High-School Maths

Establish a workflow, get to know our tools, review basic concepts

Yordan Darakchiev

Technical Trainer

Software University

SoftUni

Software University

https://softuni.bg

Have a Question?

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#MathForDevs

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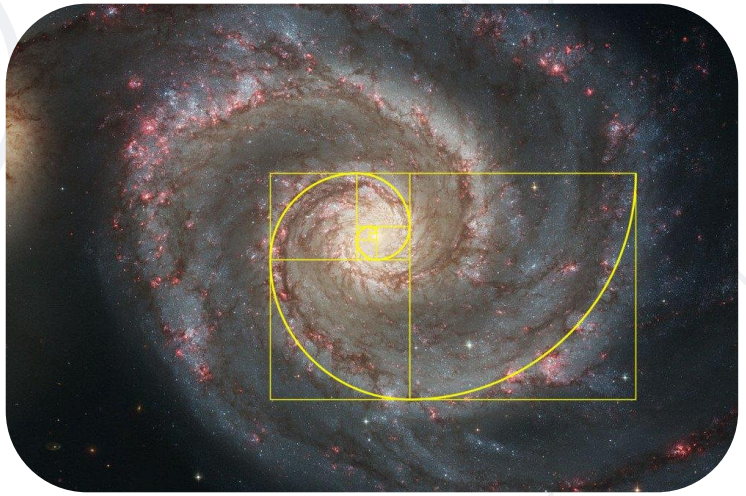
Mathematics in Nature

- **Honeycomb cells**
  - The **hexagonal cells** leave no unused space, and consume the least amount of wax and energy

- **Snowflakes**
  - All snowflakes are **unique** but they are **perfectly symmetrical**
  - This makes them strong enough to stay together

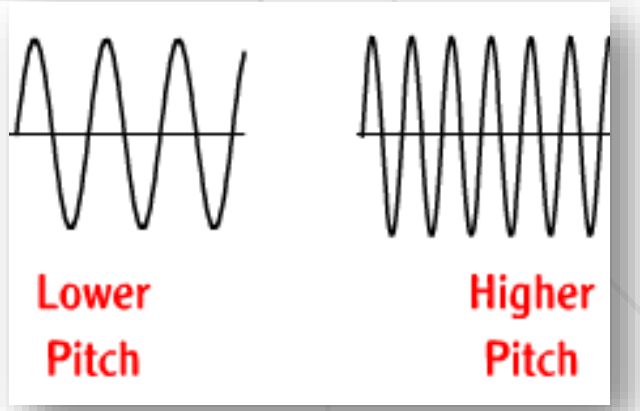
Mathematics in Nature

- **Romanesco broccoli**
  - Each little floret looks exactly like the **whole plant**
  - Seen from above, the florets form a **spiral**
- **Fibonacci spirals everywhere**
  - Flowers, pinecones
  - Animal shells
  - Hurricanes
  - Galaxies



Mathematics in Music

- Sound is a combination of waves travelling through the air
  - Each sound wave has a **frequency** (pitch)
  - Every note is associated with a **certain frequency**
    - **A4 produces 440 oscillations every second ($440\ Hz$)**
  - Some combinations of tones sound **pleasant**, others sound **harsh**
  - **Example**: "A major" chord
    - A4: $440\ Hz$, C#5: $554{,}37\ Hz$, E5: $659{,}25\ Hz$
    - $A4 : C\#5 : E5 \approx 4 : 5 : 6$
    - $A4 : E5 \approx 2 : 3$



