

# **Applied Numerical Methods for Civil Engineering**

CGN 3405 - 0002

## **Week 3: Introduction to Python Programming: Part I**

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How to understand

## **Applied Numerical Methods for Civil Engineering?**

**Numerical methods** are techniques by which **mathematical problems** are formulated so that they can be solved with **arithmetic operations**.

# Programming Environment

- No prior programming experience required!
- Setting up your **environment**
  - Free, no installation
  - Cloud-based Jupyter notebooks
  - Access anywhere with browser
  - Link: <https://colab.research.google.com>

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- Try it now!

```
1 print('Hello Civil Engineering!')
2 print('Welcome to Applied Numerical Methods')
```

- What is **print()**?
  - A **function** that displays text
  - Anything in quotes is text (string)

## Quizzes Now!

- **Today's participation** (ungraded survey): Please check out

“Class Participation Quiz 5”

**Time slot: 2:30PM – 3:00PM**

on Canvas.

- Online engagement (graded quizzes)

“Quiz 5” (11 questions)

**Deadline: 11:59PM, January 26, 2026**

on Canvas.

# Variables: Storing Data

Variables are containers for data

```
1 # Assign values to variables
2 length = 10.5          # meters
3 width = 5.2           # meters
4 material = 'Steel'
```

Rules for variable names:

1. Start with letter or underscore
2. Can contain letters, numbers, underscores
3. Case-sensitive: Length  $\neq$  length
4. Descriptive names recommended
5. Avoid Python keywords, e.g., lambda, class, list, def, etc.

Examples:

```
1 length = 4
2 Length = 4.5
3 print('length = {}'.format(length))
4 print('Length = {}'.format(Length))
```

# Basic Data Types

## Four essential types

- **Integers:** Whole numbers  $\dots, -2, -1, 0, 1, 2, \dots$

```
1 length = 4
```

- **Floats:** Decimal numbers

```
1 deflection = 0.025 # meters
```

- **Strings:** Text

```
1 material = 'Steel'
```

- **Booleans:** True/False

```
1 a = True
2 if a is True:
3     print(1)
4 else:
5     print(0)
```

## Checking Data Types

- Use `type()` function:

```
1 # Check types
2 length = 4
3 print(type(length))           # <class 'int'>
4
5 deflection = 0.025
6 print(type(deflection))      # <class 'float'>
7
8 material = Steel
9 print(type(material))        # <class 'str'>
10
11 safe = True
12 print(type(safe))           # <class 'bool'>
```

- Why check types?
  - Different operations work with different types
  - Avoid errors like adding string to number
  - Understand what your code is doing

# Basic Arithmetic Operations

## Python programming example.

```
1 a = 2
2 b = 3
3 print(a + b) # plus
4 print(a - b) # minus
5 print(a * b) # product
6 print(a / b) # division
7 print(a ** 2) # quadratic function
8 print(a ** 3) # cubic function
```

## Corresponding arithmetic operations:

Line 3:  $a + b$

Line 6:  $\frac{a}{b}$

Line 4:  $a - b$

Line 7:  $a^2$

Line 5:  $a \cdot b$

Line 8:  $a^3$

Note:  $a ** n$  refers to  $a$  to the power of  $n$ , or  $a^n$ .

# Basic Arithmetic Operations

## Engineering example.

- Definition of normal stress:

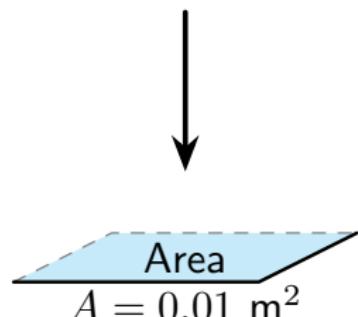
$$\sigma = \frac{F}{A}$$

$$F = 5000 \text{ N}$$

where

- $F = 5000 \text{ N}$  (force)
- $A = 0.01 \text{ m}^2$  (area)

```
1 force = 5000 # N
2 area = 0.01 # m^2
3 stress = force / area # Pa
4 print('stress = {}'.format(stress))
```



## Order of Operations

Python follows PEMDAS:

1. Parentheses
2. Exponents
3. Multiplication
4. Division
5. Addition
6. Subtraction

```
1 # Different results!
2 a1 = 10 + 5 * 2      # (5*2 first)
3 a2 = (10 + 5) * 2    # (parentheses first)
```

## Order of Operations

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```
1 # Different results!
2 a1 = 10 + 5 * 2      # (5*2 first)
3 a2 = (10 + 5) * 2    # (parentheses first)
```

Which one is correct?

$$c = \frac{w}{24 \cdot E \cdot I}$$

```
1 w = 10 ** 4          # uniform load
2 E = 2 * 10 ** 11     # modulus
3 I = 3.25 * 10 ** (-4) # moment of inertia
4 c1 = w / 24 * E * I
5 c2 = w / (24 * E * I)
```

## Lists: Storing Multiple Values

- Lists store collections of data

