Today, we will:

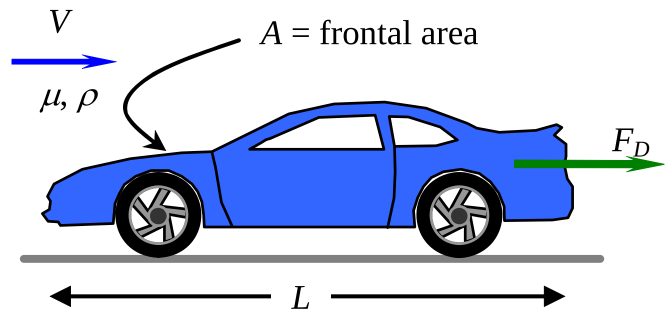
- Finish the example problem from last lecture.
- Do some more example problems – dimensional analysis
- Discuss experimental testing and incomplete similarity

Example: Dimensional analysis – Car drag

Given: The drag force F_D on a car is a function of four variables: air velocity V, air density ρ, air viscosity μ, and the length L of the car.

To do: Express this relationship in terms of nondimensional parameters.

Solution: We follow the six steps for the method of repeating variables.



See previous lecture. We were in the middle of step 5, and had

$$\Pi_1 = \text{ dependent Pi} = F_D V^a L^b \rho^c \ = F_D V^{-2} L^{-2} \rho^{-1} = \frac{F_D}{\rho V^2 L^2}$$

Guidelines for Manipulating the Π Parameters

There are several guidelines for manipulating the Π parameters. These guidelines are listed concisely in Table 7-4 in the text, as summarized below: See Table 7-4 for more details.

1. We may impose a constant (dimensionless) exponent on a Π or perform a functional operation on a Π.
2. We may multiply a Π by a pure (dimensionless) constant.
3. We may form a product (or quotient) of any Π with any other Π in the problem to replace one of the Π's.
4. We may use any of guidelines 1 to 3 in combination.
5. We may substitute a dimensional parameter in the Π with other parameter(s) of the same dimensions.

The goal is to get each Π into a form that looks like one of the common *established* nondimensional parameters that are listed in Table 7-5 in the text. Some of the most popular and often-used ones are listed below. A more exhaustive list is given in the text.

TABLE 7–5

Some common established nondimensional parameters or Π's encountered in fluid mechanics and heat transfer*

Name	Definition	Ratio of Significance
Darcy friction factor	$f = \frac{8\tau_w}{\rho V^2}$	$\frac{\text{Wall friction force}}{\text{Inertial force}}$
Drag coefficient	$C_D = \frac{F_D}{\frac{1}{2}\rho V^2 A}$	$\frac{\text{Drag force}}{\text{Dynamic force}}$
Froude number	$\text{Fr} = \frac{V}{\sqrt{gL}} \left(\text{sometimes } \frac{V^2}{gL}\right)$	$\frac{\text{Inertial force}}{\text{Gravitational force}}$
Lift coefficient	$C_L = \frac{F_L}{\frac{1}{2}\rho V^2 A}$	$\frac{\text{Lift force}}{\text{Dynamic force}}$
Mach number	$\text{Ma (sometimes } M) = \frac{V}{c}$	$\frac{\text{Flow speed}}{\text{Speed of sound}}$
Reynolds number	$\text{Re} = \frac{\rho V L}{\mu} = \frac{VL}{\nu}$	$\frac{\text{Inertial force}}{\text{Viscous force}}$
Strouhal number	$\text{St (sometimes S or Sr)} = \frac{fL}{V}$	$\frac{\text{Characteristic flow time}}{\text{Period of oscillation}}$

Reynolds number is the most important nondimensional parameter in fluid mechanics.

Example: Dimensional analysis – shaft power

Given: The output power $\dot{W}$ of a spinning shaft is a function of torque T and angular velocity ω.

To do: Express the relationship between $\dot{W}$, T, and ω in dimensionless form.

Solution:

Step 1:

Step 2:

Step 3:

Step 4:

Step 5: