
10
```

Can also display a combination of strings and variables,

```
>>> name = input('What is your name?: ')
What is your name?: Charles

>>> print('Hello', name)
Hello Charles
```

Note that a comma is used to separate the individual items being printed, which causes a space to appear between each when displayed. Thus, the output of the print function in this case is

```
Hello Charles
```

and not

```
HelloCharles
```

We will soon learn more about variables, operators, and input/output in Python.