# COMP 1023 Introduction to Python Programming

## Python Basic Operations

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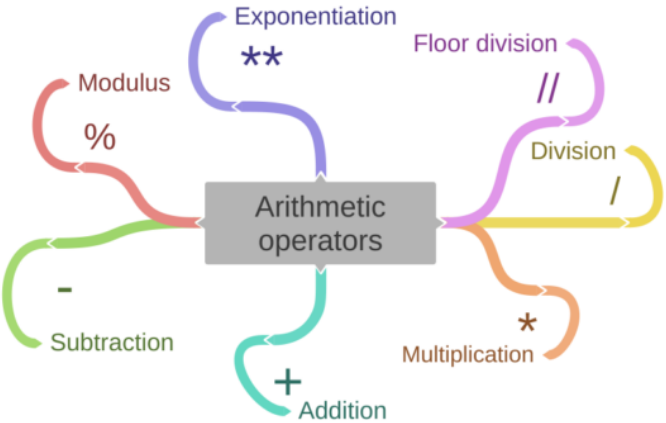
# Introduction

- According to what we covered in the last topic, now you should know the following:
  - The basic structure of Python programs.
  - Python programs can "memorize" data through objects referenced by variables.
  - Using input and print functions, we can read data from and write data to I/O devices (e.g., keyboard, monitor, etc.).
- In this topic, we will continue to discuss more about Python programming, particularly the basic operations that Python programs can perform.
- Topics to be discussed include:
  1. Arithmetic operations (also known as mathematical operations).
  2. Relational (Comparison) operations.
  3. Logical operations.
  4. Other operations.

# Part I

## Arithmetic Operations



# Arithmetic Operations

- In Python, the following arithmetic operations are supported:

| Symbol(s) | Meaning | Example | Result |
|---|---|---|---|
| `+` | Addition | `34 + 1` | `35` |
| `-` | Subtraction | `34.0 - 0.1` | `33.9` |
| `*` | Multiplication | `300 * 30` | `9000` |
| `/` | Float division | `1 / 2` | `0.5` |
| `//` | Integer division | `1 // 2` | `0` |
| `**` | Exponentiation | `4 ** 0.5` | `2.0` |
| `%` | Remainder | `20 % 3` | `2` |

- `+`, `-`, `*`, `/`, `//`, `**`, `%` are called arithmetic operators.
- The input (or arguments) around the operators are called arithmetic operands.

**Note**

To improve readability, Python allows us to use underscores to separate digits in a number literal. For example:

```
value = 232_45_4519
amount = 23.24_4545_4519_3415
```

However, `45_` or `_45` is incorrect. The underscore must be placed between two digits.

# What Can You Conclude From These?

| Operator(s) | Example | Result |
|---|---|---|
| + | `1 + 2` | `3` |
| | `1 + 2.0` | `3.0` |
| | `1.0 + 2` | `3.0` |
| | `1.0 + 2.0` | `3.0` |
| - | `1 - 2` | `-1` |
| | `1 - 2.0` | `-1.0` |
| | `1.0 - 2` | `-1.0` |
| | `1.0 - 2.0` | `-1.0` |
| * | `1 * 2` | `2` |
| | `1 * 2.0` | `2.0` |
| | `1.0 * 2` | `2.0` |
| | `1.0 * 2.0` | `2.0` |
| / | `1 / 2` | `0.5` |
| | `1 / 2.0` | `0.5` |
| | `1.0 / 2` | `0.5` |
| | `1.0 / 2.0` | `0.5` |

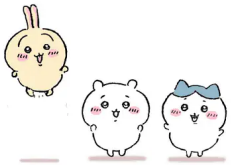
- In Python, if one of the operands for `+`, `-`, `*` is of float type, the result of the operation will also be float.
  In fact, this also applies to `//`, `**`, and `%`, which we will introduce later.
- For `/`, the result will always be float.

**Note**

If an integer and a float are involved in a binary operation, Python automatically converts the integer to a float value. This is called implicit type conversion.

# Arithmetic Operations

```python
def main():  # Filename: arithmetic_operations.py
    # Addition
    print('1 + 2 =', 1 + 2, 'and type is', type(1 + 2))
    print('1 + 2.0 =', 1 + 2.0, 'and type is', type(1 + 2.0))
    print('1.0 + 2 =', 1.0 + 2, 'and type is', type(1.0 + 2))
    print('1.0 + 2.0 =', 1.0 + 2.0, 'and type is', type(1.0 + 2.0))
    # Subtraction
    print('1 - 2 =', 1 - 2, 'and type is', type(1 - 2))
    print('1 - 2.0 =', 1 - 2.0, 'and type is', type(1 - 2.0))
    print('1.0 - 2 =', 1.0 - 2, 'and type is', type(1.0 - 2))
    print('1.0 - 2.0 =', 1.0 - 2.0, 'and type is', type(1.0 - 2.0))
    # Multiplication
    print('1 * 2 =', 1 * 2, 'and type is', type(1 * 2))
    print('1 * 2.0 =', 1 * 2.0, 'and type is', type(1 * 2.0))
    print('1.0 * 2 =', 1.0 * 2, 'and type is', type(1.0 * 2))
    print('1.0 * 2.0 =', 1.0 * 2.0, 'and type is', type(1.0 * 2.0))
    # Division
    print('1 / 2 =', 1 / 2, 'and type is', type(1 / 2))
    print('1 / 2.0 =', 1 / 2.0, 'and type is', type(1 / 2.0))
    print('1.0 / 2 =', 1.0 / 2, 'and type is', type(1.0 / 2))
    print('1.0 / 2.0 =', 1.0 / 2.0, 'and type is', type(1.0 / 2.0))

if __name__ == "__main__":
    main()
```



