

Dynamic Similarity

Lecture 1



ME EN 412
Andrew Ning
aning@byu.edu

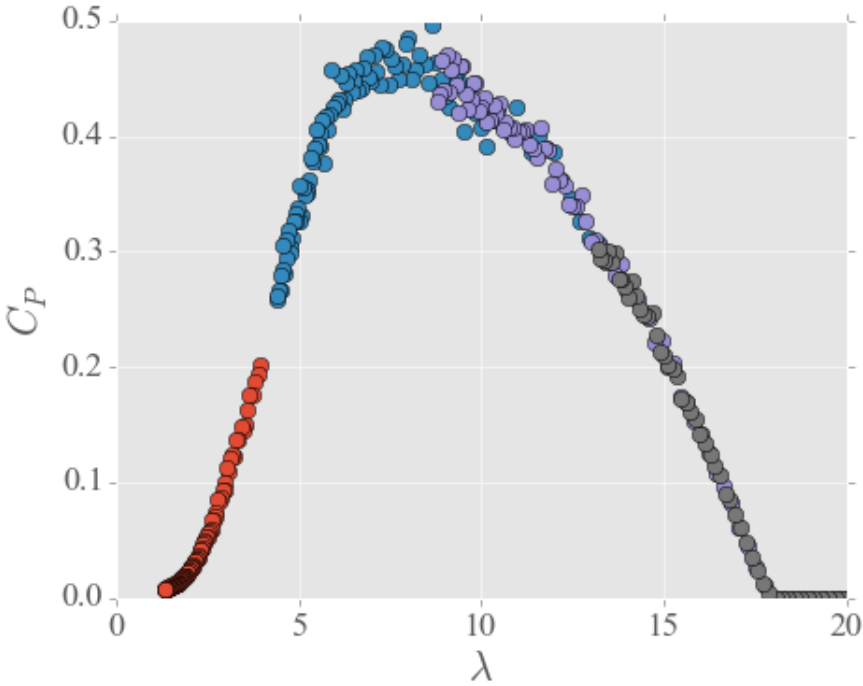
Outline

Motivating Example

Dynamic Similarity

Some Important Nondimensional
Quantities

Motivating Example



[View Jupyter notebook](#)

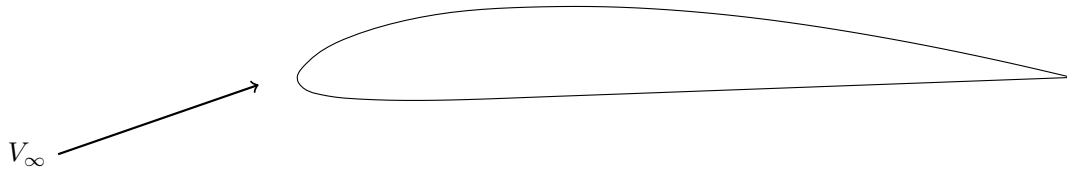
Three basic ways or methods of obtaining living water from the scriptural reservoir:

1. reading the scriptures from beginning to end
2. studying the scriptures by topic
3. searching the scriptures for connections, patterns, and themes

- Elder Bednar

Dynamic Similarity

What parameters might you expect the aerodynamic drag of this airfoil to depend on?



2D incompressible Navier-Stokes equation
(x-momentum)

$$u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} = -\frac{1}{\rho} \frac{\partial p}{\partial x} + \frac{\mu}{\rho} \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \right)$$

Try to nondimensionalize this equation.

$$u^* \frac{\partial u^*}{\partial x^*} + v^* \frac{\partial u^*}{\partial y^*} = -\frac{\partial p^*}{\partial x^*} + \frac{\mu}{\rho V_\infty c} \left(\frac{\partial^2 u^*}{\partial x^{*2}} + \frac{\partial^2 u^*}{\partial y^{*2}} \right)$$

where

$$x^* = \frac{x}{c}, \quad y^* = \frac{y}{c}$$

$$u^* = \frac{u}{V_\infty}, \quad v^* = \frac{v}{V_\infty}$$

$$p^* = \frac{p - p_\infty}{\rho V_\infty^2}$$

$$Re \equiv \frac{\rho V c}{\mu}$$

The solution, in terms of these nondimensional positions and velocities, will be the same if:

- The nondimensional geometry and boundary conditions are the same
- The Reynolds number is the same

$$C_p = f\left(Re, \frac{\text{geometry}}{c}\right)$$

Some Important Nondimensional Quantities

Reynolds number

$$Re = \frac{\rho V l}{\mu}$$

Mach number

$$Ma = \frac{V}{a}$$

Froude number

$$Fr = \frac{V}{\sqrt{gl}}$$

Strouhal number

$$St = \frac{\omega l}{V}$$

Others...