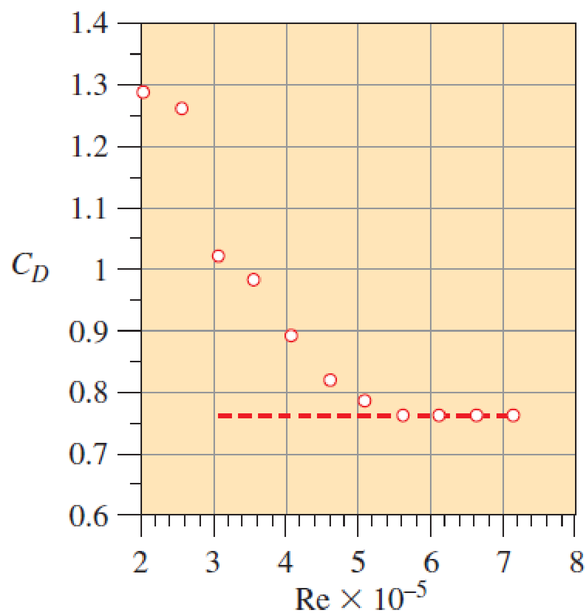
Today, we will:

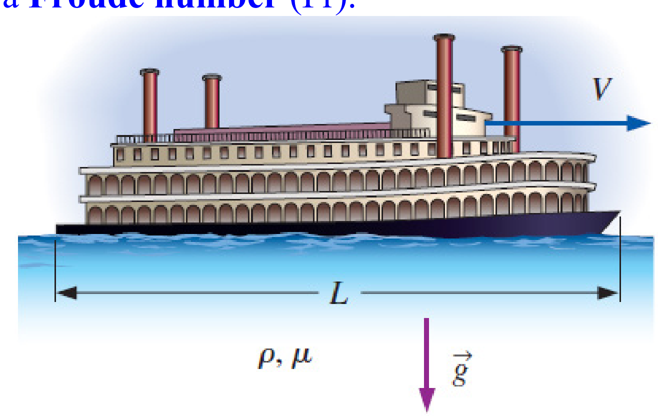
- Finish Chapter 7 – Dimensional Analysis (incomplete similarity)
- Begin Chapter 8 – Internal Flow (flow in pipes)

Incomplete Similarity: Sometimes, we cannot exactly match all the dimensionless parameters. For example, we might not be able to run a wind tunnel at high enough speed to match the Reynolds number. Even if we *could* run the wind tunnel fast enough, we would run into compressibility effects. Fortunately, drag coefficient often becomes *independent* of Reynolds number, beyond a certain threshold.

Example (see textbook, Example 7-10):
Model truck wind tunnel experiments.



Another example of incomplete similarity is flows with ***free surfaces*** (e.g., rivers, boats, etc.). It turns out that dimensional analysis usually yields both a **Reynolds number** (Re) and a **Froude number** (Fr).



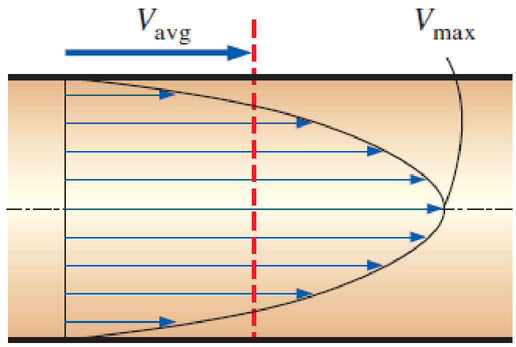
$$\mathrm{Re} = \frac{\rho V L}{\mu} = \frac{VL}{\nu}$$

$$\mathrm{Fr} = \frac{V}{\sqrt{gL}}$$

VI. Internal Flow in Pipes (Chapter 8)

A. Introduction

1. Average velocity in a pipe



2. Laminar versus turbulent flow – a comparison

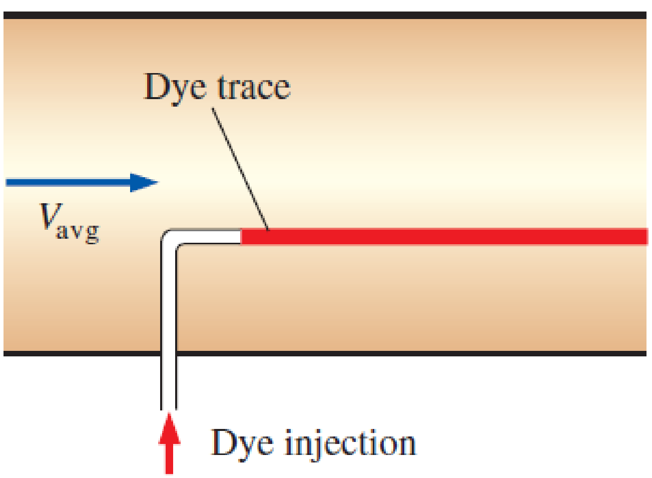
Laminar Flow

Can be steady or unsteady.

(Steady means that the flow field at any instant in time is the same as at any other instant in time.)

Can be one-, two-, or three-dimensional.

Has regular, *predictable* behavior



Analytical solutions are possible (see Chapter 9).

Occurs at *low* Reynolds numbers.

Turbulent Flow

Is always *unsteady*.

Why? There are always random, swirling motions (vortices or eddies) in a turbulent flow.

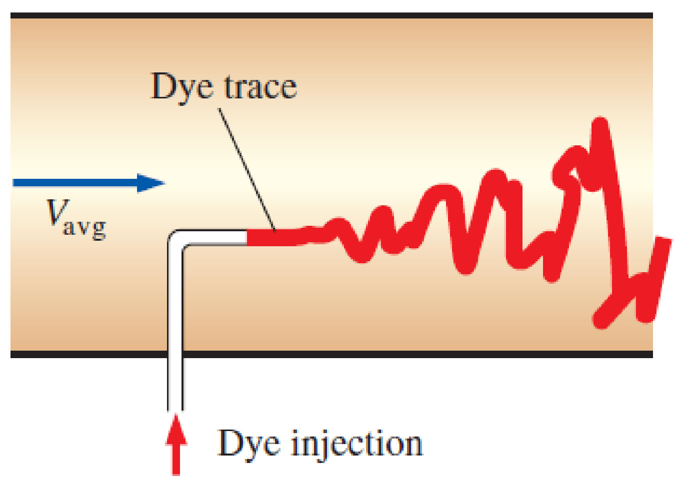
Note: However, a turbulent flow can be steady *in the mean*. We call this a *stationary turbulent flow*.

Is always *three-dimensional*.

Why? Again because of the random swirling eddies, which are in all directions.

Note: However, a turbulent flow can be 1-D or 2-D *in the mean*.

Has irregular or *chaotic* behavior (cannot predict exactly – there is some randomness associated with any turbulent flow.



No analytical solutions exist! (It is too complicated, again because of the 3-D, unsteady, chaotic swirling eddies.)

Occurs at *high* Reynolds numbers.

d. The entrance region