# Output of Arithmetic Operations

```
1 + 2 = 3 and type is <class 'int'>
1 + 2.0 = 3.0 and type is <class 'float'>
1.0 + 2 = 3.0 and type is <class 'float'>
1.0 + 2.0 = 3.0 and type is <class 'float'>

1 - 2 = -1 and type is <class 'int'>
1 - 2.0 = -1.0 and type is <class 'float'>
1.0 - 2 = -1.0 and type is <class 'float'>
1.0 - 2.0 = -1.0 and type is <class 'float'>

1 * 2 = 2 and type is <class 'int'>
1 * 2.0 = 2.0 and type is <class 'float'>
1.0 * 2 = 2.0 and type is <class 'float'>
1.0 * 2.0 = 2.0 and type is <class 'float'>

1 / 2 = 0.5 and type is <class 'float'>
1 / 2.0 = 0.5 and type is <class 'float'>
1.0 / 2 = 0.5 and type is <class 'float'>
1.0 / 2.0 = 0.5 and type is <class 'float'>
```

# Integer Division (//)

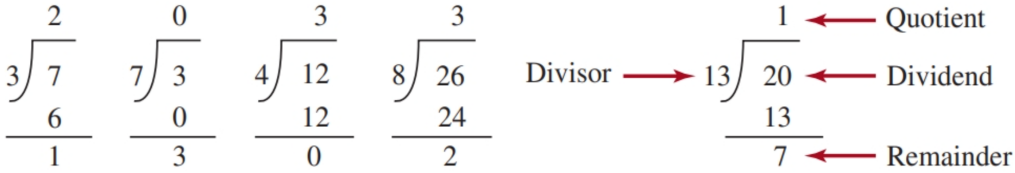
- The operator `//` is used for integer division, also known as floor division.
- The `//` operator divides two numbers and returns the largest integer that is less than or equal to the result (the floor of the division).
- Examples:
  - `5 // 2` returns `2`, because 5 divided by 2 is 2.5, and the largest integer less than or equal to 2.5 is 2.
  - `5.0 // 2` returns `2.0`, because the result is a float.
  - `5 // 2.0` also returns `2.0`.
  - `5.5 // 2` returns `2.0`, as the largest integer less than or equal to 2.75 is 2.
  - `5.5 // -2` returns `-3.0`, as the largest integer less than or equal to $-2.75$ is $-3$.

# Exponentiation (**)

- The operator `**` is used for exponentiation, which raises a number (the base) to the power of another number (the exponent).
- Examples:
  - `2 ** 3` evaluates to `8`, because it is equivalent to $2^3 = 8$.
  - `4.0 ** 0.5` evaluates to `2.0`, because it is equivalent to $4.0^{0.5} = 4.0^{\frac{1}{2}} = \sqrt{4.0} = 2.0$.
  - `2 ** -2` evaluates to `0.25`, because it is equivalent to $2^{-2} = \frac{1}{2^2} = 0.25$.
  - `2 ** 3 ** 2` evaluates to `512`, because it is equivalent to $2^{(3**2)}$, which is $2^9$ and equals 512.
  - Tricky: `(-1) ** 0.5` evaluates to `1j`, because it is equivalent to $\sqrt{-1}$, and equal to $6.123233995736766e-17+1j$.

# Modulo Operation (%)

- The arithmetic operator % is referred to as the "modulo operator", "mod operator", or simply "mod".
- It is used to find the remainder after integer division.




- The modulo operator has many useful applications in computer programs:
  - Testing whether a number is even or odd: `number % 2 == 0` for even numbers, `number % 2 == 1` for odd numbers.
  - Finding individual digits of a number: `number % 10` gives the least significant digit (rightmost digit) of the number.
  - Finding the last four digits of an HKID number: `ID % 10000`.

