UCEST 105: ALGORITHMIC THINKING WITH PYTHON

MODULE 1

SYLLABUS MODULE 1 PART 1

PROBLEM-SOLVING STRATEGIES:- Problem-Solving strategies defined, Importance of understanding multiple problem-solving strategies, Trial and Error, Heuristics, Means-Ends Analysis, and Backtracking (Working backward).

INTRODUCTION

A computer is a very powerful and versatile machine capable of performing various tasks, yet it has no intelligence or thinking power. A computer performs many tasks exactly in the same manner as it is told to do. This places responsibility on the user to instruct the computer in a correct and a precise manner, so that the machine is able to perform the required job in a proper manner.

In order to instruct a computer correctly, the user must have a clear understanding of the problem to be solved. The term "problem" refers to a solution where the solution is not immediately apparent.

A problem is defined by four conditions or parameters. They are:-

- Initial situation
- Goal
- Set of resources
- Commitment.

If one or more of these components are missing, the problem is not well defined.Problems can be categorized into two: -

1. **Well-defined Problems**: That have specific goals, clear solutions and known expected outcomes.
2. **Ill-defined Problems**: That lack clear goals, solution paths and expected solutions.

Q1. Differentiate between Well-defined problems and Ill-defined problems.

	Well-defined Problems	***Ill-defined Problems***
1.	Clear goals and Objectives	Unclear and Vague goals and Objectives
2.	Specific, measurable outcomes	Multiple , conflicting outcomes
3.	Well defined constraints	Ambiguous or uncertain constraints

4.	Relevant data available	Insufficient data available
5.	Single , Identifiable Solution	Multiple possible solutions
6.	Logical, step by step approach	Requires creative, iterative approach
7.	Ex : Chess Game	Ex: Paint a beautiful picture

Q2. State any three Well-defined and Ill-defined problems, Justify your answer.

Well-Defined Problems

These problems have clear goals, a defined path to a solution, and specific criteria for determining when the problem is solved. Let's explore three examples:

1. **Mathematical Equation:**
   - **Problem:** Solve the equation 2x+3=7.
   - **Why it's Well-Defined:** The problem has a clear goal (find the value of x), a specific method (solve for xx using algebraic rules), and a definite solution (x=2).
2. **Crossword Puzzle:**
   - **Problem:** Complete a standard crossword puzzle.
   - **Why it's Well-Defined:** The crossword has a clear objective (fill in all the squares with the correct words), a specific set of rules, and a single correct solution.
3. **Recipe Execution:**
   - **Problem:** Bake a chocolate cake using a provided recipe.
   - **Why it's Well-Defined:** The goal (bake a chocolate cake) is clear, the process is outlined step-by-step in the recipe, and success is measurable by the outcome (a baked cake that meets the description).

Ill-Defined Problems

These problems are ambiguous, lack clear criteria for solutions, and often have multiple possible solutions. Here are three examples:

1. **Designing a Sustainable City:**
   - **Problem:** How can we design a sustainable city for the future?
   - **Why it's Ill-Defined:** The problem is broad, with no single clear solution. Various factors like environmental impact, social equity, and

economic viability come into play, and different stakeholders might have different views on what constitutes a "sustainable" city.

2. **Writing a Novel:**
    - **Problem:** Write a compelling novel that appeals to a broad audience.
    - **Why it's Ill-Defined:** The goal is subjective (what is "compelling"?), the process can vary widely, and success is difficult to measure. Different readers may have different interpretations of what makes the novel appealing.
3. **Resolving Workplace Conflict:**
    - **Problem:** Resolve a conflict between two team members in the workplace.
    - **Why it's Ill-Defined:** The problem is complex with no clear solution. It involves interpersonal dynamics, emotions, and communication styles, and what works in one situation might not work in another. Multiple solutions may exist, and the "right" one depends on various factors.

Summary

- **Well-Defined Problems** are structured, with a clear path and solution.
- **Ill-Defined Problems** are open-ended, ambiguous, and often subjective.

Understanding the nature of the problem helps in choosing the right approach to solving it.

Problem-Solving strategies defined

A problem solving strategy is a plan used to find a solution or overcome a challenge. Each problem solving strategy includes multiple steps to provide you with helpful guidelines on how to resolve a problem. Effective problem solving requires you to identify the problem, select the right process to approach it and develop a plan to resolve the issue.

Importance of Understanding Problem solving Strategies

Understanding multiple problem solving strategies is crucial because it equips individuals with a diverse toolkit to tackle a variety of challenges. Some problems might be best solved through a systematic trial and error method, while others might benefit from a more analytical approach like means-ends analysis. By knowing several strategies, one can quickly switch tactics when one method does not work, increasing the chances of finding a successful solution. Having a collection of problem-solving strategies enhances critical thinking and creativity thereby leading to more innovative and effective solutions. It boosts confidence and competence in facing various challenges.

Benefits include :-

- Adaptability
- Efficiency
- Improved Outcomes
- Skill Development

Steps Involved in Problem Solving:- Identify the problem, Define the problem, List all the possible solutions, Evaluate options and Implement the solution.

Problem Solving Strategies

Commonly used problem-solving strategies include

1. **Trial and Error**
2. **Algorithm**
3. **Heuristics**
4. **Means-Ends Analysis**
5. **Backtracking**

1. Trial and Error

A trial-and-error approach to problem-solving involves trying a number of different solutions and ruling out those that do not work. This approach can be a good option if you have a very limited number of options available. Using trial and error, one has to try different solutions until the problem is solved.

Steps :

1. Identify the problem – Start by clearly defining the issue
2. Try a solution – Attempt a possible solution
3. Evaluate the outcome – Check if the solution worked.
4. Repeat – If the solution failed, try a different one.

Example

1. In terms of a broken printer for example, one could try checking the ink levels, and if that doesn't work, you could check to make sure the paper tray isn't jammed. Or maybe the printer isn't actually connected to a laptop.
2. Restarting phone, turning off WiFi, turning off bluetooth in order to determine why your phone is malfunctioning.

Although trial and error is not typically one of the most time-efficient strategies, it is a commonly used one.

2. Algorithm

An algorithm is a step-by-step, logical procedure that guarantees a solution to a problem. It is systematic and follows a defined sequence of operations, ensuring consistency and accuracy in finding the correct solution.

Example: Algorithm for Baking a Cake

1. Gather ingredients
2. Preheat Oven
3. Mix Ingredients
4. Prepare baking Pan
5. Pour Batter
6. Bake
7. Check for Doneness
8. Cool and Serve

When you run a search on the Internet, search engines like Google use algorithms to decide which entries will appear first in your list of results. Facebook also uses algorithms to decide which posts to display on your newsfeed.

3. Heuristics

A heuristic is another type of problem solving strategy that allow us to make decisions quickly without having all the relevant information. It can thought of as mental shortcuts that are used to solve problems. A "rule of thumb" is an example of a heuristic. Such a rule saves the person time and energy when making a decision. Different types of heuristics are used in different types of situations, but the impulse to use a heuristic occurs when one of five conditions is met:-

- When one is faced with too much information
- When the time to make a decision is limited
- When the decision to be made is unimportant
- When there is access to very little information to use in making the decision
- When an appropriate heuristic happens to come to mind in the same moment

Different types of heuristics are :

a. Breaking a large goal or task into a series of smaller steps.

For example : For completing a large research project, they typically start by

- students typically brainstorm, develop a thesis or main topic,
- research the chosen topic, organize their information into an outline,
- write a rough draft

- revise and edit the rough draft, develop a final draft, organize the references list
- proofread their work before turning in the project.

The large task becomes less overwhelming when it is broken down into a series of small steps.

b. Guess and Check

This method involves making a guess, checking if it solves the problem, and refining the guess based on outcomes. This method is particularly useful when the problem doesn't have an obvious solution, and you can try different possibilities until you find the correct one.

How Guess and Check Works:

1. Make an Initial Guess: Start by guessing a possible solution based on what you know.
2. Check the Guess: Determine if your guess solves the problem.
3. Refine the Guess: If the guess is incorrect, use the information you gained from checking to make a better guess.
4. Repeat: Continue guessing, checking, and refining until you find the correct solution.

Example : Find the number that when added to 15, gives 32.

Solution :-

- Initially make a guess as the number is 20.
- Check the guess, 15+20=35, since 35 is larger than the expected answer, refine the guess based on the outcome.
- Now refine the guess taking the number as 18.
- Check the guess 15+18=33.
- Now the answer is very close.
- Again lower the guess to 17 and check, 15+17=32, and the guess is now correct.

c. **Working backwards**

This is a useful heuristic in which you begin solving the problem by focusing on the end result.

Consider this example: Imagine you need to arrive at an important meeting by 3.00pm. To plan your day using the working backwards heuristic, you need to start from the end result and think about the steps needed to get there. You consider that it takes 30 minutes to get to the meeting location, so you need to leave by 2.30pm. Before that you need an hour to prepare,so you start getting ready at 1.30pm. If you also want to finish a task that takes an hour before getting ready, you need to start that by 12.30pm. By working backwards, you effectively plan your day to ensure you arrive at the meeting on time.

4. Means Ends Analysis (MEA)

This strategy involves choosing and analyzing a problem at a series of smaller steps to move closer to the goal.

Example 1 : The Tower of Hanoi problem.

The **Tower of Hanoi** is a mathematical puzzle. There are three rods, source(A), Auxiliary (B) and Destination(C). Rod A contains a set of disks stacked to resemble a tower, with the largest disk at the bottom and the smallest disk at the top. **Fig:- 1** Illustrate the initial configuration of the rods for 3 disks. The objective is to transfer the entire tower of disks in rod A to rod C maintaining the same order of the disks.

Rules:

1. Only one disk can be transferred at a time.
2. Each move consists of taking the upper disk from one of the rods and placing it on the top of another rod i.e. a disk can only be moved if it is the uppermost disk of the rod.
3. Never a larger disk is placed on a smaller disk during the transfer.