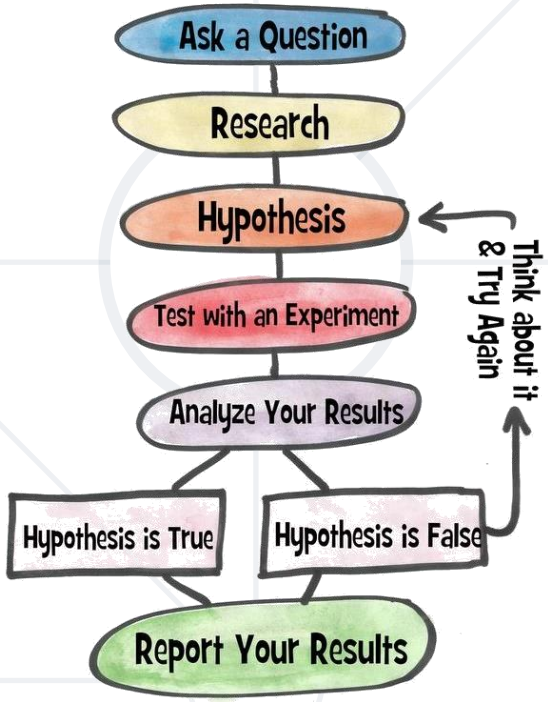
Methods

Divide and Conquer

- Useful for any **kind of problem**
- **Assumption**: **Complicated things are a combination of many, very simple things**
  - **Algorithms**: Merge sort, Discrete Fourier transform
  - **Software architecture**
    - "I want to build an ecommerce system"
      ⇒ I want shop owners to add new products
      ⇒ I want to store products in the DB ⇒ …
      ⇒ `def save_product(name, price)`
  - **Debugging**
    - The bug is somewhere in my code ⇒ the bug is ">=" instead of ">" on line 45 in `user.py`

The Scientific Method Steps

- **Ask a question**
- **Do some research**
- **Form a hypothesis**
- **Test the hypothesis with an experiment**
  - Experiment works ⇒ Analyze the data
  - Experiment doesn't work ⇒ Fix experiment
- **Results align with hypothesis** ⇒ OK
- **Results don't align with hypothesis** ⇒ new question, new hypothesis
- **Communicate the results**



Why Use the Scientific Method?

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- Useful when we're exploring something **new**
- Based on common logic
- Experiments
- **Examples**
  - **Research:** My logs show that this Web page on my server takes too much time to load
  - **Hypothesis:** This piece of code is too slow. I need to improve it
  - **Control:** Measure the runtime (in seconds)
  - **Experiment:** Try to fix the problem and repeat the runtime test
  - **Communication:** Show the results and implement the fix

Setting Up Our Environment

Getting ready to conquer math, science and programming

Anaconda

- You can install the **Python interpreter** and all libraries manually
  - Hard, boring and repetitive work
  - Error-prone
- Easy solution: platforms like **Anaconda**

  - Everything you need to get started with Python for science:
    Python interpreter, packages (720+), package manager, IDE
- Download from the Anaconda website
- Current version (March 2024): **Anaconda 2024.02-1 (Py3.11)**

Setting Up an IDE (Optional)

- You can use the built-in IDE called **Spyder**
- If you want to use another IDE, you need to configure it to work with Python
- **Visual Studio Code**
  - Preferred editor / IDE
  - Python in VSCode – tutorial
  - Python extension
- **Visual Studio**
  - Python Tools

Python Online

- There are places where you can execute your code online:
  - https://www.python.org/shell/
  - https://www.pythonanywhere.com/try-ipython/
- To share your code, you can use:
  - http://ideone.com
  - https://gist.github.com/
  - http://pastebin.com/

Jupyter Notebook

- A very **nice** and **clean** way to **document** your research
- Included in **Anaconda**
- Can create documents that contain **live code**, **equations**, **visualizations** and **explanatory text**
  - **HTML / CSS / JavaScript**
  - **Markdown**
  - **Latex**
  - **Python**
- Start
  - use the **Anaconda shortcut**
  - type into the **Command Prompt**