# Modulo Operations

```python
# Filename: mod_operations.py
# An example demonstrating mod operations
def main():
    print('1023 % 2 is', 1023 % 2)       # Remainder when 1023 is divided by 2
    print('1023 % 10 is', 1023 % 10)     # Remainder when 1023 is divided by 10
    print('1023 % 100 is', 1023 % 100)   # Remainder when 1023 is divided by 100
    print('1023 % 1000 is', 1023 % 1000) # Remainder when 1023 is divided by 1000
    # Last 4 digits of ID
    print('The last 4 digits of ID: 8121232 % 10000 is', 8121232 % 10000)

if __name__ == "__main__":
    main()
```

**Output:**

```
The result of 1023 % 2 is 1
The result of 1023 % 10 is 3
The result of 1023 % 100 is 23
The result of 1023 % 1000 is 23
The last 4 digits of ID: 8121232 % 10000 is 1232
```

# Display Time

- This program converts an amount of time given in seconds into minutes and remaining seconds.

```python
# Filename: display_time.py
# A program that obtains minutes and remaining seconds from an amount of time in seconds
def main():
    # Prompt the user for input
    seconds = int(input("Enter an integer for seconds: "))

    # Calculate minutes and remaining seconds
    minutes = seconds // 60  # Calculate whole minutes
    remaining_seconds = seconds % 60  # Calculate remaining seconds

    # Display the result
    print(seconds, "seconds is", minutes, "minutes and", remaining_seconds, "seconds")

if __name__ == "__main__":
    main()
```

**Output:**

# More about Modulo Operations

- The operands of the modulo operator can be positive or negative integers or floats.
- For `a % b`, it is computed based on the following formula:

$$r = a - (a//b) * b$$

- Examples:
  - `10 % 3 = 10 - (10 // 3) * 3 = 10 - 3 * 3 = 1`
  - `10 % -3 = 10 - (10 // -3) * (-3) = 10 - (-4) * (-3) = 10 - 12 = -2`
  - `-10 % 3 = -10 - (-10 // 3) * 3 = -10 - (-4) * 3 = -10 + 12 = 2`
  - `-10 % -3 = -10 - (-10 // -3) * (-3) = -10 - 3 * (-3) = -10 + 9 = -1`
  - `-5.3 % 3 = -5.3 - (-5.3 // 3) * 3 = -5.3 - (-2) * 3 = -5.3 + 6 = 0.7`
  - `5.3 % -3 = 5.3 - (5.3 // -3) * (-3) = 5.3 - (-2) * (-3) = 5.3 - 6 = -0.7`
  - `-5.3 % -3 = -5.3 - (-5.3 // -3) * (-3) = -5.3 - 1 * (-3) = -5.3 + 3 = -2.3`

Can you calculate `6.4 % -1.7`?

# Subtraction and Negation Operations (-)

- The operator - is used as both a binary subtraction operator and a unary negation operator.
  - The binary subtraction operator takes 2 operands (e.g., `10 - 20`).
  - The unary negation operator takes 1 operand (e.g., `-3`).

```
# Filename: subtraction_negation.py

def main():
    print("The result of 10 - 20 is", 10 - 20) # Subtraction
    print("This is", -3)                       # Negation

if __name__ == "__main__":
    main()
```

**Output:**

```
The result of 10 - 20 is -10
This is -3
```

# Division by Zero in Python

- Division by zero is an error in Python.
- Common operations that raise this error:
  - Division:

```
result = 5 / 0   # Raises ZeroDivisionError
```

  - Integer Division:

```
result = 5 // 0  # Raises ZeroDivisionError
```

  - Modulo:

```
result = 5 % 0   # Raises ZeroDivisionError
```

- Exponentiation:

```
result = 0 ** 0  # This is defined as 1
```

Always check for zero before performing division or related operations!

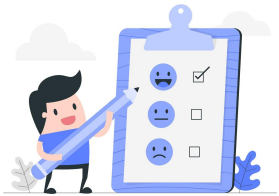
# Expressions

- In programming, we often need to include values and operations; the technical term for these is expressions.
- An expression is a simple value or a combination of operations that produces a value.
- Examples:
  - Simplest expressions (just an integer or a floating-point literal): `89` or `30.23`.
  - A combination of operations that produces a value:

    ```
    (3 * 7) + (4 * 4) + 8
    ```

    (The resulting value of the above expression is `45`).

The process of obtaining the value of an expression is called evaluation.