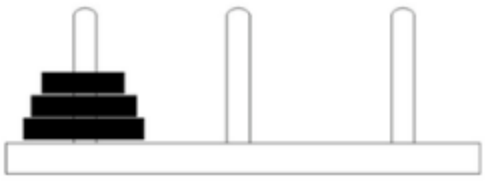


Fig 1:- Initial State

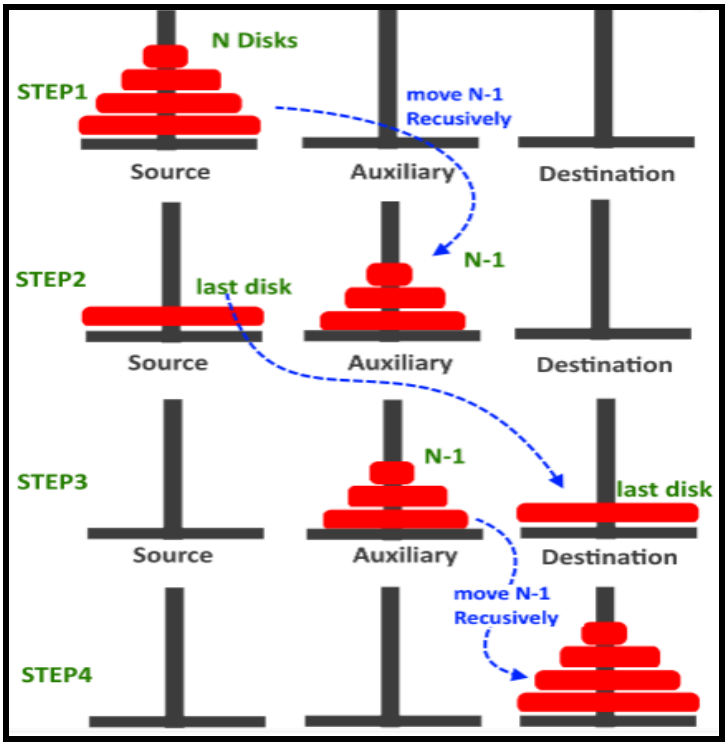
The solution to the puzzle calls for an application of recursive functions and recurrence relations.

A recursive procedure for the solution of the problem for N number of disks is as follows:

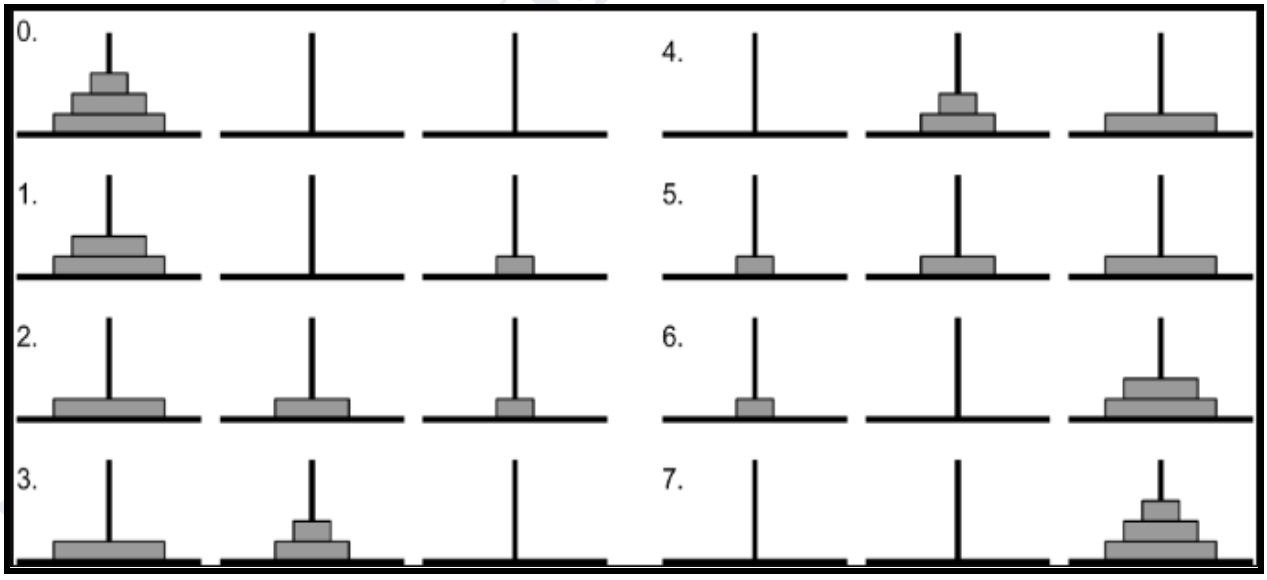
1. Move the top N-1 disks from rod A to rod B using C as an auxiliary rod
2. Move the bottom disk from rod A to rod C
3. Move N-1 disks from rod B to rod C using Peg A as an auxiliary rod

The minimum number of moves required to solve a Tower of Hanoi puzzle is given by **2^N − 1**, where N is the number of disks. i.e., if there are 14 disks, then minimum number of moves needed = (2^14) - 1 = 16383.

The pictorial representation of the recursive procedure for N=4 disks is shown in Fig 2:-

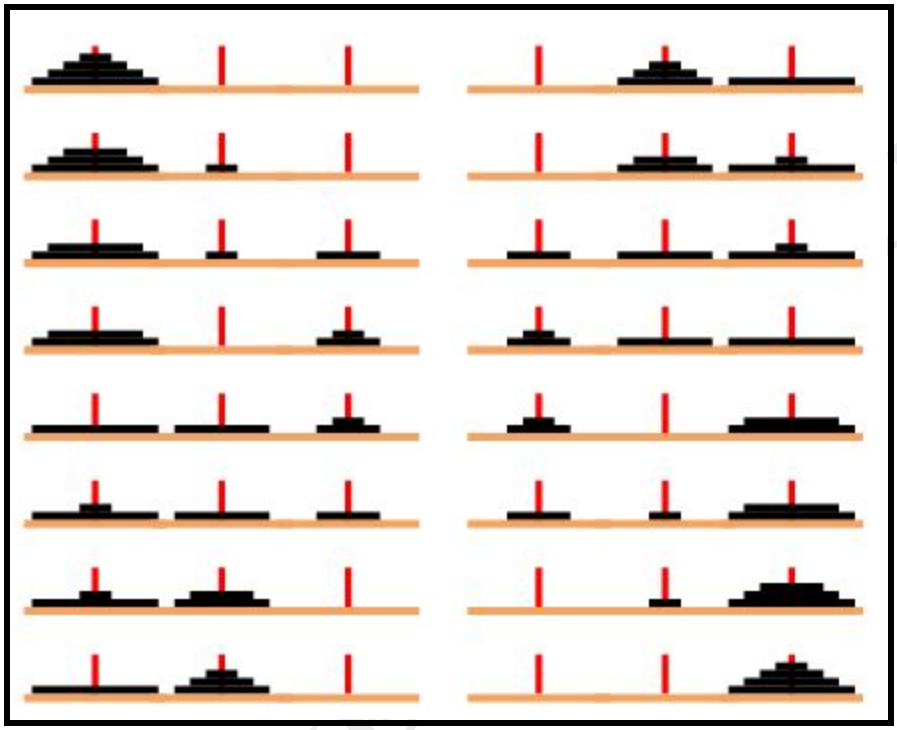


Example of Tower of Hanoi for n=3**.**



Minimum number of moves with 3 disks= 2^n-1= 2^3-1=7.

Example of Tower of Hanoi for n=4.



Minimum number of moves with 4 disks= 2^n-1= 2^4 -1=15.

Example 2: Imagine you want to plan a road trip from Trivandrum to Kashmir. Here is how you might use means-ends analysis:

A. Define the Goal: Your ultimate goal is to drive from Trivandrum to Kashmir.
B. Analyze the Current State: You start in Trivandrum with your car ready to go.
C. Identify the Differences: The primary difference is the distance between Trivandrum and Kashmir, which is approximately 3,700 kilometers.
D. Set Sub-Goals (Means):
    a. Fuel and Rest Stops: Determine where you will need to stop for fuel and rest.
    b. Daily Driving Targets: Break the trip into daily segments, driving 500-600 kms per day.
    c. Route Planning: Choose the most efficient and scenic route, considering highways, weather conditions, and places you want to visit.
E. Implement the Plan:
    a. Day 1: Drive from Trivandrum to Bangalore, Karnataka (approx. 720 km). Refuel in Madurai, Tamil Nadu. Overnight stay in Bangalore.

b. Day 2: Drive from Bangalore to Hyderabad, Telangana (approx. 570 km). Refuel in Anantapur, Andhra Pradesh. Overnight stay in Hyderabad.
c. Day 3: Drive from Hyderabad to Nagpur, Maharashtra (approx. 500 km). Refuel in Adilabad, Telangana. Overnight stay in Nagpur.
d. Day 4: Drive from Nagpur to Jhansi, Uttar Pradesh (approx. 580 km). Refuel in Sagar, Madhya Pradesh. Overnight stay in Jhansi.
e. Day 5: Drive from Jhansi to Agra, Uttar Pradesh (approx. 290 km). Refuel in Gwalior, Madhya Pradesh. Overnight stay in Agra. Visit the Taj Mahal.
f. Day 6: Drive from Agra to Chandigarh (approx. 450 km). Refuel in Karnal, Haryana. Overnight stay in Chandigarh.
g. Day 7: Drive from Chandigarh to Jammu (approx. 350 km). Refuel in Pathankot, Punjab. Overnight stay in Jammu.
h. Day 8: Drive from Jammu to Srinagar, Kashmir (approx. 270 km).

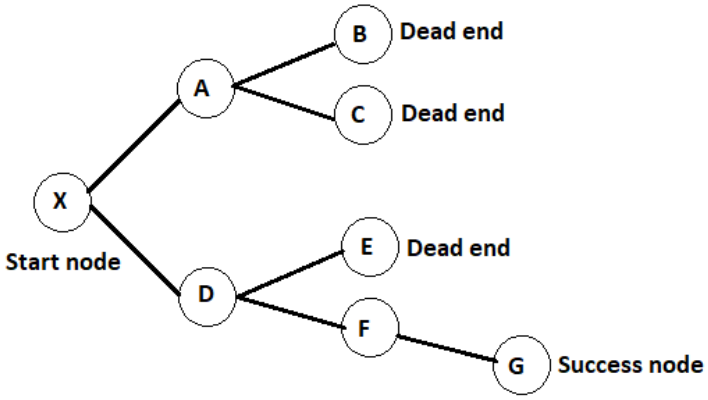
F. Adjust as Needed: Throughout the trip, you may need to make adjustments based on traffic, road conditions, or personal preferences.

By breaking down the long journey into smaller segments and addressing each part systematically, you can effectively plan and complete the road trip. This method ensures that you stay on track and make steady progress toward your final destination, despite the complexity and distance of the trip.

5. Backtracking

Backtracking is a problem solving technique that involves trying different options until the right solution is found. Backtracking algorithms are problem solving strategies that explore various options to find the optimal solution. They operate by testing different paths, and if a path doesn't lead to a solution they backtrack and try another route until they find the correct one. Backtracking can also be defined as a technique that involves finding a solution incrementally by trying different options and undoing them if they lead to a dead end.

Example given below:-



In the above problem, the Start node is X and destination node is G. We first move through the route X-A-B but it reaches a dead end, then we backtrack again and select another path X-A-C, it also encounters a dead end. Try different paths X-D-E,also reach a dead end. Next we move through X-D-F-G and reach the destination node.

Whenever a dead end is encountered it goes back to the start node and continues searching for a different route until the solution is discovered or all options have been considered.
Other examples :- Sudoku puzzle, Maze problem, forgetting the PIN to unlock your smartphone etc.

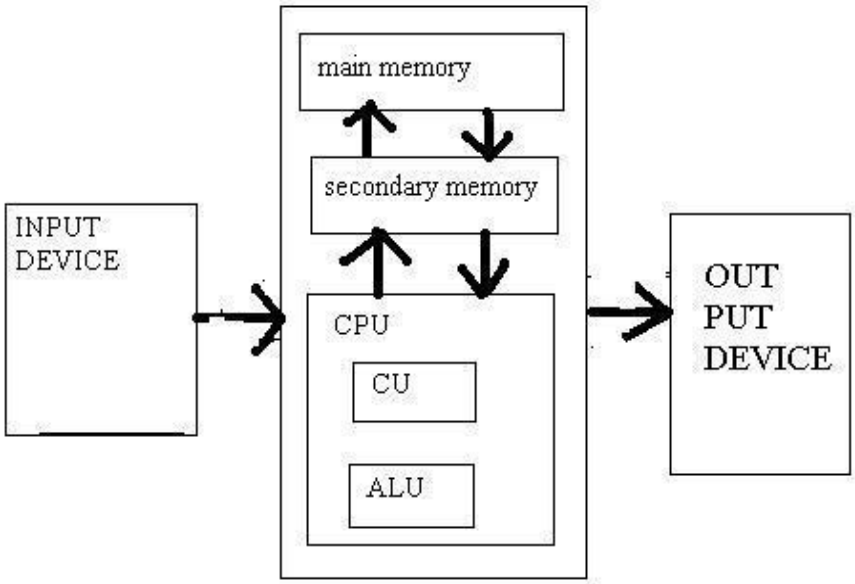
SYLLABUS MODULE - 1 PART - 2

THE PROBLEM-SOLVING PROCESS:- Computer as a model of computation, Understanding the problem, Formulating a model, Developing an algorithm, Writing the program, Testing the program, and Evaluating the solution.

Basic Model of a Computer

Computer science is all about solving problems with computers. The problems that we want to solve can come from any real-world problem or from the abstract world. We need to have a standard systematic approach to solving problems. Since we will be using computers to solve problems, it is important to first understand the computer's information processing model.

Von Neumann Architecture



BLOCK DIAGRAM OF A DIGITAL COMPUTER

The model shown in figure below assumes a single CPU (Central Processing Unit). Many computers today have multiple CPUs, so it can be imagined the model in the figure can be duplicated multiple times within the computer.

INSTRUCTION EXECUTION CYCLE

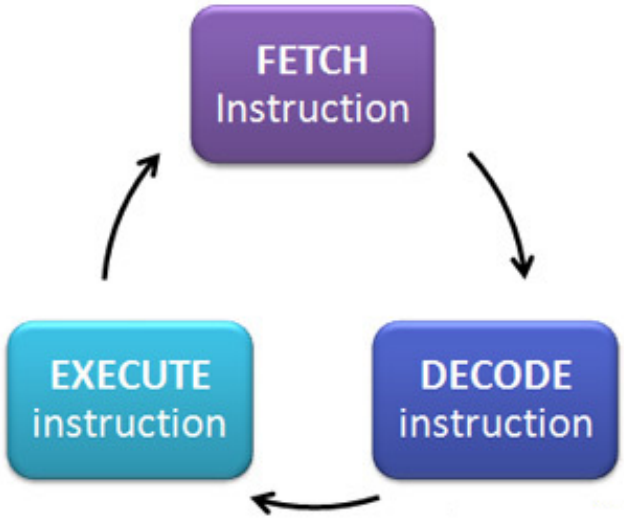
CPU executes an instruction in a series of steps called ***instruction execution cycle.*** An instruction cycle (sometimes called a **fetch–decode–execute** cycle) is the process by which a computer retrieves a program instruction from its memory, determines what actions to perform, and carries out those actions to produce meaningful output.

The cycle comprises the following steps:

1. ***Fetch*** the instruction from memory
2. ***Decode*** the instruction, and the operation to be performed is thus identified.
3. ***Execute*** the instruction, performing the operation identified in the decode step by the CPU.
4. ***Store*** the result in the main memory, or send it to an output device.

This cycle is then repeated for the next instruction.

Instruction Execution Cycle



A typical computer architecture comprises of three main components:

1. Input/Output (I/O) Unit

2. Central Processing Unit (CPU)

3. Memory Unit

The I/O unit consists of the input unit and output devices. The input devices accept data from the user, which the CPU processes. The output devices transfer the processed data (information) to the user. The memory unit is used to store the input data, the instructions required to process the input, and the output information.

Input devices

Input devices allow users to input data into the computer for processing. The data input to a computer can be in the form of text, audio, video, etc. Input devices are classified into two categories:

1. Human data entry devices – the user enters data into the computer by typing or pointing a device to a particular location. Some examples are

a. **Keyboard** – the most common typing device.

b. **Mouse** – the most common pointing device. You move the mouse around on a mouse pad and a small pointer called cursor follows your movements on the computer screen.

c. **Trackball** – an alternative to a mouse which has a ball on the top. The cursor on the computer screen moves in the direction in which the ball is moved.

d. **Joystick** – has a stick whose movement determines the cursor position.

e. **Graphics tablet** – converts hand-drawn images into a format suitable for computer processing.

2. Source data entry devices –They use special equipment to collect data at the source, create machine-readable data, and feed them directly into the computer. This category comprises:

a. **Audio input devices** – It uses human voice or speech to give input. Microphones are an example.

b. **Video input devices** – They accept input in the form of video or images. Video cameras and webcams are examples.

c. **Optical input devices** – They use optical technology (light source) to input the data into computers. Some common optical input devices are scanners and barcode readers.

Output devices

An output device takes processed data from the computer and converts them into information that can be understood by humans. The output could be on paper or can be audio, video, etc. Output devices are classified as follows:

1. **Hard copy devices** – The output obtained on paper or any surface is called hard copy output. The hard copy can be stored permanently and is portable. The hard copy output can be read or used without a computer. Examples in this category include:

a. **Printer** – prints information on paper. The information could be textual or even images. Drum printers, laser printers, and inkjet printers are some commonly used printer types.
b. **Plotter** – used to produce very large drawings on paper using very fine pens. Flatbed plotters and drum plotters are two types of plotters.

2. **Soft Copy Devices** – Generates a soft copy of the output on a visual display (monitor), audio unit, or video unit. The soft copy can be stored and sent via e-mail to other users. It also allows corrections to be made. The soft copy output requires a computer to be read or used. This category comprises:

a. **Monitor** – the primary output device of a computer.
b. **Video output devices** – produce output in the form of video or images. An example is a screen image projector or data projector that displays information from the computer onto a large white screen.
c. **Audio output devices** – speakers, headsets, or headphones, are used for audio output (in the form of sound) from a computer.

Central Processing Unit

The Central Processing Unit (CPU) or the processor, is known as the brain of a computer. It consists of an Arithmetic Logic Unit (ALU) and a Control Unit (CU). In addition, the CPU also has a set of registers which are temporary storage areas for holding data and instructions.

I. Arithmetic Logic Unit

This unit consists of two sub-units, namely arithmetic and logic units.

a. **Arithmetic unit** – performs arithmetic operations like addition, subtraction, multiplication, and division, on the data.

b. **Logic unit** – performs logical operations like comparisons of data values.

II. Registers

Registers are high-speed storage areas within the CPU but have the least storage capacity. They store data, instructions, addresses, and intermediate results of processing. Some of the commonly used registers are:

a. **Accumulator (ACC)** – stores the result of arithmetic and logic operations.
b. **Instruction Register (IR)** – holds the instruction that is currently being executed.
c. **Program Counter (PC)** – holds the address of the next instruction to be processed.

III. Control Unit

This unit manages and coordinates the operations of all parts of the computer. The functions of this unit are:

- generate control signals.
- obtain instructions from the memory, interpret them, and then direct the ALU to execute those instructions.
- communicate with I/O devices.
- decides when to fetch the data and instructions, what operation to perform, where to store the results.

Memory unit

Memory is the storage space in a computer where data to be processed and instructions required for processing are stored. The various memories can be organized hierarchically called memory hierarchy as shown in figure below.

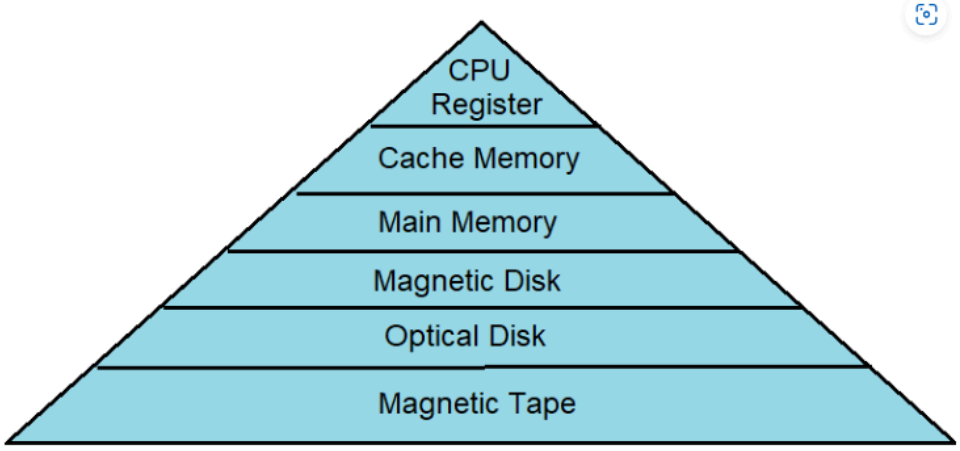


Fig:- Memory Hierarchy

Memory is primarily of two types:

I. **Internal Memory**: memories that reside on the motherboard.

Internal memory includes:

1. **Registers** – high-speed storage areas within the CPU.

2. **Primary memory** – main memory of the computer. It is categorized into two:
   a. **Random Access Memory (RAM)** – used for storing data and instructions during the operation of a computer. Data to be processed is brought to RAM from input devices or secondary memory. It is a volatile memory, because stored data may get lost if it is not saved. After processing, the results are stored in RAM before being sent to the output device.

   b. **Read Only Memory (ROM)** – a non-volatile primary memory. It does not lose its content when the power is switched off. ROM, as the name implies, has only reading capability and no write capability. After the information is stored in ROM, it is permanent and cannot be modified. Therefore, ROM is used to store the data that does not require a change, for example, the boot information(means computer's startup process).

