Today, we will:

- Do a brief intro to Chapter 15: **Introduction to CFD**
- If time, do a live FlowLab demo - CFD

1. Intro

For an incomp. fluid flow problem,

$\vec{V} = (u, v, w) = 3$ unknowns

4 unknowns → P, $\vec{V}$

4 eq'n → continuity $\vec{\nabla} \cdot \vec{V} = 0$ (1)

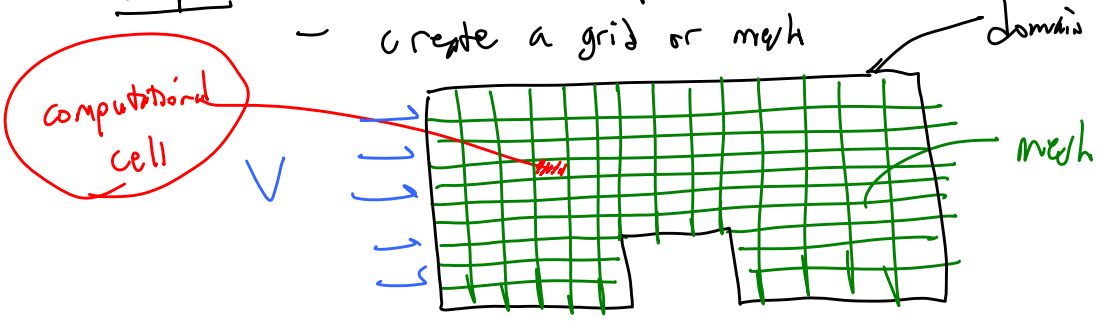
N-S (3) $\rho\left[\frac{\partial \vec{V}}{\partial t} + (\vec{V} \cdot \vec{\nabla})\vec{V}\right] = -\vec{\nabla}P + \rho\vec{g} + \mu\nabla^2\vec{V}$

How to solve?

- Solve analytically (w/ paper & pencil) → Ch. 9 (exact)
  Can do this only for very simple problems
- Solve approximately (eliminate some terms in N-S eq. to simplify)
  Ch. 10
- Solve numerically w/ing CFD Ch. 15

2. CFD Solution Procedure

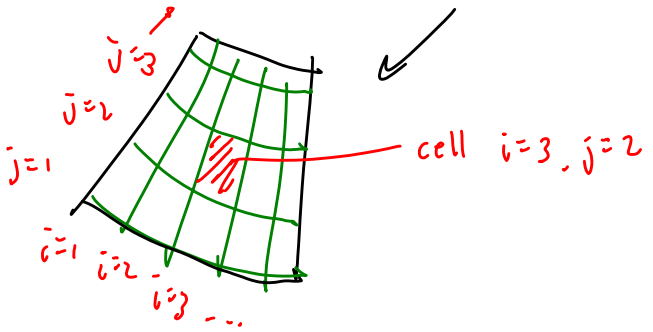
- Step 1 → Choose a computational domain
  - create a grid or mesh

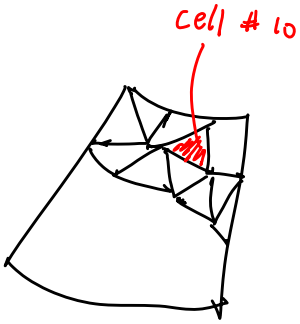


• Types of grids:

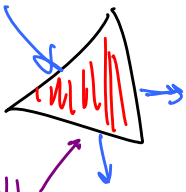
• Structured (like above) ↑

(can identify rows & columns)



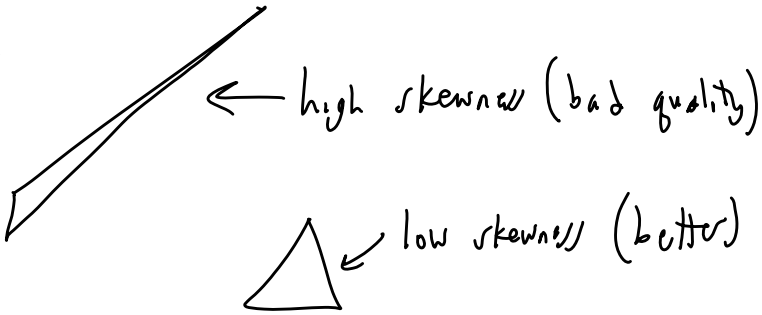


• Unstructured cannot define rows & columns

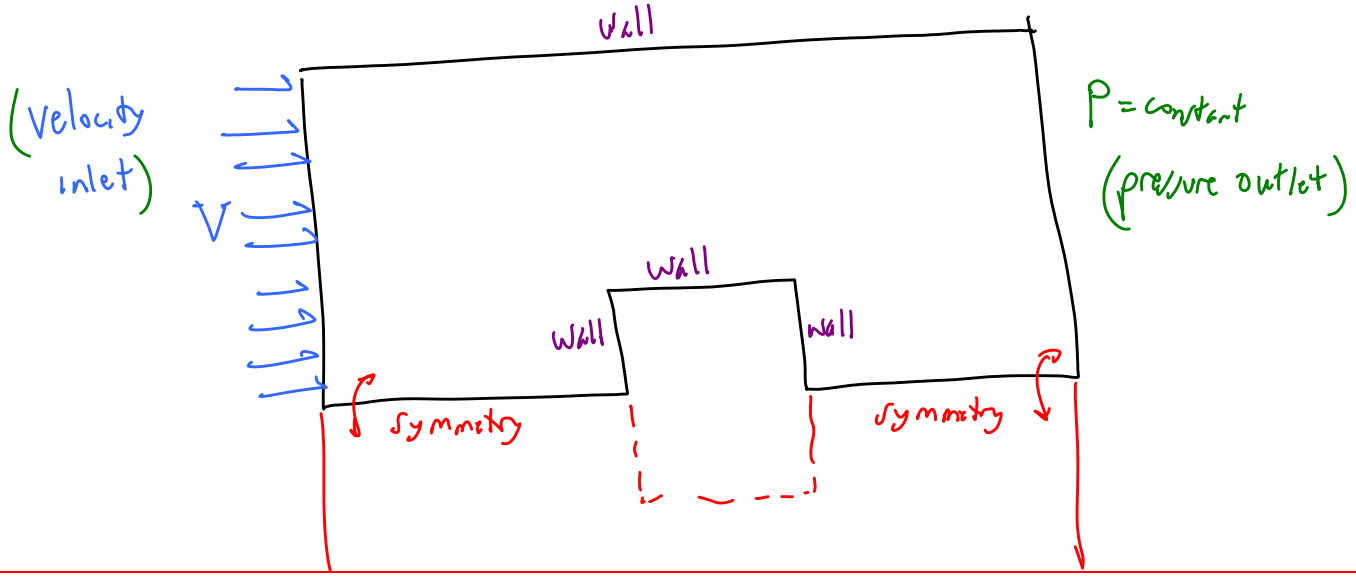


Solve eqn of motion (cont. & mom) on each cell

• Cell quality is important



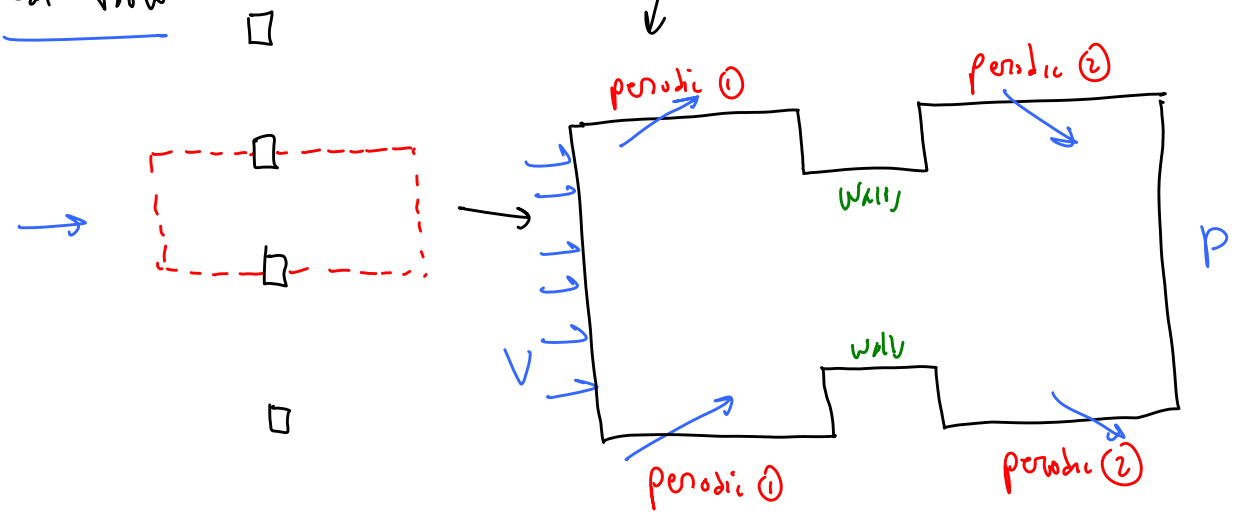
• Step 2 Specify Boundary Conditions (BCs) on each edge of the domain