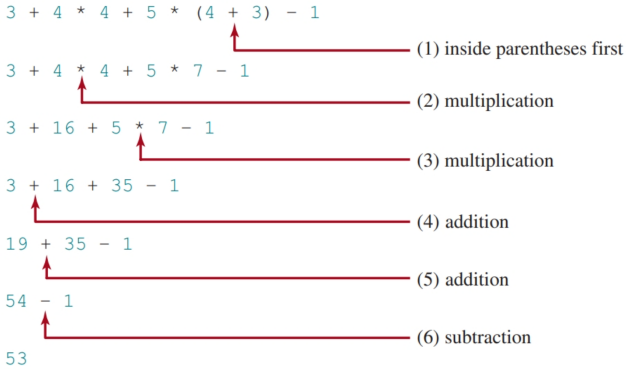


# Precedence of Arithmetic Operators

**Q:** If there are multiple operators involved in an expression, how should we evaluate it?

- This is determined by the precedence of operators.
- Operator precedence determines the order in which operations are performed in an expression.
- For arithmetic expressions, there are three levels of precedence:
  - Exponentiation (`**`) is applied first.
  - Multiplication (`*`), float division (`/`), integer division (`//`), and remainder (`%`) operators are applied next. If an expression contains several of these operations, they are applied from left to right.
  - Addition (`+`) and subtraction (`-`) operators are applied last. If an expression contains multiple addition and subtraction operators, they are also applied from left to right.
- Can I override these rules?
  Yes, by using parentheses (`()`).

# Precedence of Arithmetic Operators




- This diagram illustrates the precedence of arithmetic operators in Python.
- Higher precedence operators are evaluated before lower precedence operators.
- Use parentheses to override the default precedence rules.

# Precedence of Arithmetic Operators

```
# Filename: precedence_arithmetic_operators.py

def main():
    print("The result of 3 + 4 * 4 + 5 * (4 + 3) - 1 is",
          3 + 4 * 4 + 5 * (4 + 3) - 1)

if __name__ == "__main__":
    main()
```

**Output:**

```
The result of 3 + 4 * 4 + 5 * (4 + 3) - 1 is 53
```

# Arithmetic Operations on Variables

- Arithmetic operators can also be applied to variables.
- The precedence of operations remains the same when using variables.
- This example demonstrates various arithmetic operations on variables:

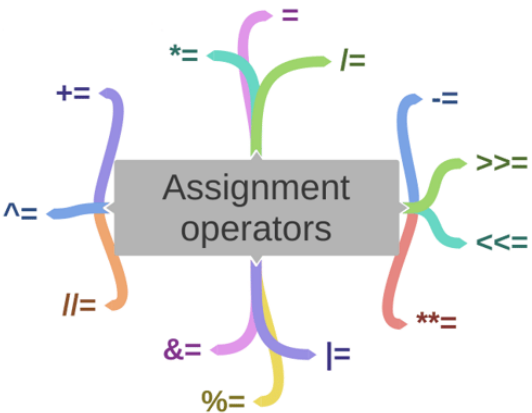
```
def main():
    a, c = 10, 22
    b, d = 20.1, 18.9
    print("Addition:", a + b)
    print("Subtraction:", a - b)
    print("Multiplication:", a * b)
    print("Division:", a / b)
    # The following has a precision error
    print("Combination:", a * 10 + b / c - d + 6)

if __name__ == "__main__":
    main()
```

**Output:**

```
Addition: 30.1
Subtraction: -10.100000000000001
Multiplication: 201.0
Division: 0.49751243781094523
Combination: 88.01363636363635
```

# Part II

## Assignment Operation



# Assignment Operation

- The assignment operator = is used to assign a value to an object referenced by a variable.

**Syntax**

```
<var name> = <initial value>
# Cascading assignment
<var name1> = <var name2> = <initial value>
# Simultaneous assignments
<var name1>, <var name2>, ... = <initial value1>, <initial value2>, ...
<var name> = <expression>
<var name1> = <var name2> = <expression>
<var name1>, <var name2>, ... = <expression1>, <expression2>, ...
```

where <var name> or <var nameN> is the variable name in the program, referring to its location in memory; <initial value> or <initial valueN> is the value initially assigned to the object referenced by a variable (this is called initialization); <expression> or <expressionN> refers to a value obtained from operations.

# Assignment Operation

- Examples:

```
# Simultaneous assignments
x, y = 3, 4  # Create objects with values 3 and 4 and referenced by x and y
x = 2 + 9    # Create an object with the result of 2 + 9 (11) and referenced by x
x = y        # Create an object to store the value of y (4) and referenced by x
x = x + 1    # Create an object to store the value of x + 1 (5) and referenced by x
```

- Common Confusion:
  - Many students may get confused because assignment statements, such as `x = x + 1`, do not follow traditional mathematical rules.
  - In mathematics, no real number can satisfy the equation `x = x + 1`.

  However, in programming, we are simply assigning the value of `(x + 1)` to the variable `x`. This is not a mathematical equation, but an assignment operation.