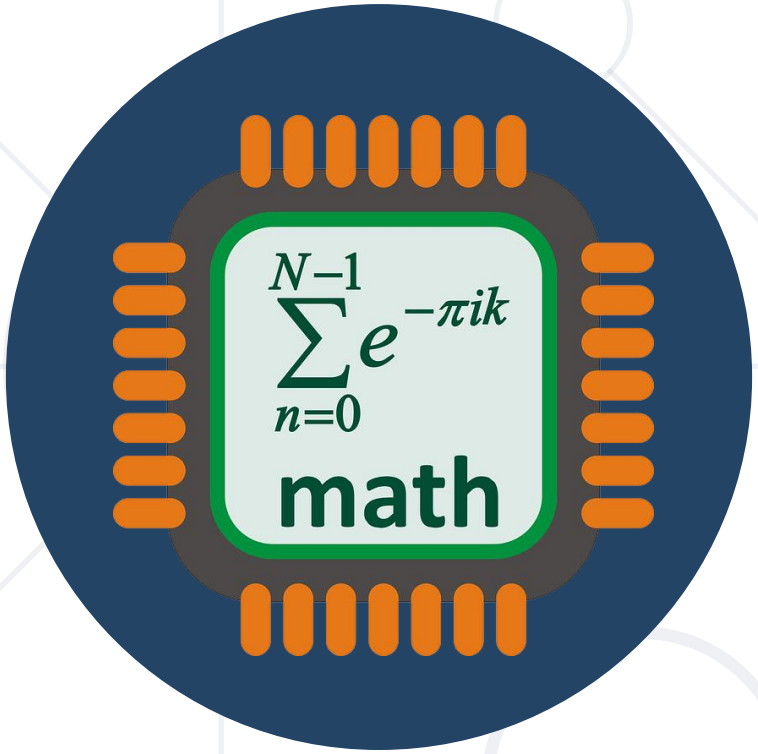
```
jupyter lab
```

How to Use Jupyter Lab?

- Create a **new notebook**
- Every piece of text or code is in a **cell**
  - Text cells just contain text or Markdown
  - Code cells contain code (obviously)
  - Code can be executed
  - Jupyter "remembers" the code
- Execute cell: **`Ctrl + Enter`**

```
In [2]: print("Hello world")

        Hello world
```

