Lab 12: External Flow

SAFETY SECTION: We will be dropping things down stairwells and propelling small plastic tubes around the room. Try to direct your falling/flying objects away from other people. Long pants, closed toed shoes and safety glasses must be worn at all times, whether inside or outside the lab.

Begin your lab by holding a team planning session (3 minutes):

1. Review the safety information above.
2. One person should serve as leader/coordinator. All team members should strive to make the team function better through various roles: observer, recorder, devil's advocate, etc. Ask for each other's input and opinions, help each other, and try to come to consensus after an appropriate amount of brainstorming and analysis.
3. Make a plan for how you will complete the lab activities. Each person should fill out their own lab report as activities are completed. At the end of the hour, after cleaning up, get the TA to initial the end of your report. **This is one of the longer labs**: additional time will be needed before and after the lab time to complete the calculations.

Background: External flow refers to fluid moving around the outside of an object. This flow can lead to a drag force (force in opposition to the movement) or a lift force (orthogonal to the movement). In this lab you will investigate both phenomena in terms of coefficients of drag and lift (C_D and C_L). Lift imparted to a spinning object works by a principle known as the Magnus Effect.

Project: To investigate drag, you will drop coffee filters down a stairwell and determine the drag coefficient. To investigate lift you will propel spinning tubes off of a tabletop and determine the lift coefficient. The tubes are harvested from the barrels of Bic pens.

You may use a meter stick available in the lab to measure distances and a mass balance to weigh objects. You can use your phone to measure times. In addition, making a video of a falling or flying object, and counting video frames with an appropriate frame-by-frame or slow-motion viewing app, can also give more accurate time vs. position measurements (most videos are 30 frames/sec).

1. **Pre-Lab Preparation:** Answer the following questions to prepare for the data collection and analysis. The internet is your friend.
    a. What is meant by "terminal velocity" of a falling object?

    b. What is the formula for gravitational force on an object?

c. What is the formula for drag force on an object, in terms of fluid velocity (relative to the object), C_D, area, density? Describe what area is intended in the formula.

d. What is the density of air in the EB? Temperature in BYU buildings is normally around $22°C$. The atmospheric pressure of Provo is around 0.84 atm.

e. Look up “Magnus Effect” online. What is it? Draw a picture of the flow paths around the spinning object. Give at least one example of the effect’s use in a real-world situation.

f. What is the formula for lift force on an object, in terms of fluid velocity (relative to the object), C_L, area, etc.? Describe what area is intended in the formula.

g. What would be a maximum expected value of C_D for a blunt (not streamlined) 3D object? What would be a maximum expected value of C_L for an airplane wing?

2. Drag Force data collection and analysis
    a. Drop a coffee filter (flat side down) down a stairwell and determine its terminal velocity. Repeat the experiment a few times to make sure you have a repeatable result. Put your results below.

    b. Repeat part **a** with two and three coffee filters nested together to increase the weight of the object without changing the aerodynamic profile. Put your results below.

    c. Based on the data in parts **a** and **b**, compute the coefficient of drag for the coffee filter shape. What is the trend of C_D with the different velocities? Explain.

d. Would a single coffee filter fall faster or slower if the air were at a lower temperature than the temperature of your experiment? Explain.

3. Lift Force data collection and analysis
   a. All team members should practice propelling the tubes off of tabletops in the manner showed by the instructor/TA. After a couple minutes practice, nominate a “champion” to represent your team for official data collection.
      Technique: Push down with the tips of all 8 fingers on top of the tube, with thumbs under the edge of the table. Let the tube pop out from underneath the fingers, being propelled forward off the table and having a strong backspin. If done right, the tube will produce enough lift to glide. If your fingers are slightly damp, you will get better grip.

   b. In the best case, how far can the team champion get the tube to go before it touches the ground?

   c. For a case when the tube glides nearly horizontally, compute the effective value of C_L. You will need a value of tube horizontal velocity; do you best to estimate or measure this.

4. **Brainstorm**: Do you have any ideas for future changes to this experiment or ways to clarify the instructions?

Grading Rubric (to be completed by TAs)

	Points	Max
Completed Activities and write-up		7
Measurements and calculations accurate		7
Safety and cleanup **TA initial:______**		1
Total		15