# Assignment Operation

```python
# Filename: bmi_example.py

def main():
    weight, height = 195, 70  # Initialize weight and height
    bmi = weight / (height * height) * 703  # Calculate BMI
    print("Previous BMI:", bmi)

    weight = 180  # Update weight
    bmi = weight / (height * height) * 703  # Recalculate BMI
    print("Current BMI:", bmi)

if __name__ == "__main__":
    main()
```

**Output:**

```
Previous BMI: 27.976530612244897
Current BMI: 25.82448979591837
```

# What is Wrong in This Code?

```
def main():
    count = count + 1  # Error: count is not defined yet
    print(count)

if __name__ == "__main__":
    main()
```

- An error occurs in the line `count = count + 1` because the variable `count` has not been defined before this line.
- To fix it, we can define the object referenced by the variable `count` first:

```
def main():
    count = 1           # Initialize count
    count = count + 1   # Increment count by 1
    print(count)

if __name__ == "__main__":
    main()
```

# Simultaneous Assignments and Cascading Assignments

```python
# Filename: simultaneous_cascading_assignment.py

def main():
    x, y = 10, 20  # Simultaneous assignments
    ''' This is equivalent to:
        x = 10
        y = 20 '''
    print(x, y)

    i = j = k = 1  # Cascading assignments
    ''' This is equivalent to:
        temp = 1
        i = 1
        j = 1
        k = 1 '''
    print(i, j, k)

if __name__ == "__main__":
    main()
```

**Output:**

```
10 20
1 1 1
```

# Assignment Operation - Swapping Two Variables

```python
# Filename: swapping.py
def main():
    x = 5
    y = 10

    # Swap x with y
    x, y = y, x
    print(f"x: {x}, y: {y}")

    ''' x, y = y, x
    is equivalent to:
        temp = x
        x = y
        y = temp '''

if __name__ == "__main__":
    main()
```

**How it Works?**

We will discuss this in detail when we talk about tuples!

- Tuple Packing: On the right side of the assignment `(y, x)`, Python creates a tuple containing the current values of `y` and `x`. For example, if `x` is 5 and `y` is 10, the expression `(y, x)` evaluates to the tuple `(10, 5)`.
- Tuple Unpacking: On the left side of the assignment, the values from this tuple are unpacked into the variables `x` and `y`. In this case, `x` will get the value of 10, and `y` will get the value of 5.

# Augmented Assignment Operations

- Python allows augmented assignment operations to simplify coding.

| Operator | Description | Example | Equivalent |
|---|---|---|---|
| `+=` | Addition assignment | `i += 8` | `i = i + 8` |
| `-=` | Subtraction assignment | `i -= 8` | `i = i - 8` |
| `*=` | Multiplication assignment | `i *= 8` | `i = i * 8` |
| `/=` | Float division assignment | `i /= 8` | `i = i / 8` |
| `//=` | Integer division assignment | `i //= 8` | `i = i // 8` |
| `%=` | Remainder assignment | `i %= 8` | `i = i % 8` |
| `**=` | Exponentiation assignment | `i **= 8` | `i = i ** 8` |

These augmented assignment operators are syntactic sugar, providing more convenient and expressive ways to perform operations that could be done with more verbose syntax.

- Example:
  - `x /= 4 + 5.5 + 1.5` is equivalent to `x = x / (4 + 5.5 + 1.5)`.

**Note**

There are no spaces in augmented assignment operators. For example, `+=` should not have a space.

# Augmented Assignment Operation

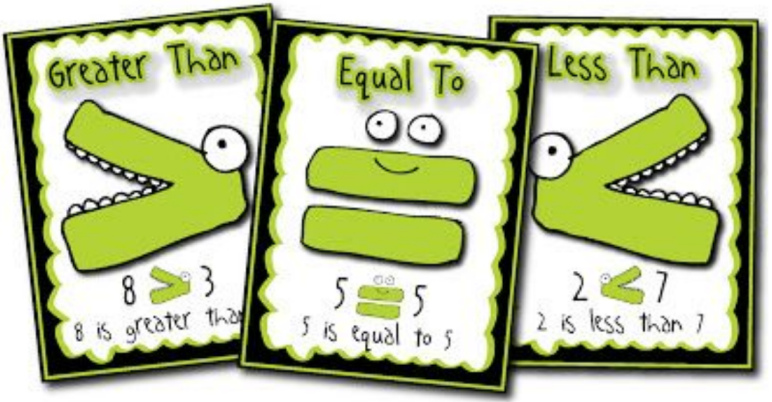
```
# Filename: augmented_assignment.py

def main():
    account = 2000.0
    income = 1000.0
    print("Account =", account, ", income =", income)
    account += income  # Augmented assignment to update account
    print("Account =", account, ", income =", income)

if __name__ == "__main__":
    main()
```

**Output:**

```
Account = 2000.0 , income = 1000.0
Account = 3000.0 , income = 1000.0
```

# Part III

## Relational (Comparison) Operations



# Relational Operations

- Relational (comparison) operators define the relationships between values.

| Operator | Maths Symbol | Description | Example (radius is 5) | Result |
|---|---|---|---|---|
| < | $<$ | less than | radius < 0 | False |
| <= | $\leq$ | less than or equal to | radius <= 0 | False |
| > | $>$ | greater than | radius > 0 | True |
| >= | $\geq$ | greater than or equal to | radius >= 0 | True |
| == | $=$ | equal to | radius == 0 | False |
| != | $\neq$ | not equal to | radius != 0 | True |