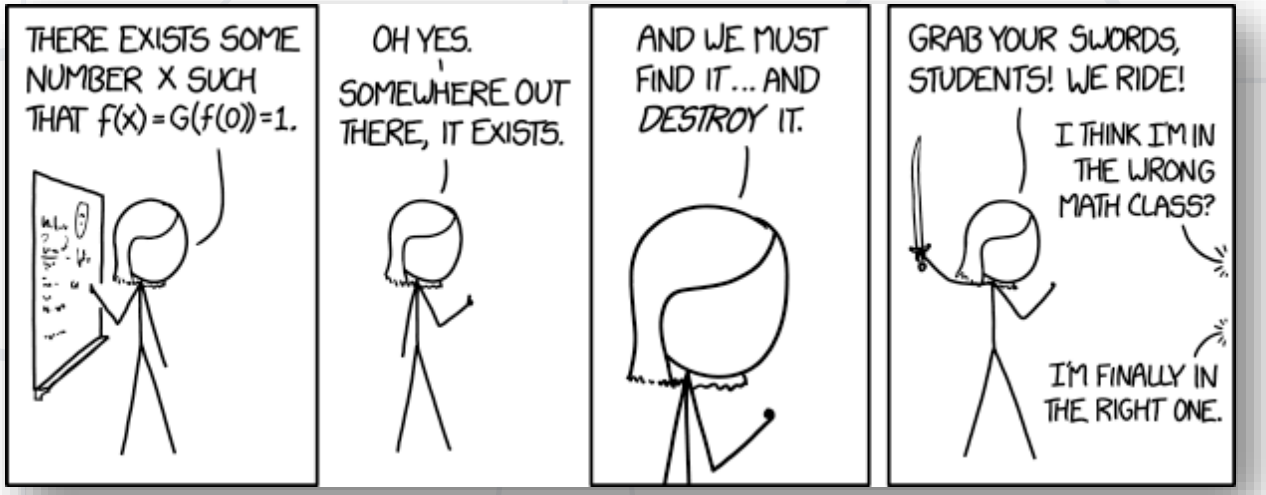


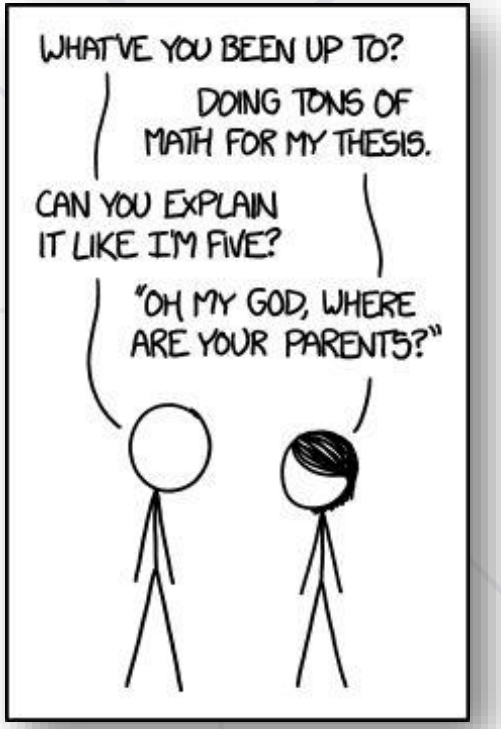
Math Notation

How to write more quickly and concisely

Math Notation

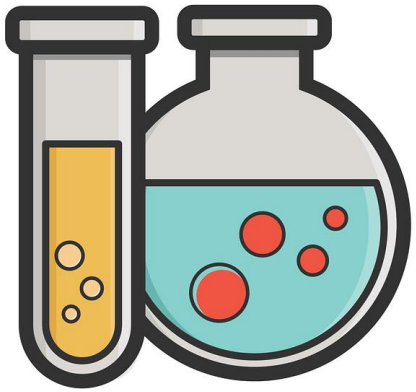
- The basic symbols we use are **numbers** and **letters**
  - Usually **English** or **Greek** letters
- **Special symbols:** $=,\ \geq,\ \in,\ \rightarrow,\ \nabla, \infty, \int$
- **Indices:** $\sum_{n=0}^{10},\ \lim_{x \to 0}$





Scientific Notation

- Used for **very large** or **very small** numbers
- Numbers are expressed as decimals with **exactly one** digit before the decimal point
- All other digits are expressed as a **power of 10**
- $\mathbf{15\,000 = 1,5.10^{4}}$
- $\mathbf{0,000015 = 1,5.10^{-5}}$



Summation Notation

- "Sigma" notation
- Used as a **shorthand** for writing long sums of numbers or symbols
  - Very similar to a **for-loop**
  - Greek capital "sigma" **denotes the sum**, the two numbers below and above it denote the start and end points

$$\sum_{i=1}^{5} i = 1 + 2 + 3 + 4 + 5$$

$$\sum_{k=1}^{n} x_k = x_1 + x_2 + \cdots + x_n$$

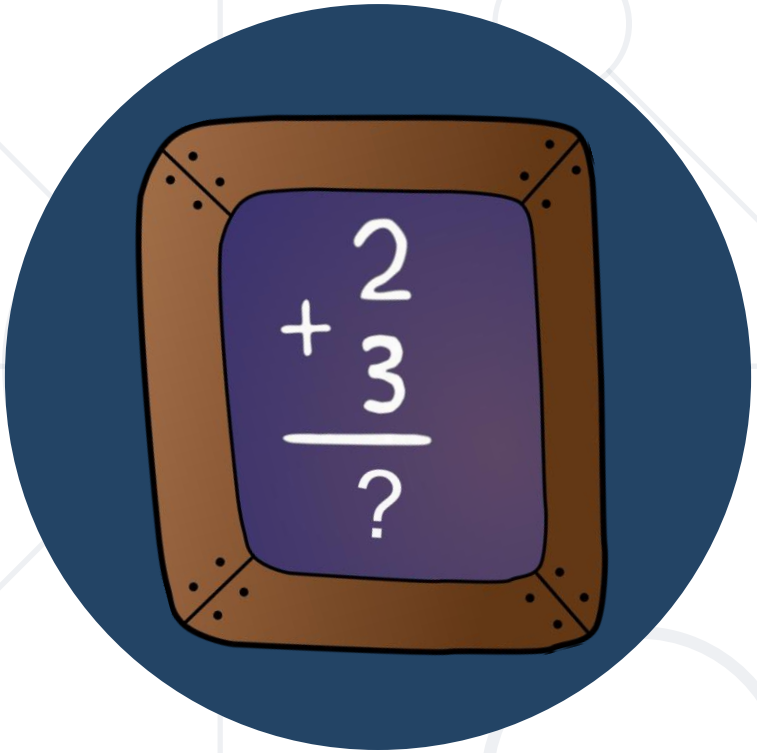
Equality Sign

- Important as it has different meanings
  - Like programming: "=", "==" and "==="
- **Identity**
  - The two statements around "=" are always equal: $x(x+3) = x^2 + 3x$
  - We can also use the "identity" symbol: $(a+b)^2 \equiv a^2 + 2ab + b^2$
- **Equation**
  - The two statements are true only for specific values of the symbols

$$2x + 5 = 4,\ x = -0.5 \qquad x^2 - 1 = 0,\ x = \pm 1 \qquad \frac{\mathrm{d}x}{\mathrm{d}t} = 5x - 3$$