3. **Cache memory** – placed between RAM and CPU and stores the data and instructions that are frequently used.

II. **External memory**: memories that are outside the motherboard.

External memory includes:

1. **Magnetic tape** – a plastic tape with magnetic coating mounted. It is a sequential access device, meaning that the data can be read only in the order in which it is stored.

2. **Magnetic disk** – a thin plastic or metallic circular plate coated with magnetic oxide and encased in a protective cover. Hard disk is an example.

3. **Optical disk** – a flat circular disk coated with reflective plastic material that can be altered by laser light. CDs and DVDs are examples.

Computer as a model of computation

Regarding problem solving, we will apply the above model for simple computations. For larger and more complex problems, we need to iterate (i.e., repeat) the input/process/output stages multiple times in sequence.

Definition: Problem Solving is the sequential process of analyzing information related to a given situation and generating appropriate response options.

In solving a problem, there are some well-defined steps to be followed. It is noted that the problem is easily solved by simply getting the input, computing something and producing the output. We now examine **the steps to problem solving** within the context of various examples.

Steps involved in problem solving

1. **Understanding the problem**
2. **Formulating a model**
3. **Developing an algorithm**
4. **Writing the program**
5. **Testing the program**
6. **Evaluating the solution**

Understanding the problem

- The First Step in Problem Solving
  - It may sound simple, but the first step in solving any problem is to fully understand it.
- Identifying Input, Output and Processing Needs

EXAMPLE 1:- Finding sum of two numbers

- INPUT REQUIREMENTS

We need to understand the input we require to solve the problem. For the given example, input requirement is two numbers whether it can be of any type, like real number, integer number or whole number.

- OUTPUT REQUIREMENTS

  Next we need to understand the output to obtain corresponding to the input given. if we are giving real numbers as input the output obtained will be real, or if it is integer then output will be integer.

- PROCESSING CONSIDERATIONS

  We also need to understand how to reach the solution from the input given i.e, to understand a path to reach the solution.

Formulating a model

- The next step is to understand the processing part of the problem.
- In the example given, the sum of two numbers is to be computed. A model is thus needed for computing the sum of two numbers. If there is no such "formula", one must be developed.
- Assuming that the input data is two integer numbers Number1, Number2 representing a two numbers

Sum = Number1 + Number2

The main point to understand this step in the problems solving process is that it is all about figuring out how to make use of the available data to compute an answer.

Developing an algorithm

- Next step is to develop a precise plan of what the computer is expected to do.
- An **algorithm** is a set of steps for solving a particular problem, or
  An **algorithm** is a precise sequence of instructions for solving a problem.
- To develop an algorithm, the instructions must be represented in a way that is understandable to a person who is trying to figure out the steps involved.
- Two commonly used representations for an algorithm is by using
  i. **Pseudo code** :- an informal representation of an algorithm without using any programming syntax
  ii. **Flowchart** :- a diagrammatic representation of an algorithm

- Example: - Let's use a simple math problem to develop an algorithm, a pseudo code and a flow chart

  - Algorithm

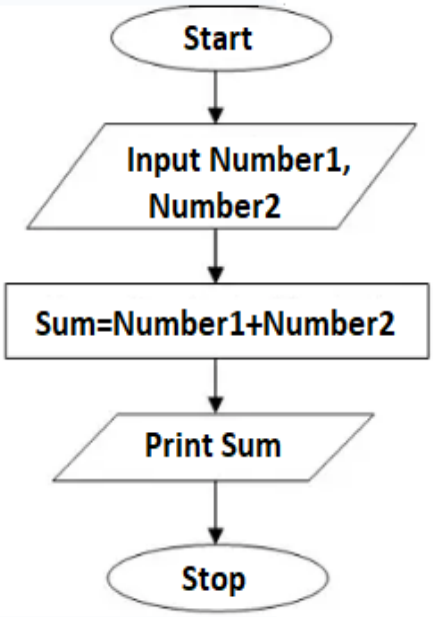
    Step 1: Start
    Step 2: Input the first number
    Step 3: Input the second number
    Step 4: Add the two numbers
    Step 5: Display the result

Step 6: End

- Pseudo code

1. Start
2. Input Number1
3. Input Number2
4. Sum = Number1 + Number2
5. Output Sum
6. End

- Flow chart



Writing the Program

- Once the algorithm is defined, the next step is to convert it into a form that a computer can execute. This process is known as **writing the program, coding, or implementing an algorithm.**
- The next step is to transform the algorithm into a set of instructions that can be understood by the computer. Writing a program is often called "**coding" or "implementing an algorithm**".
  - Program in Python

```
n1 = 21
n2 = 7
sum = n1 + n2
print('Sum =', sum)
```

- After writing the code, test it with various inputs to ensure it works as expected. Debug and compile the program to find issues or errors that arise during testing.
- **Debugging** is the method of **finding and fixing errors.**
- **Compiling** is the process of **converting a program into instructions that can be understood by the computer.**

Testing the Program

- Once a program has been written and compiled, the next critical step is to ensure that whether the program performs the intended task correctly. Testing the program involves running it with various inputs to verify its accuracy and reliability.
- Running a program is the process of telling the computer to evaluate the compiled instructions.
- If the program runs correctly, the expected output should be displayed.
- If the program doesn't run correctly for some inputs then the user has to go back to the algorithm development step that handles all situations that could arise.
    - If the output is incorrect, it could be due to the algorithm not being properly implemented in the program. or
    - A flaw or a bug in the algorithm itself, which does not account for certain situations.

      Bugs are errors in a program that cause it to produce incorrect or undesirable results.

Evaluating the Solution

- Once a program produces a result, revisit the original problem.
- Ensure the output is formatted as a proper solution.
- Examine if the result aligns with the original intent.
- Determine if the output meets the problem's requirements.
    - Remember that the computer executes instructions as given. The user must interpret results to determine effectiveness.

EXAMPLE 2: Calculate the average grade for all students in a class.

Understanding the problem

INPUT REQUIREMENT**:** get all the grades … possibly by typing them in via the keyboard

- Key Questions:
    - What input data/information is available?
    - What does the data represent, and in what format?
    - Is anything missing from the data?
    - Do I have everything needed to solve the problem?

- Example: Grades as Input:
  - Grades could be numbers (0-100) or letter grades (A-F).
  - If the grade is represented in number then it can be whole integer(eg:- 73) or real number(e g:- 73.45)
  - Consider how to handle missing grades (eg: - if we do not have the grade for absent students: for instance should we be able to include that person in our average calculation as 0 or ignore them when computing the average)?

OUTPUT REQUIREMENTS: output the answer to either the monitor, or to the printer

- What output is needed, and in what format (text, number, graph)?
- Example: Should the result be a number, a letter grade, or a pie chart

PROCESSING CONSIDERATIONS: Add them all up and compute the average grade. Understand the processing steps required to achieve the desired output. This understanding guides the problem-solving process.

Formulating a model

In the example given, the average of the incoming grades is to be computed. A model (or formula) is thus needed for computing the average of a bunch of numbers. If there is no such "formula", one must be developed.

· Assuming that the input data is a bunch of integers or real numbers $x1, x2, \cdots, xn$ representing a grade percentage, the following computational model may apply:

$Average\mathbf{1} = (x\mathbf{1} + x\mathbf{2} + x\mathbf{3} + \cdots + xn)/n$ where the output will be a number from 0 to 100.

·

The challenge facing in the above calculation is Letter grades (e.g., A, B-, C+) cannot be directly added or divided.Solution is Assign Values to letter grades

- Convert letter grades to numerical equivalents

$A+ = 12$	$A = 11$	$A- = 10$	$B+ = 9$	
$B = 8$	$B- = 7$	$C+ = 6$	$C = 5$	
$C- = 4$	$D+ = 3$	$D = 2$	$D- = 1$	$F = 0$

- If it is assumed that these newly assigned grade numbers are $y1, y2, \cdots, yn$, then the following computational model may be used:

  $Average\mathbf{2} = (y\mathbf{1} + y\mathbf{2} + y\mathbf{3} + \cdots + yn)/n$ where the result will be a number from 0 to 12.

If we want the output in percentage, you can convert it as:

Average (in percentage) = (Average$_2$ / 13)

The main point to understand this step in the problems solving process is that it is all about figuring out how to make use of the available data to compute an answer.

Developing an algorithm:

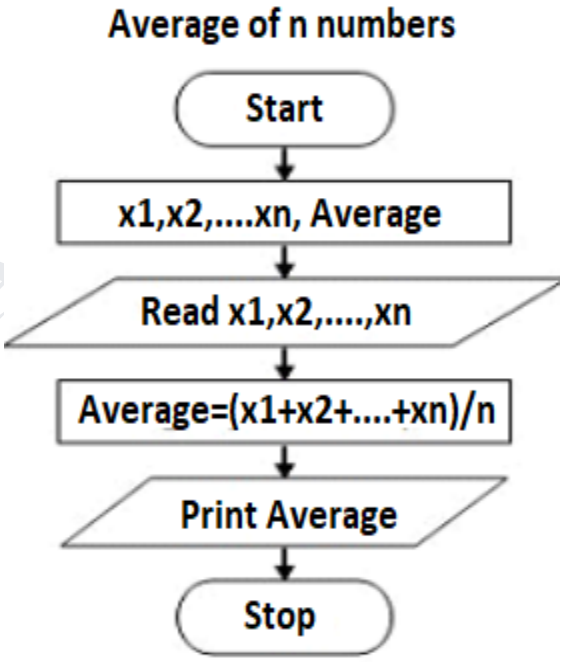
Algorithm

STEP 1: Start
STEP 2: Read number of students, n
STEP 2: Read the marks of n students
STEP 3: Compute average using the formula
STEP 4: Display Average
STEP 5: Stop

Pseudo code

1. Start
2. Input n
3. Input the marks of n students, x1,x2,x3,…,xn
4. Average=(x1+x2+x3+…+xn)/n
5. Output Average
6. End

Flow chart



Writing the program:

```
# Program in Python

n = int("input(Enter number"))
sum = 0
# loop from 1 to n
for num in range(1,n+1,1):
        sum = sum+num
average=sum/n
print("Average of ",n,"numbers is: ",average)
```

Test the program: You create a test suite with various types of numbers and check whether the output obtained is correct or not.

EXAMPLE 3 : - A case study - The Discriminant calculator

1. **Understanding the problem**: Here we formally define the problem by specifying the inputs and output.
   Input: The three coefficients a, b and c of the quadratic equation
   Output: The discriminant value D for the quadratic equation

2. **Formulating a model**: Develop a mathematical model for the solution, that is identify the mathematical expression for the quadratic equation discriminant D:

   $$D = b^2 - 4ac$$

3. **Developing an algorithm**: A possible algorithm (actually, a pseudocode) for our discriminant problem is given below:

   STEP 1: Start
   STEP 2: Read (a,b,c)
   STEP 3: d = b*b−4*a*c
   STEP 4: Print (d)
   STEP 5: Stop

4. **Writing the program**: The Python program to calculate the discriminant is as follows:

```
#Input the coefficients
a = int(input("Enter the value of first coefficient"))
b = int(input("Enter the value of second coefficient"))
c = int(input("Enter the value of third coefficient"))
```

```
#Find the discriminant
d = (b**2) - (4*a*c)
#Print the discriminant
print(d)
```

5. **Testing the program**: You create a test suite similar to the one shown in Table 1.2. Each row denotes a set of inputs (a,b, and c) and the expected output (d) with which the actual output is to be compared.

Sl No	a	b	c	d
1	10	2	5	-196
2	5	7	1	29
3	2	4	2	0
4	1	1	1	-3
5	3	2	5	-56
6	2	8	2	48

SYLLABUS MODULE - 1 PART - 3

ESSENTIALS OF PYTHON PROGRAMMING:- Creating and using variables in Python, Numeric and String data types in Python, Using the math module, Using the Python Standard Library for handling basic I/O - print, input, Python operators and their precedence.

Essentials of Python Programming

INTRODUCTION

PROGRAMMING LANGUAGES

Programming languages are used to write programs that useare precise representations of algorithms and control the behavior of a computer. Each language has a unique set of keywords (words that it understands) and syntax (set of rules) to organize the program instructions.

Programming languages fall into three categories:

1. **Machine language:-** is what the computer can understand, but it is difficult for the programmer to understand. Machine languages consist of binary numbers only. No translation of the program is needed and it can be executed very fast. It is machine-dependent ie. A machine-level program written for one type of computer may not work on another type.

Example 3.1. Assume that the opcode and operands occupy 4 bits each and that the opcode for addition is 1010, then to add 3 and 6, the binary code would be $\underbrace{1010}_{add}\underbrace{0011}_{3}\underbrace{0110}_{6}$

2. **Assembly language:-** falls in between machine language and high-level language. It is similar to machine language, but easier to write code because it allows the programmer to use symbolic names (like ADD, SUB) for operations called **mnemonic codes** that are much easier to remember.

Example : *If the mnemonic code for addition is ADD, then to add 3 and 6, the assembly level code will be ADD 3,6.*

Machine languages and assembly languages are also called ***low level languages****.*

3. **High-level language:-** is easier to understand and use for the programmer but difficult for the computer. The programs written in high-level languages contain English-like statements as well as programming.

Eg:- C, FORTRAN, Pascal, Java, Python etc. that enables a programmer to write programs. High level language programs are easier to write, read, and understand. They are easily portable from one computer to another, since they are not machine-dependent.

Example : To add 3 and 6, the high level language code will be 3+6.

Here '+' is the operator for addition.

TRANSLATOR SOFTWARE

The computer can understand only machine code (strings of 0's and 1's). Thus when the program is written in other languages (assembly or high-level languages) has to be converted to machine code. This conversion is called **translation** and is performed by the translator software.

The original program is called ***source code*****,** and the translated code (object code) is the ***target code*****.**

There are three types of translator software as discussed below:

1. **Assembler :** is a software that converts a program written in assembly language into machine code.
2. **Compiler :** is a software that translates programs written in high-level language to machine code.
3. **Interpreter :** The interpreter also converts the high-level language program into machine code. However, the reads the source code line-by-line, converts it into machine code, executes the line, and then proceeds to the next line.

Q: Differentiate between Compiler and Interpreter.

Compiler	Interpreter
Compiler Takes **Entire** program as input	Interpreter Takes **Single** instruction as input .
Intermediate Object Code is **Generated**	**No** Intermediate Object Code is **Generated**
Memory Requirement : More (Since Object Code is Generated)	**Memory Requirement** is **Less**
Program need not be **compiled** every time	Every time higher level program is converted into lower level program
Errors are displayed after **entire program** is checked	**Errors** are displayed for **every instruction** interpreted (if any)
Example : C Compiler	**Example** : BASIC

INTRODUCTION TO PYTHON

Python is a **general purpose, high-level, interpreted** programming language developed by ***Guido van Rossum*** in the late 1980s at the National Research Institute for Mathematics and Computer Science in the Netherlands. Python is one of the most popular and widely used programming languages used for a set of tasks including **Console based, GUI based, web programming and data analysis**. Python is named after the comedy television show Monty Python's Flying Circus.

FEATURES OF PYTHON

APPLICATIONS OF PYTHON

Python is a general purpose programming language. It is widely applied in various fields.

- **Data Science :** Python libraries like Numpy, Pandas, and Matplotlib are used for data analysis and visualization.
- **Web Applications** : Python frameworks like Django, and Pyramid, make the development and deployment of Web Applications easy**.**
- **Desktop GUI Applications**
- **Software Development**
- **Scientific and Numeric computations**
- **Business Applications**
- **Audio or Video based Applications.**

START PROGRAMMING WITH PYTHON

There are two major Python versions, those are Python 2 and Python 3. Python 3 is more semantically correct and supports newer features. After successful installation of python software we can interpret or execute python script / program.

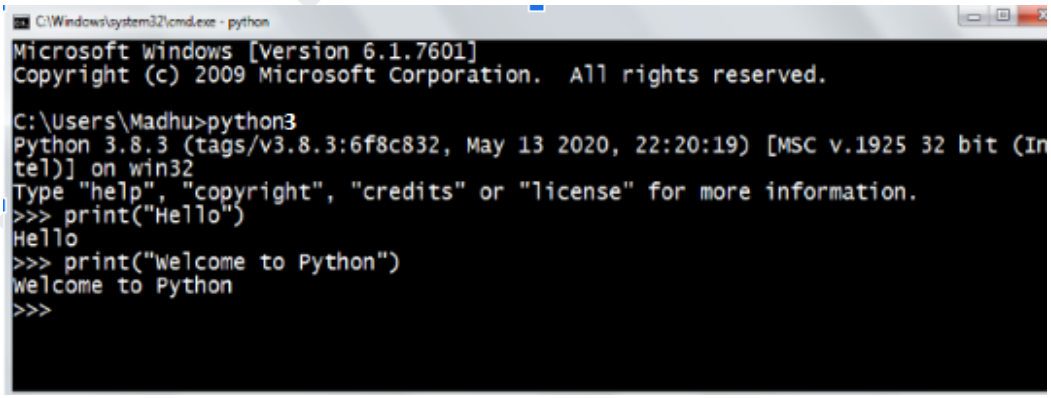
Python provides us the two ways to run a python script:

1. **Using Interactive interpreter prompt**
2. **Using a script file**

Using Interactive interpreter prompt:

Python provides us the feature to execute the python statement one by one at the interactive prompt. It is preferable in the case where we are concerned about the output of each line of our python program. To open the interactive mode, open the terminal (or command prompt) and type python3.

Through Command Prompt or Python Shell



The **Python shell** is an interactive terminal-based environment wherein you can directly communicate with the Python interpreter. First, you open a terminal and type python3. Now the shell turns up with a welcome message as shown below.

user@Ubuntu2204LTS:~$ python3
Python 3.10.12 (main, Jul 29 2024, 16:56:48) [GCC 11.4.0] on linux
Type "help", "copyright", "credits" or "license" for more information

The symbol >>> is called the **shell prompt**. This symbol prompts you for Python statements. When you enter a statement in the shell, the Python interpreter processes it and displays the result, if any, then followed by a new prompt as shown below:

>>> "Welcome to the world of Python programming"
'Welcome to the world of Python programming'
>>>

Using Script File

Interpreter prompt is good to run the individual statements of the code. However if we want to execute multiple python statements at a time instead of executing one by one, then we can use script files. We need to write our script into a file which can be executed later. For this purpose, open an editor like notepad, create a file named filename.py (python used .py extension) and write the python script in it.

Example: "*First.py*"

```
print("Hello !")
print("Welcome to Python Programming")
```

Output: $python3 First.py

```
Hello !
Welcome to Python Programming
```

Running as a script

1. Combine all the statements that you wish to execute into a Python program. Program is known as a script and should be saved with the **"py"** extension, for example sample.py.
2. You may use some text editor to create your script. **gedit**, vim are some of the editors that you can probably use.
3. Then open a terminal in the directory where the script is stored. To run your script (assuming the name is First.py), just give

python3 First.py

Now the script will be executed and you get the desired output.

Example : Suppose you have written a script sample.py to display the message "My first Python program!". This is how you run it (The second line below shows the output):

user@Ubuntu2204LTS:~$ python3 First.py

My first Python program!

Comments in Python

- Comments are used in a programming language to describe the program or to hide some part of code from the interpreter.
- Comment is not a part of the program, but it enhances the interactivity of the program and makes the program readable.
- Python supports two types of comments:
    1. Single Line Comment
    2. Multi Line Comment

Single Line Comment:
In case user wants to specify a single line comment, then comment must start with '#'

Example:

```
# This is single line comment
print "Hello Python"
```

Output:

```
Hello Python
```

Multi Line Comment:
Multi lined comment can be given inside triple quotes.

Example:

```
'''This is
   Multiline
   Comment'''
print "Hello Python"
```

Output:

```
Hello Python
```

Python Character Sets

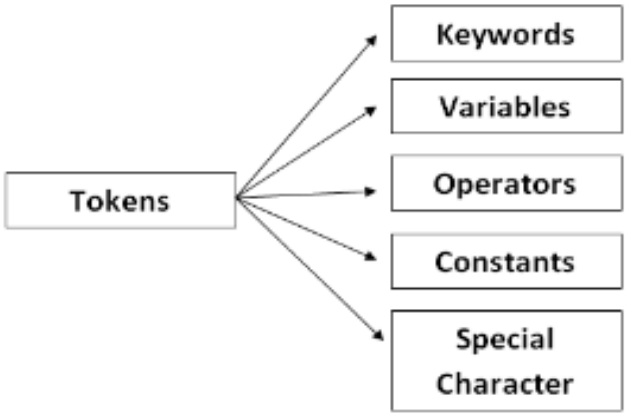
A character set is a set of valid characters acceptable by a programming language in scripting.

Character set

- Alphabets: All capital (A-Z) and small (a-z) alphabets.
- Digits: All digits 0-9.
- Special Symbols: Python supports all kind of special symbols like, " ' l ; : ! ~ @ # $ % ^ ` & * ( ) _ + – = { } [ ] \
- White Spaces: White spaces like tab space, blank space, newline, and carriage return.

Python tokens

- A token is the smallest individual unit in a python program.
- All statements and instructions in a program are built with tokens.
- The various tokens in python are :



1. Keyword (Reserved words)

- Keywords are words that have some special meaning or significance in a programming language.
- They can't be used as variable names, function names, or for any other random purpose.