Periodic BCs

real flow

CFD analysis



- Step 3 Specify type of fluid, fluid properties, etc.
- Step 4 Specify numerical options & solution options
- Step 5 Specify initial guesses for all variables u, v, w, P on each cell
- Step 6 Solve the equations

→ This is an iterative solution process

March along in steps until it converges

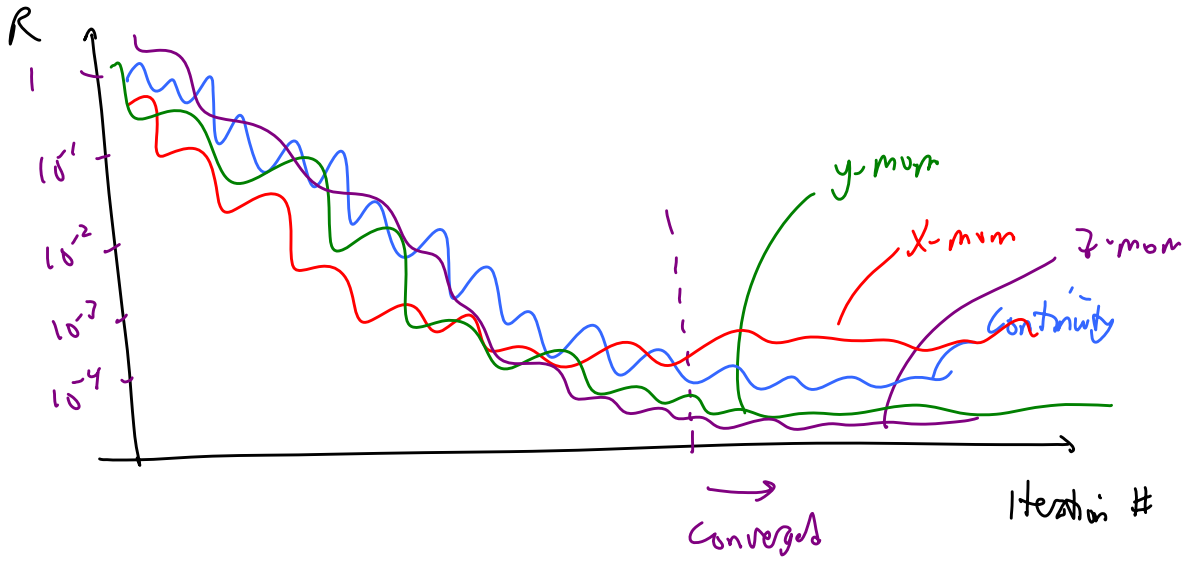
Residual = the error associated with an equation

e.g. Continuity $\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$ ← exact

Numerically discretized ⇒ $\frac{\Delta u}{\Delta x} + \frac{\Delta v}{\Delta y} + \frac{\Delta w}{\Delta z} = R$ ← residual = the error

if $R = 0$, the equation is solved exactly

As we iterate, R decays — eventually levels off at some low value (10^{-5})



Step 7 Post processing → Plot streamlines, velocity vectors, etc.

Step 8 Calculate global properties → Drag on a body
Torque on a pump blade, etc.

Examples
- DVD that comes with the textbook — lots of videos
- FlowLab — try some cases on your own
  I will have some homework
- Videos from my research program