

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 4: $a - b$

Line 5: $a \cdot b$

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

Line 7: a^2

Line 8: a^3

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

Basic Arithmetic Operations

Engineering example.

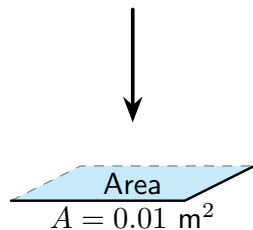
- Definition of normal stress:

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

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)
```

$$a_1 = 10 + 5 \times 2 \qquad a_2 = (10 + 5) \times 2$$

Order of Operations

Python follows PEMDAS:

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

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

- Lists store collections of data

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1 # List of beam deflections (mm)
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3 print(deflections) # [12.3, 15.7, 18.2, 14.9, 16.5]
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5 # List of materials
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8 # Access elements (0-indexed!)
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:

```
1 stress = 235 # MPa
2
3 if stress > 250:
4     print('WARNING: Stress exceeds yield strength!')
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7 else:
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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)
```

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     t = np.sqrt(b**2 - 4*a*c)
5     x1 = (-b + t) / (2*a)
6     x2 = (-b - t) / (2*a)
7     return x1, x2
```

Line 4 Compute $t = \sqrt{b^2 - 4ac}$

Line 5 Compute $x_1 = \frac{-b + t}{2a}$

Line 6 Compute $x_2 = \frac{-b - t}{2a}$

Functions: Reusable Code Blocks

- Given **parameters**: uniform load $w = 1 \times 10^4$ kg/m, modulus $E = 2 \times 10^{11}$ Pa, and moment of inertia $I = 3.25 \times 10^{-4}$ m⁴.
- 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