False	class	finally	is	return
None	continue	for	lambda	try
True	def	from	nonlocal	while
and	del	global	not	with
as	elif	if	or	yield
assert	else	import	pass	
break	except	in	raise	

2. Identifiers

- Identifiers are the names given to any variable, function, class, list, methods, etc. for their identification.
- Python has some rules and regulations to name an identifier.
- Rules to name an identifier:-
  - Python is **case-sensitive**. So case matters in naming identifiers. And hence **geeks and Geeks** are two different identifiers.
  - Identifiers start with a capital letter (A-Z) , a small letter (az) or an

underscore(_).

- It can't start with any other character.
- Except for letters and underscore, digits can also be a part of an identifier but can't be the first character of it.
- Any other special characters or whitespaces are strictly prohibited in an identifier.
- An identifier can't be a keyword.

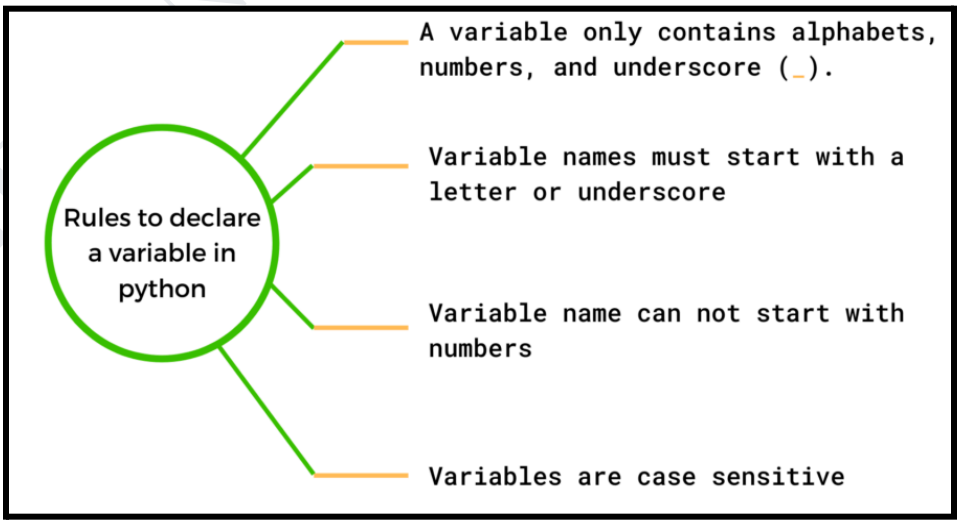
Valid and Invalid Identifiers

IDENTIFIER	VALID?	REASON IF INVALID
totalSales	Yes	
total_Sales	Yes	
total.Sales	No	Cannot contain period
4thQtrSales	No	Cannot begin with digit
totalSale$	No	Cannot contain $

Creating and using variables in Python

Variable in Python

- A variable is a named memory location in which we can store values for the particular program. In other words, Variable is a name which is used to refer to memory location.
- Variable also known as **identifier** and used to hold value.
- In Python, when we assign any value to the variable that variable is declared automatically. Also, we don't need to specify the type of variable in Python.



EXAMPLE

Example: Vardemo.py

```
a=10 #integer
b="StudyGlance" #string
c=12.5 #float
print(a)
print(b)
print(c)
```

output:

```
$python3 Vardemo.py
10
StudyGlance
12.5
```

- Python allows us to assign a value to multiple variables and multiple values to multiple variables in a single statement which is also known as multiple assignment.

EXAMPLE

Assign single value to multiple variables :

Example: Vardemo1.py

```
x=y=z=50
print x
print y
print z
```

output:

```
$python3 Vardemo1.py
50
50
50
```

Assign multiple values to multiple variables :

Example: Vardemo2.py

```
a,b,c=5,10,15
print a
print b
print c
```

output:

```
$python3 Vardemo2.py
5
10
15
```

3. Literals (Constants)

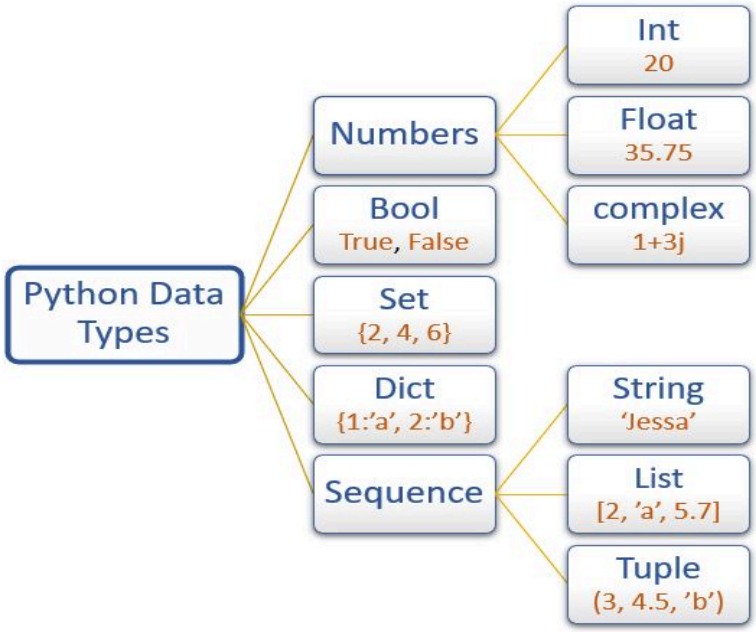
- Python literals are a data type and can hold any value type, such as strings, numbers, and more
- The way of using literals depends on its type.
- The various types of literals used in the Python program are as follows:
  - String literals
  - Numeric literals - integer, float, complex
  - Boolean literals
  - Literal Collections - list, tuple, set, dictionary

Numeric and String data types in Python

4. Data Types

- Data Types specifies what type of data will be stored in variables.
- Variables can hold values of different data types.
- Python is dynamically typed, hence we need not define the type of the variable while declaring it.

- The interpreter implicitly binds the value with its type.
- Python provides us the **type ()** function which enables us to check the type of the variable.



A. Numeric datatype

- The numeric data type in Python represents the data that has a numeric value.
- A numeric value can be an integer, a floating number, or even a complex number.
- There are three numeric types in Python:
    1. **int**
    2. **float**
    3. **complex**

1. int: Int, or integer, is a whole number, positive or negative, without decimals, of unlimited length.	Example: a=10 b=-12 c=123456789
2. float: Float or "floating point number" is a number, positive or negative, containing one or more decimals.	Example: X=1.0 Y=12.3 Z=-13.4
3. complex: Complex numbers are written with a "j" as the imaginary part.	Example: A=2+5j B=-3+4j C=-6j

EXAMPLE

PROGRAM

```
num1 = 5
print(num1, 'is of type', type(num1))
num2 = 2.0
print(num2, 'is of type', type(num2))
num3 = 1 + 2j
print(num3, 'is of type', type(num3))
```

OUTPUT

```
5 is of type <class 'int'>
2.0 is of type <class 'float'>
(1+2j) is of type <class 'complex'>
```

Type Conversion in Python

- Python provides **Explicit type conversion** functions to directly convert one data type to another. It is also called as **Type Casting** in Python
- Python supports following functions
    1. int() : This function converts any data type to integer.
    2. float() : This function is used to convert any data type to a floating point number.
    3. str() : This function is used to convert any data type to a string.

EXAMPLE

PROGRAM

```
#convert from int to float:
x = float(1)

#convert from float to int:
y = int(2.8)

#convert from int to complex:
z = complex(1)

print(x)
print(y)
print(z)

print(type(x))
print(type(y))
print(type(z))
```

OUTPUT

```
1.0
2
(1+0j)
<class 'float'>
<class 'int'>
<class 'complex'>
```

Escape sequence

The escape sequence is a sequence of characters treated as special when the Python interpreter encounters it in the string literal. The escape sequence is represented using the backslash **('\')** followed by the character.

Code	Result
\'	Single Quote
\\	Backslash
\n	New Line
\r	Carriage Return
\t	Tab
\b	Backspace
\f	Form Feed

EXAMPLE

```
1  print("Hello\nWorld")
2  print("Hello\tWorld")
3  print("This is a backslash: \\")
4  print('It\'s a beautiful day')
5  print("She said, \"Hello!\"")
```

Output

```
Hello
World
Hello   World
This is a backslash: \
It's a beautiful day
She said, "Hello!"
```

B. Sequence Data Types in Python

- The sequence Data Type in Python is the ordered collection of similar or different Python data types.
- Sequences allow storing of multiple values in an organized and efficient fashion.
- There are several sequence data types of Python:

- String
- List
- Tuple

a. String:- A string is a collection of one or more characters. Strings are represented by either single, double or triple quotes.

EXAMPLE

main.py

```
# Creating a String
# with single Quotes
String1 = 'Welcome to the Geeks World'
print('String with the use of Single Quotes: ')
print(String1)

# with double Quotes
String1 = "I'm a Geek"
print("\nString with the use of Double Quotes: ")
print(String1)

# with triple Quotes
String1 = '''I'm a Geek and I live in a world of "Geeks"'''
print("\nString with the use of Triple Quotes: ")
print(String1)

```

Output

```
String with the use of Single Quotes:
Welcome to the Geeks World

String with the use of Double Quotes:
I'm a Geek

String with the use of Triple Quotes:
I'm a Geek and I live in a world of "Geeks"

=== Code Execution Successful ===
```

b. List

List is an ordered sequence of some data written using square brackets([]) and commas(,). List is mutable (means values in the list can be changed during execution time).

EXAMPLE

```
# Creating a List
List = []
print("Blank List: ")
print(List)

# Creating a List of numbers
List = [10, 20, 14]
print("\nList of numbers: ")
print(List)
```

Output

```
Blank List:
[]

List of numbers:
[10, 20, 14]
```

c. Tuple

The tuple is another data type which is a sequence of data similar to a list. But it is immutable. That means data in a tuple is write-protected. Data in a tuple is written using parentheses and commas.

EXAMPLE

```
var = ("Geeks", "for", "Geeks")
print(var)
```

Output:

```
('Geeks', 'for', 'Geeks')
```

C. Dictionary

Dictionary is an ordered sequence of data of key-value pair form. Dictionaries are written within curly braces in the form **key:value.**

PROGRAM

```
capitals = {"USA":"Washington D.C.","France":"Paris", "India"
:"New Delhi"}
print(type(capitals))
```

OUTPUT

```
<class 'dict'>
```

D. Set

Set is an unordered collection of unique items defined by values separated by commas inside braces{}.

```
thisset = {"apple", "banana", "cherry"}
print(thisset)
```

OUTPUT

```
{'apple', 'banana', 'cherry'}
```

E. Boolean

Boolean data type that has one of two possible values (usually denoted True and False) which is intended to represent the two truth values of Boolean algebra.