```
1 # List of beam deflections (mm)
2 deflections = [12.3, 15.7, 18.2, 14.9, 16.5]
3 print(deflections) # [12.3, 15.7, 18.2, 14.9, 16.5]
4
5 # List of materials
6 materials = ['Steel', 'Concrete', 'Timber', 'Aluminum']
7
8 # Access elements (0-indexed!)
9 print(deflections[0]) # First: 12.3
10 print(deflections[-1]) # Last: 16.5
```

## Lists: Storing Multiple Values

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9 print(deflections[0]) # First: 12.3
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```

- List operations for engineering data

```
1 print(len(deflections)) # Number of deflections
2 print(min(deflections)) # Minimum deflection
3 print(max(deflections)) # Maximum deflection
4 print(sum(deflection)) # Total
5 print(sum(deflections)/len(deflections)) # Average
```

## Conditionals (if/elif/else)

- Make decisions in code:

```
1 stress = 235 # MPa
2
3 if stress > 250:
4     print('WARNING: Stress exceeds yield strength!')
5 elif stress > 200:
6     print('Alert: Stress approaching limit')
7 else:
8     print('Stress within safe limits')
```

## Conditionals (if/elif/else)

- Make decisions in code:

```
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```

- Comparison operators:

- > greater than
- < less than
- >= greater or equal
- <= less or equal
- == equal to
- != not equal to

## Logical Operators (and/or/not)

- Use the logical operator `and`:

```
1 stress = 235
2
3 if stress <= 250 and stress > 200:
4     print('Alert!')
5 else:
6     print('Others')
```

- Use the logical operator `or`:

```
1 stress = 235
2
3 if stress > 250 or stress > 200:
4     print('At least alert!')
5 else:
6     print('Safe!')
```

## for Loop: Repeating Tasks

- Process each item in a sequence:

```
1 # List of beam deflections
2 deflections = [12.3, 15.7, 18.2, 14.9, 16.5]    # mm
3
4 # Check each beam
5 for d in deflections:
6     if d > 15:
7         print('Deflection exceeds limit')
8     else:
9         print('Deflection is OK')
```

- Common pattern: Process each item in experimental data

## range() Function for Numerical Loops

- Generate sequences of numbers:

```
1 # Count from 0 to 4
2 for i in range(5):
3     print(i)
4
5 # With start and end
6 for i in range(2, 6):
7     print(i)
8
9 # With step
10 for i in range(0, 10, 2):
11     print(i)
```

Line 2-3 Result: 0, 1, 2, 3, 4

Line 6-7 Result: 2, 3, 4, 5

Line 10-11 Result: 0, 2, 4, 6, 8

## while Loop: Repeat Until Condition

- Repeat while condition is true:

```
1 a = [1, 2, 3, 4, 5, 6, 7, 8]
2 i = 0
3 while a[i] < 6:
4     print(a[i])
5     i = i + 1
```

Result: 0, 1, 2, 3, 4, 5

## Functions: Reusable Code Blocks

- **Quadratic formula.** Given  $ax^2 + bx + c = 0$  ( $a \neq 0$ ), the quadratic formula is

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

```
1 import numpy as np
2
3 def quad_formula(a, b, c):
4     term = np.sqrt(b**2 - 4*a*c)
5     x1 = (-b + term) / (2*a)
6     x2 = (-b - term) / (2*a)
7     return x1, x2
```

- **Case study.** Solve  $9x^2 + 3x - 2 = (3x - 1)(3x + 2) = 0$ .

```
1 a, b, c = 9, 3, -2
2 x1, x2 = quad_formula(a, b, c)
3 print(x1)
4 print(x2)
```

## Functions: Reusable Code Blocks

- Given **parameters**: uniform load  $w = 1 \times 10^4 \text{ kg/m}$ , modulus  $E = 2 \times 10^{11} \text{ Pa}$ , and moment of inertia  $I = 3.25 \times 10^{-4} \text{ m}^4$ .
- Compute the **constant factor**:

$$c = \frac{w}{24 \cdot E \cdot I} = \frac{10^4}{24 \times (2 \times 10^{11}) \times (3.25 \times 10^{-4})} = 6.41 \times 10^{-6}$$

```
1 import numpy as np
2
3 def const(w, E, I):
4     return w / (24 * E * I)
5
6 w = 10 ** 4                  # uniform load
7 E = 2 * 10 ** 11             # modulus
8 I = 3.25 * 10 ** (-4)       # moment of inertia
9 c = const(w, E, I)          # constant factor
10 print(c)
```

## Quick Summary

### Monday's Class:

- Python environment (no installation with Colab)
- Introduction to Python: Variables, data types (integer, float, string, and Boolean).
- Arithmetic operations, order of operations.
- Storing multiple values with lists
- Logical operators (`for` and `while`)
- Defining functions by yourself

TBD