- The result of the comparison is a Boolean value: True or False.

```
radius = 5
print(radius > 0)  # Prints True
```

# Relational Operations

```python
def main():  # Filename: relational_operations.py
    x = 10
    y = 20
    x_greater_than_y = (x > y)
    x_greater_than_equal_y = (x >= y)
    x_less_than_y = (x < y)
    x_less_than_equal_y = (x <= y)
    x_equal_y = (x == y)
    x_not_equal_y = (x != y)

    print("x, y:", x, y)
    print("x > y:", x_greater_than_y)
    print("x >= y:", x_greater_than_equal_y)
    print("x < y:", x_less_than_y)
    print("x <= y:", x_less_than_equal_y)
    print("x == y:", x_equal_y)
    print("x != y:", x_not_equal_y)

if __name__ == "__main__":
    main()
```

**Output:**

```
x, y: 10 20
x > y: False
x >= y: False
x < y: True
x <= y: True
x == y: False
x != y: True
```

# String Comparisons in Python

- Strings in Python can be compared using relational operators: `<`, `>`, `<=`, `>=`, `==`, `!=`
- Comparisons are based on lexicographical order, which is determined by the ASCII values of characters.

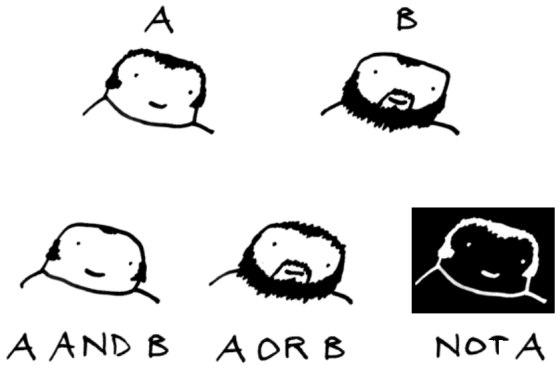
**ASCII Code Explanation**

- Each character has a corresponding ASCII value:
  - `'a'` = 97, `'b'` = 98, `'c'` = 99
  - `'A'` = 65, `'B'` = 66
- When comparing strings:
  - Compare the ASCII values of each character from left to right.
  - The string with the smaller ASCII value comes first.

- Examples:
  - `"apple"` < `"banana"`: `'a'` (97) < `'b'` (98) (`True`)
  - `"Box"` < `"Boy"`: `'x'` (120) < `'y'` (121) (`True`)

# Part IV

## Logical Operations



# Logical Operations

- There are three logical operators in Python:

| Operator | Description |
|---|---|
| `not` | logical negation |
| `and` | logical conjunction |
| `or` | logical disjunction |

- Logical operators combine two Boolean values and produce a single Boolean result based on the corresponding truth table.

| Truth Table | | | | |
|---|---|---|---|---|
| **p** | **q** | **p and q** | **p or q** | **not p** |
| True | True | True | True | False |
| True | False | False | True | False |
| False | True | False | True | True |
| False | False | False | False | True |

- The variables $p$ and $q$ can be Boolean literal values or evaluated Boolean values from expressions.

# Logical Operations

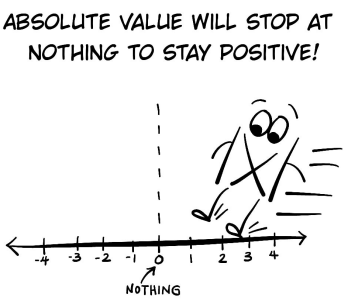
- Return True if x is in the range $[3, 10]$:

  ```
  in_range = ( (x >= 3) and (x <= 10) )
  ```

  Python supports chained comparison operators:

  ```
  # in_range = ( 3 <= x <= 10 ) # Equivalent statement
  ```

- Return True if $|x| > 1$:
  - `abs_x_greater_than_1 = ( (x > 1) or (x < -1) )`
- Return True if x is not equal to 0. The two statements below are equivalent:
  - `non_zero = (x != 0)`
  - `non_zero = not(x == 0)`



# Example: Determining Leap Years

- A leap year has 366 days. The February of a leap year has 29 days.
- A leap year is divisible by 4 but not by 100, or divisible by 400

```
def main():  # Filename: leap_year.py
    year = int(input("Enter a year: "))

    # Check if the year is a leap year
    is_leap_year = (year % 4 == 0 and year % 100 != 0) or \
                   (year % 400 == 0)

    # Display the result
    print(year, "is a leap year?", is_leap_year)

if __name__ == "__main__":
    main()
```


**Output:**

# Short Circuiting or Lazy Operations

- Short-circuiting is a technique where the execution of a boolean expression containing 'or' and 'and' operators is halted as soon as the truth value of the expression is determined.
- This technique makes computation faster by not evaluating the remaining expressions once the truth value is established.