EXAMPLE

```
Input: 1==1
Output: True
Input: 2<1
Output: False
```

```
# Returns False as x is not equal to y
x = 5
y = 10
print(bool(x==y))
```

Output

```
False
```

Using the math module

- A module is a logical organization of Python code. Related code is grouped into a module which makes the code easier to understand and use.
- Math module is an in-built Python library made to simplify mathematical tasks in Python.
- It consists of various mathematical constants and functions that can be used after importing the math module.
- To use math function, command given below is used

import math

- Various functions in math module are:-

NUMERIC FUNCTIONS

1. math.sqrt()

   The math.sqrt() method returns the square root of a given number.
   >>>math.sqrt(100)
   10.0
   >>>math.sqrt(3)
   1.7320508075688772

2. math.ceil()

   The ceil() function approximates the given number to the smallest integer, greater than or equal to the given floating point number.
   >>>math.ceil(4.5867)
   5

3. math.floor()

   The floor() function returns the largest integer less than or equal to the given number.
   >>>math.floor(4.5687)
   4

4. math.fabs()

   Returns the absolute value of x
   >>> math.fabs(-5.5)
   5.5

5. math.pi()

   constant, returns the value of PI (3.14...)
   >>>x = math.pi
   >>>print(x)
   3.14…

6. math.factorial()

   Used for finding factorial of a given in a single line
   >>>a=5
   >>>print(“The factorial of” a “ is”,math.factorial(a))
   The factorial of a 5 is 120

7. math.gcd()

   Used to find the greatest common divisor of two numbers
   >>>a = 15
   >>>b = 5
   >>>print ("The gcd of 5 and 15 is : ")
   >>>print (math.gcd(b, a))
   The gcd of 5 and 15 is : 5

LOGARITHMIC AND POWER FUNCTION

8. math.exp()

Used to calculate the power of e
>>>test = 4
>>>print (math.exp(test))
54.598150033144236

9. math.pow()

The math.pow() method receives two float arguments, raises the first to the second and returns the result. In other words, pow(2,3) is equivalent to 2**3.
>>>math.pow(2,4)
16.0

10. math.log()

Used to calculate the logarithmic value of a with base b
>>>print ("The value of log 2 with base 3 is : ")
>>>print (math.log(2,3))
The value of log 2 with base 3 is : 0.6309297535714574

TRIGONOMETRIC AND ANGULAR FUNCTION

sin(), cos(), and tan() functions return the sine, cosine, and tangent of value passed as the argument.

PROGRAM

```
import math
a = math.pi/6
print ("The value of sine of pi/6 is : ", end="")
print (math.sin(a))
print ("The value of cosine of pi/6 is : ", end="")
print (math.cos(a))
print ("The value of tangent of pi/6 is : ", end="")
print (math.tan(a))
```

OUTPUT

```
The value of sine of pi/6 is : 0.49999999999999994
The value of cosine of pi/6 is : 0.8660254037844387
The value of tangent of pi/6 is : 0.5773502691896257
```

Using the Python Standard Library for handling basic I/O - input(), print()

Python offers us several built-in functions that make it easy to create a program quickly. Two of the most commonly used built-in functions are the **input() and print()** functions that are used for frequent input and output operations, respectively.

Python Input

To run an application, programmers often need to obtain input in Python from a user. The simplest way to do this is to use the **input()** function. The function pauses program execution to let the user type a line of information from the keyboard. When the user hits "Enter", the input is read and returned as a string.
Syntax:-

input([<prompt>])

where the prompt is an optional string that we wish to display for the user.

EXAMPLE

```
>>>name = input ('What is your name? - ')
>>>print ('Hello,', name)

What is your name? - John
Hello, John
```

By default, the input() function accepts only string arguments. However, we can convert this to a number by using the int() of float() functions.

EXAMPLE

```
>>>number = input ('What is your number? ')

What is your number? 45
>>> number
'45'
>>> int(45)
45
>>> float(45)
45.0
```

Or

```
>>>price=float(input("Enter the price of each item"))
>>>print(price)

Enter the price of each item 50
50.0
```

For taking multiple inputs from the user in a single line we use the function **split().**

EXAMPLE

```
>>>x,y=input("Enter two numbers: ").split()
>>>print("No. of boys: ", x)
>>>print("No. of girls: ", y)
Enter two numbers: 23 22
No. of boys: 23
No. of girls: 22
```

Python Output

Once a program accepts input in Python and processes the data, it needs to present the data back to the user as output. You can choose to display the data output to the console directly or show it on a screen.

We use the **print()** function to display the output data to the (screen).

Syntax:-

print(<obj>,...,<obj>)

Using the above syntax, we can pass several objects (<obj>) in the print() function by separating them with a comma.

EXAMPLE

```
>>>print(100)

100

>>>num = 65
>>>print ('The value of the number is', num)
```

The value of the number is 65

Another Syntax:-

print(*objects, sep=' ', end='\n', file=sys.stdout, flush=False)

EXAMPLE

```
# Python program to illustrate print()
# Passing sep and end parameters
>>>num = 7
>>>print('James Bond ', num, sep = '--> 00', end = '\n\n\n')
>>>a = 2
>>>print('Value of a: ', a, sep = '000', end = '\n')
>>>print('Car', 'Bike', 'Train', 'Plane', sep = ' | ', end = '\n\n')
```

OUTPUT

James Bond --> 007

Value of a: 0002

Car | Bike | Train | Plane

Python operators and their precedence

In Python, operators are **special symbols or keywords** that carry out operations on values and python variables. They serve as a basis for expressions, which are used to modify data and execute computations. Python contains several operators, each with its unique purpose.

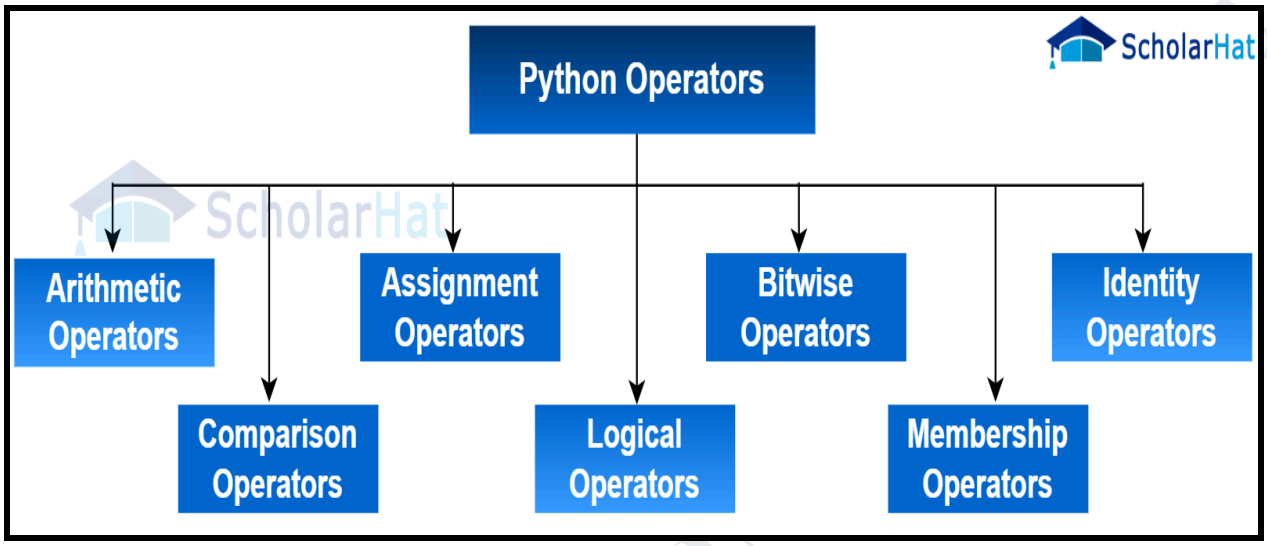
Simple answer can be given using the expression 4 + 5 is equal to 9. Here, 4 and 5 are called operands and + is called operator.

Types of Python Operators

Python language supports various types of operators, which are:

1. **Arithmetic Operators**
2. **Comparison (Relational) Operators**

3. **Assignment Operators**
4. **Logical Operators**
5. **Bitwise Operators**
6. **Membership Operators**
7. **Identity Operators**



1. Python Arithmetic Operators

- Mathematical operations including addition, subtraction, multiplication, and division are commonly carried out using Python arithmetic operators.
- They are compatible with integers, variables, and expressions.
- In addition to the standard arithmetic operators, there are operators for modulus, exponentiation, and floor division.

Operator	Name	Example
+	Addition	10 + 20 = 30
-	Subtraction	20 – 10 = 10
*	Multiplication	10 * 20 = 200
/	Division	20 / 10 = 2
%	Modulus	22 % 10 = 2
**	Exponent	4**2 = 16
//	Floor Division	9//2 = 4

Example of Python Arithmetic Operators

```
a = 21
b = 10
# Addition
print ("a + b : ", a + b)
# Subtraction
print ("a - b : ", a - b)
# Multiplication
print ("a * b : ", a * b)
# Division
print ("a / b : ", a / b)
# Modulus
print ("a % b : ", a % b)
# Exponent
print ("a ** b : ", a ** b)
# Floor Division
print ("a // b : ", a // b)
```

This code defines the two variables "a" and "b." It then applies several arithmetic operations to them (including addition, subtraction, multiplication, division, modulus, exponentiation, and floor division) and outputs the results.

Output

```
a + b : 31
a - b : 11
a * b : 210
a / b : 2.1
a % b : 1
a ** b : 16679880978201
a // b : 2
```

2. Python Comparison Operators

- To compare two values, Python comparison operators are needed.
- Based on the comparison, they produce a Boolean value (True or False).

Operator	Name	Example
==	Equal	4 == 5 is not true.
!=	Not Equal	4 != 5 is true.
>	Greater Than	4 > 5 is not true
<	Less Than	4 < 5 is true
>=	Greater than or Equal to	4 >= 5 is not true.
<=	Less than or Equal to	4 <= 5 is true.

Example of Python Comparison Operators

```
a = 4
b = 5
# Equal
print ("a == b : ", a == b)
# Not Equal
print ("a != b : ", a != b)
# Greater Than
print ("a > b : ", a > b)
# Less Than
print ("a < b : ", a < b)
# Greater Than or Equal to
print ("a >= b : ", a >= b)
# Less Than or Equal to
print ("a <= b : ", a <= b)
```

This code compares the values of python variables 'a' and 'b' and prints if they are equal, not equal, greater than, less than, more than or equal to, and less than or equal to each other.

