DRAG FORCE CALCULATION

"Drag is the component of force on a body acting parallel to the direction of relative motion." [1] This can occur between two differing fluids or between a fluid and a solid. In this lab, the drag force will be explored between a fluid, air, and a solid shape.

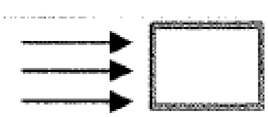
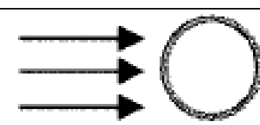
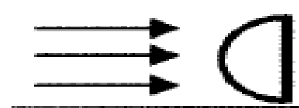
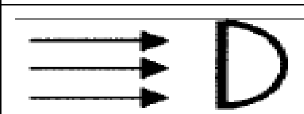
Drag force is a function of shape geometry, velocity of the moving fluid over a stationary shape, and the fluid properties density and viscosity. It can be calculated using the following equation,

$$\boldsymbol{F_D = \frac{1}{2}\rho A C_D V^2}$$

Equation 1: Drag force equation using total profile

where
ρ is density determined from Table A.9 or A.10 in your textbook
A is the frontal area of the submerged object
C_D is the drag coefficient determined from Table 1
V is the free-stream velocity measured during the lab

Table 1: Known drag coefficients for various shapes

Body	Status	Shape	C_D
Square Rod	Sharp Corner		2.2
Circular Rod			0.3
Semicircular Rod	Concave Face		1.2
	Flat Face		1.7

The drag force of an object can also be calculated by applying the conservation of momentum equation for your stationary object.

$$\vec{F} = \frac{\partial}{\partial t}\int_{CV} \vec{V}\,\rho d\forall + \int_{CS} \vec{V}\rho\vec{V}\cdot d\vec{A}$$

Assuming steady flow, the equation reduces to

$$\vec{F} = \int_{CS} \vec{V}\rho\vec{V} \cdot d\vec{A}$$

The following frontal view of the duct is shown below. Integrating the velocity profile after the shape will allow calculation of drag force per unit span.

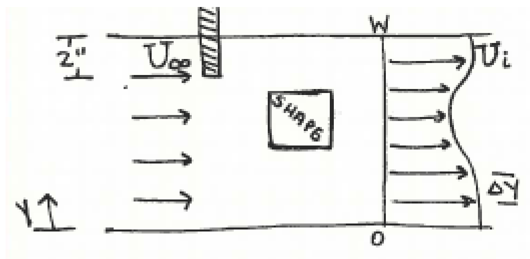


Figure 1: Velocity profile after an inserted shape.

Combining the previous equation with Figure 1, the following equation is obtained:

$$D_f = \int_{0}^{W} \rho U_i(U_\infty - U_i)Ldy$$

Simplifying the equation, you get:

$$D_f = \rho L \sum_{i=1}^{20} U_i(U_\infty - U_i)\Delta y$$

Equation 2: Drag force equation using wake profile

The pressure measurements can be converted into velocity using the Bernoulli's equation as follows:

$$U_i = \sqrt{\frac{2\Delta P_i}{\rho_{Air}}}$$

Be sure to remember that the manometers used are in W.C. which will require a substitution of $\rho_{H2O}gh$ for ΔP. Refer to page 1 of the lab procedures for Inside Wind Tunnel II for more information.

Experimental Setup:

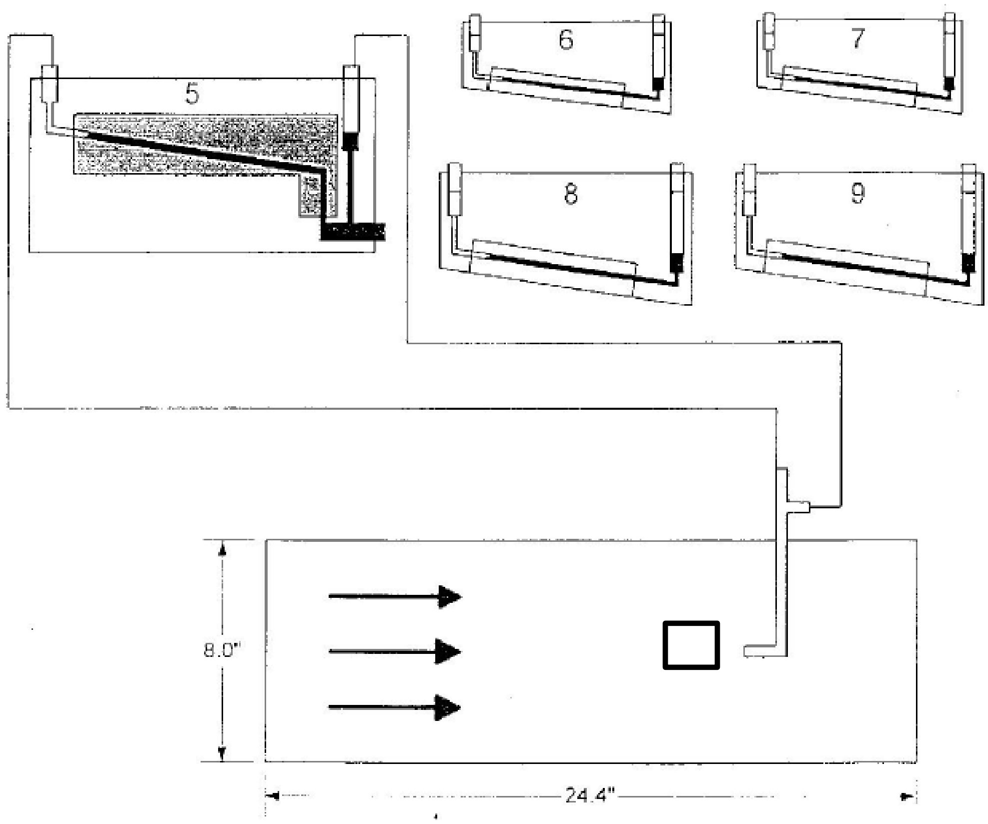


Figure 2: Experimental Setup for Drag Calculation Lab

Procedure:

1. Turn off the fan & power if necessary.
2. Install the square rod into the straight duct with a slat as shown and set up in wind tunnel.
3. Zero manometer 5.
4. Connect the hoses to the appropriate manometer shown.
5. Insert the probe approximately 4" behind the object and set it on the bottom surface of the duct.
6. Set the fan to a setting of 80 and move the probe up in 1 cm steps taking readings at each of these points until the top of the duct is reached. <u>When taking the readings, it is important to not shake or bump the table as well as to not walk near the inlet or exit of the wind tunnel.</u>

7. Use the attached anemometer in the upper left-hand corner of the wind tunnel to measure the free-stream velocity 2” from the top of the duct at the beginning of the slat.
8. Repeat steps 2-7 for each rod shape and orientation designated in Table 2.

Table 2: Pressure, velocity, and area data for different shaped rods

	Square Rod	Circular Rod	Semicircular Rod: Concave	Semicircular Rod: Flat Face
Position (cm)	ΔP (in_{H2O})	ΔP (in_{H2O})	ΔP (in_{H2O})	ΔP (in_{H2O})
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
Velocity (ft/s)				
Frontal Area (ft^2)				

LAB NOTEBOOK:

- Using Equation 1, calculate the drag force for each rod shape.
- Using Equation 2, calculate the drag force for each rod shape.
- Compare the calculated drag force for each rod shape using both equations.
- Graph the velocity profile for each rod shape.