| Operation | Notes |
|---|---|
| `p or q` | q is executed only if p is False |
| `p and q` | q is executed only if p is True |

- The evaluation of expressions takes place from left to right.

```
print(True or 2/0)      # Evaluates to True, 2/0 is not evaluated
print(False or 2/0)     # This raises an error, since 2/0 is evaluated

print(False and 2/0)    # Evaluates to False, 2/0 is not evaluated
print(True and 2/0)     # This raises an error, since 2/0 is evaluated
```

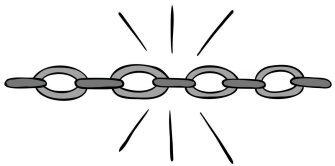
# Chain Operators in Python

- Chain operators allow you to combine multiple comparisons in a single expression.
- They evaluate to 'True' if all comparisons are 'True'.
- Example:

$$5 > x > 3$$

This checks if $x$ is greater than 3 and less than 5.

The expression `5 > x > 3` is almost equivalent to `5 > x and x > 3`.



# Part V

## Other Operations

# Identity Operations

- Identity operators check if two variables refer to the same object in memory.
- There are two identity operators:
  - `is`: Returns `True` if both operands refer to the same object.
  - `is not`: Returns `True` if both operands do not refer to the same object.
- Use identity operators when you need to check if two variables point to the same object, not just if they are equal in value.

```
a = 1
b = 1
print(a is b)      # Print True
print(a is not b)  # Print False
```

Since both a and b are assigned the value 1, and Python caches small integers (typically between -5 and 256), both a and b refer to the same integer object in memory. Therefore, `print(a is b)` evaluates to `True`, and `print(a is not b)` evaluates to `False`.

# Python Caches Small Integers

- Python caches small integers for efficiency, typically in the range of -5 to 256. But the range of these cached integers can vary depending on the platform and the Python implementation.
- This means that when you create an integer within this range, Python reuses the same object instead of creating a new one.

```
x = 100; y = 100
print(x is y)  # Print True
```

  - The `is` operator confirms that both `x` and `y` point to the same object in memory.
  - This caching mechanism can lead to performance improvements and reduced memory usage.
  - However, integers outside this range are not cached:

```
a = 1000; b = 1000
print(a is b)  # Print True in VS Code, but False in Colab
```

  - In Colab, `a` and `b` are different objects in memory.

Caching small integers is an optimization technique employed by Python to enhance performance for frequently used values.

# Membership Operations

- Membership operators check if an item exists within a collection. They return a boolean value `True` or `False`.
- There are two membership operators:
  - `in`: Returns `True` if the specified item exists in a sequence; `False` otherwise.
  - `not in`: Returns `True` if the specified item does not exist in a sequence; `False` otherwise.

**Note**

More details will be provided when discussing collections!

# Associativity of Operators

- Associativity refers to the order in which operators of the same precedence are evaluated in an expression.
- In Python, operators can be left-to-right associative or right-to-left associative.
- Left-to-right Associative Operators:
  - Most arithmetic operators (e.g., +, -, *, /) are left-to-right associative.

    `10 / 5 * 2` is evaluated as `(10 / 5) * 2 = 4.0`
- Right-to-left Associative Operators:
  - The exponentiation operator (**) is right-to-left associative.

    `2 ** 3 ** 2` is evaluated as `2 ** (3 ** 2) = 2 ** 9 = 512`

# Operator Precedence from High (Top) to Low (Down)

| Operator | Description | Associativity |
|---|---|---|
| `**` | Exponentiation | Right-to-left |
| `+, -` | Unary plus and minus | Right-to-left |
| `*, /, //, %` | Multiplication, division, integer division, and modulus | Left-to-right |
| `+, -` | Binary addition and subtraction | Left-to-right |
| `<, <=, >, >=` | Relational operators | Left-to-right |
| `==, !=` | Equality operators | Left-to-right |
| `is, is not` | Identity operators | Left-to-right |
| `in, not in` | Membership operators | Left-to-right |
| `not` | Logical negation | Left-to-right |
| `and` | Logical conjunction | Left-to-right |
| `or` | Logical disjunction | Left-to-right |
| `=, +=, -=, *=, /=, //=, %=, **=` | Assignment and augmented assignment operators | Right-to-left* |

* Refer to the last page for more details.

Reference: `https://docs.python.org/3/reference/expressions.html`

Do not rely solely on precedence rules when writing your program.

- Be cautious: logical `and` is evaluated before logical `or`.
- Example: `(p or q and r)` is equivalent to `(p or (q and r))`. Use parentheses to clarify your intention.