Output

```
a == b : False
a != b : True
a > b : False
a < b : True
a >= b : False
a <= b : True
```

3. Python Assignment Operators

- Python assignment operators are used to assign values to variables in Python.
- The single equal symbol (=) is the most fundamental assignment operator.
- It assigns the value on the operator's right side to the variable on the operator's left side.

Operator	Name	Example
=	Assignment Operator	a = 10
+=	Addition Assignment	a += 5 (Same as a = a + 5)
-=	Subtraction Assignment	a -= 5 (Same as a = a - 5)
*=	Multiplication Assignment	a *= 5 (Same as a = a * 5)
/=	Division Assignment	a /= 5 (Same as a = a / 5)
%=	Remainder Assignment	a %= 5 (Same as a = a % 5)
**=	Exponent Assignment	a **= 2 (Same as a = a ** 2)
//=	Floor Division Assignment	a //= 3 (Same as a = a // 3)

Example of Python Assignment Operators

```
# Assignment Operator
a = 10
# Addition Assignment
a += 5
print ("a += 5 : ", a)
# Subtraction Assignment
a -= 5
print ("a -= 5 : ", a)
# Multiplication Assignment
a *= 5
print ("a *= 5 : ", a)
# Division Assignment
a /= 5
print ("a /= 5 : ",a)
# Remainder Assignment
```

```
a %= 3
print ("a %= 3 : ", a)
# Exponent Assignment
a **= 2
print ("a **= 2 : ", a)
# Floor Division Assignment
a //= 3
print ("a //= 3 : ", a)
```

The Python assignment operators are shown in this code in the **Python Editor**. It begins with the value of 'a' equal to 10, and then goes through the steps of addition, subtraction, multiplication, division, remainder, exponentiation, and floor division, updating 'a' as necessary and outputting the results.

Output

```
a += 5 : 105
a -= 5 : 100
a *= 5 : 500
a /= 5 : 100.0
a %= 3 : 1.0
a **= 2 : 1.0
a //= 3 : 0.0
```

4. Python Bitwise Operators

- Python bitwise operators execute operations on individual bits of binary integers.
- They work with integer binary representations, performing logical operations on each bit location.
- Python includes various bitwise operators, such as AND (&), OR (|), NOT (), XOR (), left shift (), and right shift (>>).

Operator	Name	Example
&	Binary AND	Sets each bit to 1 if both bits are 1
|	Binary OR	Sets each bit to 1 if one of the two bits is 1
^	Binary XOR	Sets each bit to 1 if only one of two bits is 1

~	Binary Ones Complement	Inverts all the bits
<<	Binary Left Shift	Shift left by pushing zeros in from the right and let the leftmost bits fall off
>>	Binary Right Shift	Shift right by pushing copies of the leftmost bit in from the left, and let the rightmost bits fall off

Example of Python Bitwise Operators

```
a = 60            # 60 = 0011 1100
b = 13            # 13 = 0000 1101
# Binary AND
c = a & b         # 12 = 0000 1100
print ("a & b : ", c)
# Binary OR
c = a | b         # 61 = 0011 1101
print ("a | b : ", c)
# Binary XOR
c = a ^ b         # 49 = 0011 0001
print ("a ^ b : ", c)
# Binary Ones Complement
c = ~a            # -61 = 1100 0011
print ("~a : ", c)
# Binary Left Shift
c = a << 2;       # 240 = 1111 0000
print ("a << 2 : ", c)
# Binary Right Shift
c = a >> 2;       # 15 = 0000 1111
print ("a >> 2 : ", c)
```

The binary representations of the numbers 'a and b' are subjected to bitwise operations in this code. It displays the results of binary AND, OR, XOR, Ones Complement, Left Shift, and Right Shift operations.

Output

```
a & b : 12
a | b : 61
a ^ b : 49
~a : -61
```

a >> 2 : 240
a >> 2 : 15

5. Python Logical Operators

- Python logical operators are used to compose Boolean expressions and evaluate their truth values.
- They are required for the creation of conditional statements as well as for managing the flow of execution in programs.
- Python has three basic logical operators: AND, OR, and NOT.

Operator	Description	Example
and Logical AND	If both of the operands are true then the condition becomes true.	(a and b) is true.
or Logical OR	If any of the two operands is non-zero then the condition becomes true.	(a or b) is true.
not Logical NOT	Used to reverse the logical state of its operand	Not(a and b) is false.

Example of Python Logical Operators

```
x = 5
y = 10
if x > 3 and y < 15:
print("Both x and y are within the specified range")
```

The code assigns the values 5 and 10 to variables x and y. It determines whether x is larger than 3 and y is less than 15. If both conditions are met, it writes "Both x and y are within the specified range."

Output

Both x and y are within the specified range

6. Python Membership Operators

- Python membership operators are used to determine whether or not a certain value occurs within a sequence.
- They make it simple to determine the membership of elements in various Python data structures such as lists, tuples, sets, and strings.

- Python has two primary membership operators: the in and not in operators.

Operator	Description	Example
in	Evaluates to true if it finds a variable in the specified sequence and false otherwise.	x in y, here in results in a 1 if x is a member of sequence y.
not in	Evaluates to true if it does not find a variable in the specified sequence and false otherwise.	x not in y, here not in results in a 1 if x is not a member of sequence y.

Example of Python Membership Operators

```
fruits = ["apple", "banana", "cherry"]
print(“banana” in fruits)
```

The code defines a list of fruits and tests to see if the word "banana" appears in the list. If it is present, “True” is printed on screen.

Output

True

7. Python Identity Operators

- Python identity operators are used to compare two objects' memory addresses rather than their values.
- If the two objects refer to the same memory address, they evaluate to True; otherwise, they evaluate to False.
- Python includes two identity operators: the is and is not operators.

Operator	**Description**	**Example**
is	Evaluates to true if the variables on either side of the operator point to the same object and false otherwise	x is y, here are results in 1 if id(x) equals id(y)
is not	Evaluates to false if the variables on either side of the operator point to the same object and true otherwise	x is not y, there are no results in 1 if id(x) is not equal to id(y).

Example of Python Identity Operators

```
x = 10
```

```
y = 5
print(x is y)
```

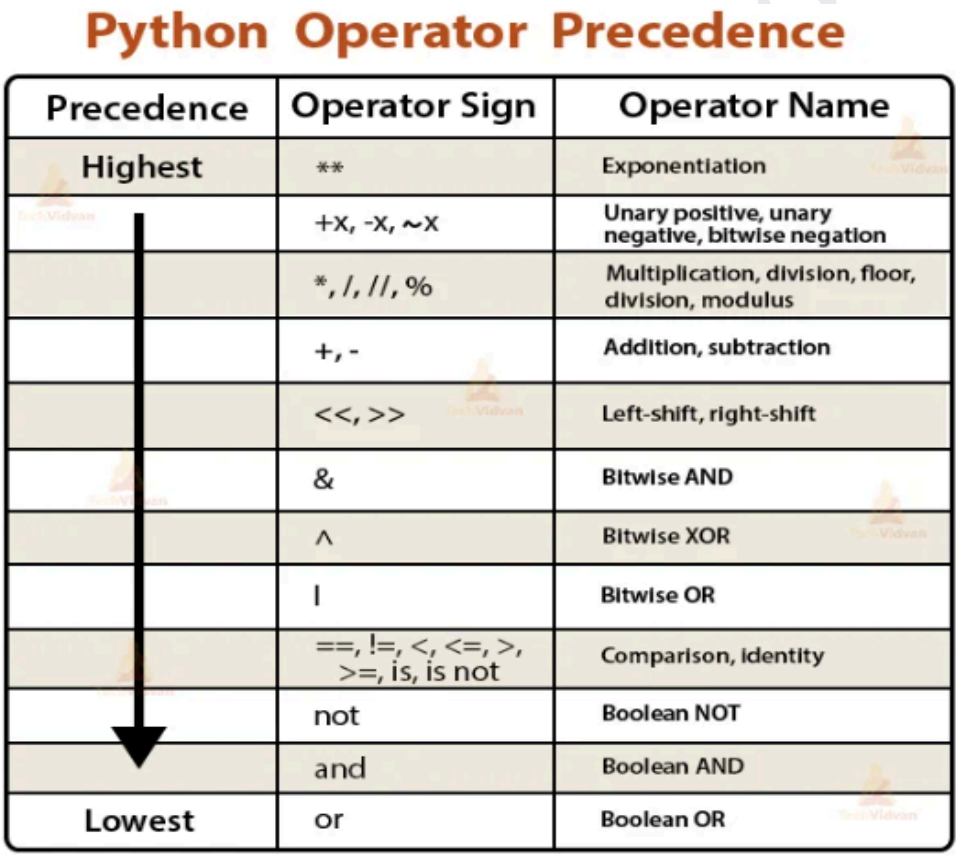
The code sets the variables x and y to 10 and 5, respectively. Then check whether the both values are equal using is operator. If correct, True value will be displayed else false value.

Output

False

OPERATOR PRECEDENCE

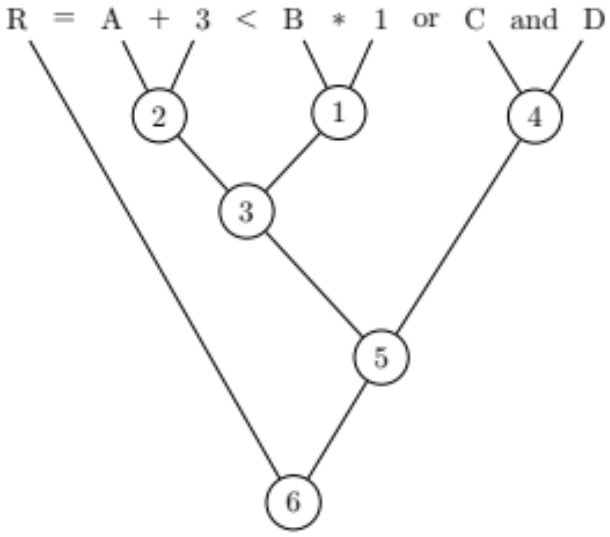
When an expression or statement involves multiple operators then it will be resolve using the following operator precedence chart :



Example 5.4. Consider the assignment statement
R = A + 3 < B ∗ 1 or C and D

Let the values of the variables be A = 1, B = 5, C = −1, andD = True. Figure 5.1 shows the structure of the evaluation. The numbers shown in the circle

denote the order in which the various operators are applied. The final result is 1, which is assigned to R.



Order	Operation	Resultant
1	$B * 1$	5
2	$A + 3$	4
3	$A + 3 < B * 1$	1
4	$C\&\&D$	1
5	$A + 3 < B * 1 \|\| C\&\&D$	1
6	$R = A + 3 < B * 1 \|\| C\&\&D$	1

Evaluation of an arithmetic expression