- **Definition**

$$\sum i := \sum_{i=1}^{n} i := 1 + 2 + 3 + \cdots + n$$



Linear Equations

Simple, yet very useful

Review

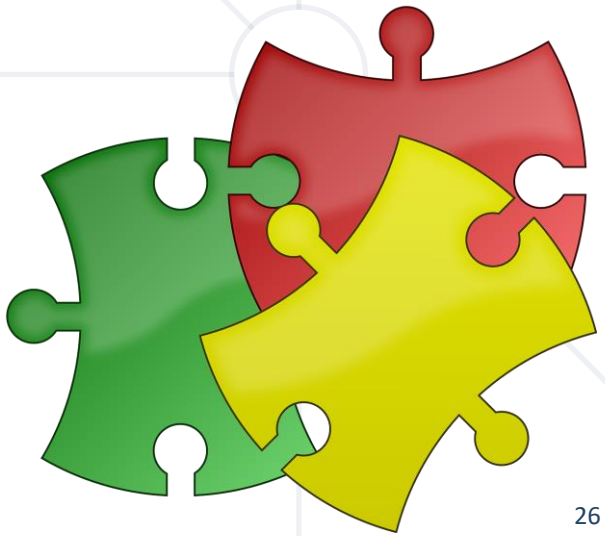
- Equations of a **variable** x
- x is "on its own"
  - Not inside a function
  - No powers
- General form: $ax + b = 0$
  - a and b: fixed numbers (**parameters**)

Examples

- $\boldsymbol{2x + 3 = 0}$
- $\boldsymbol{2(2x + 3) - 3x - 3(-4 + 3x) = 12}$
- Solutions of the **parametric equation**
  - $a = 0, b = 0 \Rightarrow 0.x = 0, \ \forall x$ (every x is a solution)
  - $a = 0, b \neq 0 \Rightarrow 0.x = -b$ (no solution)
  - $a \neq 0, \Rightarrow x = -b/a$ (one solution, regardless of b)

Exercise: Linear Equations

- Write a Python function which solves a linear equation given the definition from the previous slide
- The function should accept the **a** and **b** as arguments
- The function should return
  - The solution, if there is only one
  - Empty list **[ ]** if no solution
    or all x satisfy the equation

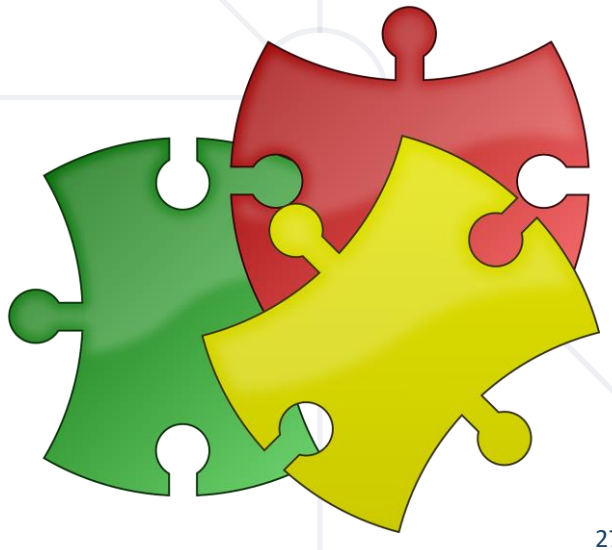


Exercise: Linear Equations

```
import math

def solve_linear_equation(a, b):
  if a == 0:
      return []
  else:
    return -b / a
```

```
solve_linear_equation(0, 0) # []
solve_linear_equation(0, 5) # []
solve_linear_equation(5, 0) # 0.0
solve_linear_equation(5, 5) # -1.0
solve_linear_equation(2.5, -5.3) # 2.12
```



Linear Systems of Equations

- Many **simultaneous equations**
  - To solve the system, we need to find values of the variable(s) which satisfy **all equations** at once
  - Even if all individual equations have solutions, the system **may have no solution**
- **Solution**
  - **Method 1**: Solve one equation and substitute
  - **Method 2**: Use sum of equations

Example

$$\left|\begin{array}{rcl} 4x+3y & = & 7 \\ 3x+5y & = & 8 \\ x-2y & = & -1 \end{array}\right.$$