# Floating Point Errors in Python

- Occur due to the way floating point numbers are represented in computer memory.
- Can lead to precision loss and unexpected results in calculations.
- Common Causes:
  - Precision Limitations:
    - Floating point numbers have limited precision (typically 15-17 decimal digits).
    - Example: `0.1 + 0.2` may not equal `0.3`.
  - Rounding Errors:
    - Operations can introduce small errors due to rounding.
    - Example: `print(0.1 + 0.2 == 0.3)` results in `False`.
- Handling Floating Point Errors:
  - Use the `math.isclose()` function for comparisons:

```
import math
print(math.isclose(0.1 + 0.2, 0.3))  # Print True
```

  - Consider using the `decimal` module for higher precision:

```
from decimal import Decimal
print(Decimal('0.1') + Decimal('0.2') == Decimal('0.3'))  # Print True
```

# Common Pitfalls in Python Programming

- Confusion between Assignment and Equality:
  - The assignment operator = is used to assign values to variables.
  - The equality operator == is used to compare two values.
  - Common mistake: Using = when you meant to use ==.
- Misunderstanding Operator Precedence:
  - Operators have different levels of precedence, which affects the order of operations.
  - Example: In the expression `a + b * c`, multiplication is performed before addition.
  - Common mistake: Assuming operations will be executed from left to right without considering precedence.
- Using `is` vs. ==:
  - The `is` operator checks for identity (same object in memory), while == checks for equality (same value).
  - Common Mistake: Using `is` to compare values instead of ==. An exception is to use `is` when comparing with `None`.

# Key Terms

- Arithmetic operators/operations
- Assignment operator/operations
- Augmented assignment operators/operations
- Cascading assignments
- Evaluations
- Expressions
- Exponentiation
- Identity operators/operations
- Integer division
- Lazy operator
- Logical operators
- Membership operators/operations
- Modulo operation
- Negation operator/operation
- Operands
- Operators
- Precedence
- Relational operators/operations
- Short-circuit evaluation
- Simultaneous assignments
- Syntactic sugar
- Truth table

# Review Questions

Fill in the blanks in each of the following sentences about the Python environment.

1. In Python, three main types of operations are _____, _____, and _____.
2. `+`, `-`, `*`, `/`, `//`, `**`, `%` are called _____, and the arguments around them are called _____.
3. When evaluating an expression with values of an `int` type and a `float` type, Python automatically converts the _____ type value to a _____ type value.
4. `//` is used for _____.
5. `**` is used for _____.
6. `%` is called the _____ operator, and is used to find the _____ after integer division.

Answer: 1. arithmetic, relational, logical, 2. operators, operands, 3. int, float, 4. integer division, 5. exponentiation, 6. modulo, remainder.

# Review Questions

Fill in the blanks in each of the following sentences about the Python environment.

7. _____ is used as both a binary operator and a unary operator.
8. An _____ is a simple value or a combination of operations that produces a value.
9. _____ can be used to force the order of evaluation to occur in any sequence.
10. The _____ is used to assign a value to an object referenced by a variable.
11. The operators in arithmetic expressions are evaluated in the order determined by the rules of _____ and _____.
12. Python provides _____ operators: `+=`, `-=`, `*=`, `/=`, `//=`, and `%=`.
13. The _____ operators (`<`, `<=`, `==`, `!=`, `>`, `>=`) yield a Boolean value.
14. Python uses _____ to represent `True`, and _____ for `False`.

Answer: 7. Operator `-`, 8. expression, 9. Parenthesis, 10. assignment operator, 11. parenthesis, operator precedence, 12. augmented assignment, 13. relational (or comparison), 14. `(1)`, `(0)`.

# Review Questions

Fill in the blanks in each of the following sentences about the Python environment.

15. _____ values are considered `True` in a Boolean context, while _____ values are evaluated as `False`.
16. The logical operators _____, _____, and _____ operate with Boolean values and variables.
17. _____ is a technique where the execution of a boolean expression containing `or` and `and` operators is halted.
18. Logical _____ is evaluated before logical _____.
19. _____ operators check if two variables refer to the same object in the memory.
20. _____ operators check if an item exists, or does not exist within a sequence.

Answer: 15. Non-zero, zero, 16. `and`, `or`, `not`, 17. Short circuiting, 18. `and`, `or`, 19. Identity, 20. Membership

# Further Reading

- Read Sections 2.5 - 2.6, 2.8 - 2.12, 3.2, 3.10, and 3.15 of "Introduction to Python Programming and Data Structures" textbook.

That's all!

Any questions?

# Understanding Assignment Operator Associativity in Python

- In Python, the assignment operator has right associativity and follows a specific rule when there are multiple targets in a cascaded assignment statement. For example:

  ```
  x = y = 1
  ```

  is executed as

  ```
  temp = 1
  x = temp
  y = temp
  ```

- This implementation strategy is specific to Python and does not apply to other programming languages like C++. Therefore, we do not plan to test students on the associativity of assignment operators in the course. Students who are interested can reach out to the instructors privately for more information.