# Quick Python Intro

A *very* quick crash-course in the basics of Python, broadly covering

Libraries (NumPy and Matplotlib, specifically)

Variables

Whitespace

Array slicing and assigment

# Step 1: 1-D Linear Convection

$$\frac{\partial u}{\partial t} + c\frac{\partial u}{\partial x} = 0 \tag{1}$$

## Math

This section introduces the reader to the "parts" of the PDE and how to discretize them.

Introduce the idea of a grid

Expand equation using the definition of a derivative

Discretize into small chunks

Re-arrange to solve for $u_i^{n+1}$

Initial and boundary conditions

## Python

Importing libraries

Assigning variables

Basic 2D plotting

Simple for-loops

YouTube videos on order of convergence, truncation error, etc...

# Step 2: 1-D Nonlinear Convection

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} = 0 \tag{2}$$

## Math

Introduce non-linear PDE equation

Expand equation using definition of derivative

Discretize

Solve for $u_i^{n+1}$

# CFL Condition

A short side-trip into the CFL condition, order of convergence and blowing things up.

### Math

The Courant number

Explanation of blow-up behavior when wave travels a distance $> dx$ during a time $dt$

### Python

Quick introduction to defining a function to use code repeatedly

## Step 3: 1-D Diffusion

$$\frac{\partial u}{\partial t} = \nu \frac{\partial^2 u}{\partial x^2} \tag{3}$$

### Math

Introduce diffusion equation

Discretize 2nd order derivative using Taylor series expansion

Discretize time derivative using def. of derivative

### Python

Nothing new, still no functions being used (yet)

## Step 4: 1-D Burgers' Equation

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} = \nu \frac{\partial^2 u}{\partial x^2} \tag{4}$$

### Math

Introduce Burgers' Equation

Note that it is combination of diffusion and non-linear convection

Introduce different I.C. and B.C. for periodic behavior

e.g. What does $u_{i+1}^n$ *mean* at the end of the frame?

### Python

Introduce Sympy

Pretty printing

Symbolic solving of derivatives

Usage of Lambdify to make solutions 'accessible' to Numpy

Matplotlib

Plotting multiple lines per plot

Setting line styles

Legends

## Array Operations

Another brief interlude to introduce handling calculations with array operations instead of iterating over the entire array.

### Python

Array operations, slicing and copying

Note about using the `%%timeit` magic function to compare performance

## Step 5: 2D Linear Convection

### Math

Introduction to 2D grid

Extension of current discretization rules into $i, j$ flatland

Discretize 2D equation and solve for unknown

### Python

meshgrid

Axes3D

surf and wireframe plots

Demonstration that nested for-loop results and array operations results are the same

## Step 6: 2D Nonlinear Convection

### Math

Introduction of coupled PDEs

Discretization of two equations

Solving for both $u_{i,j}^{n+1}$ and $v_{i,j}^{n+1}$

## Step 7: 2D Diffusion

### Math

Introduction to 2D diffusion equation

Discretization of equation, etc...

### Python

Nothing new, although functions are used to display results (probably should switch this over to `jsanim`)

## Step 8: 2D Burgers'