$(\mathbf{3}) : x = -1 + 2y$

$(\mathbf{3}) \rightarrow (\mathbf{2}) : 3(-1+2y) + 5y = 8$

$-3 + 6y + 5y = 8$

$11y = 11$

$\boxed{y = 1}$

$(\mathbf{2}) \rightarrow (\mathbf{3}) : x = -1 + 2.1$

$\boxed{x = 1}$

$(\mathbf{1}) : 4.1 + 3.1 = 7$

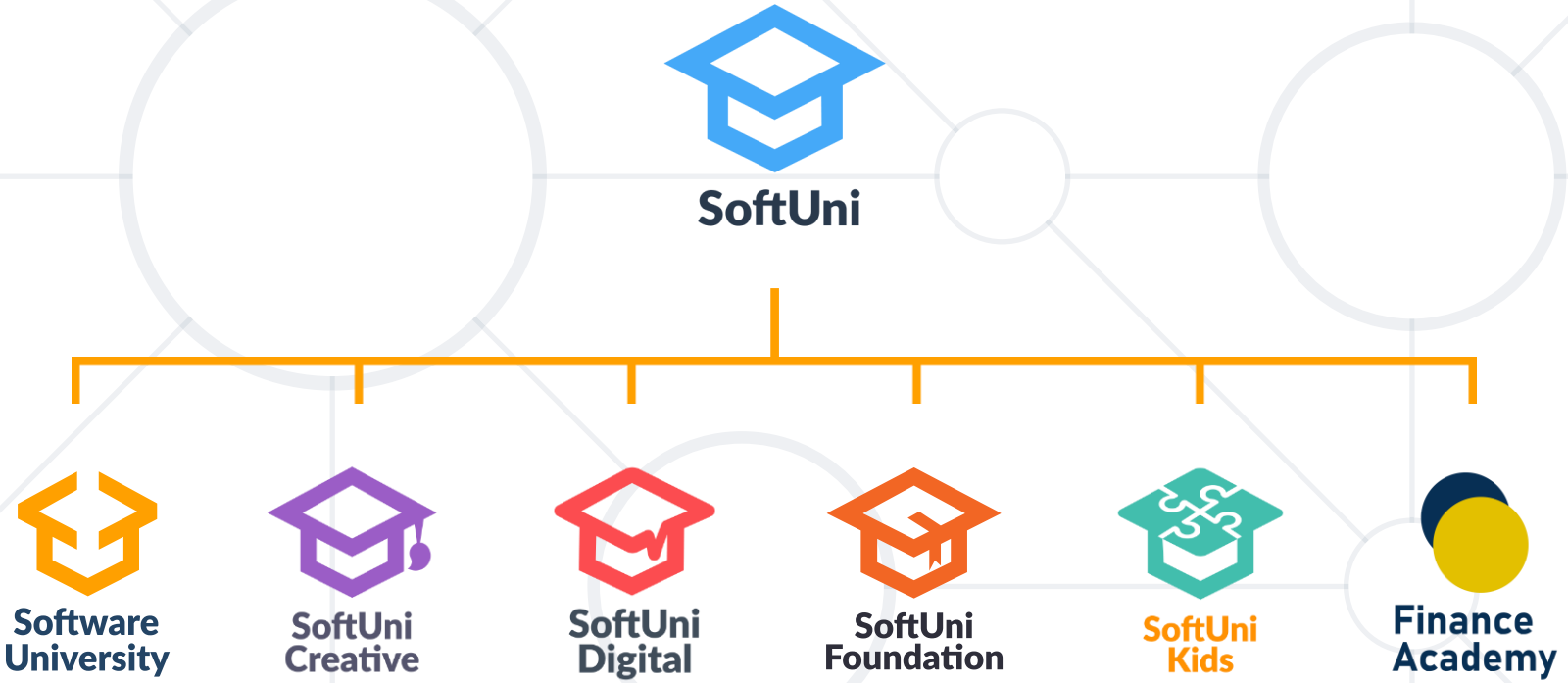
$\Rightarrow (x, y) = (1, 1)$ is the only solution of the system

Note: The numbers of equations and variables matter

Summary

- Maths in real life
  - "Pause and ponder"
- The scientific method as a "guiding light"
- Tooling
- Math notation
- Linear equations
  - Do we always have a solution?
- Systems of linear equations
  - Substitution method

Questions?



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