**Determining the Effect of Flow Separation on Aerodynamic Forces for Bluff and Aerodynamic Bodies**

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**Abstract**

**Introduction and Methods**

1. Objectives
   1. Experimentally determine the effect of flow separation on aerodynamic forces for bluff and aerodynamic bodies
   2. Explain trends by comparing with published theoretical, empirical and computational results
   3. Use this experience and knowledge to test a model of the team’s own design
   4. Perform an analysis of a proposed design change
2. Why this is important
   1. Wind tunnels are used for testing models of proposed aircraft and engine components. They are an integral part of the prototyping process.
   2. Wind tunnels are also used for flow visualization, which can be useful to see how the flow changes over and behind a specific shape like an airplane wing.
   3. Many different fields use wind tunnels to test their products before they become operational. For example, race cars and airplanes both focus on aerodynamic efficiency and therefore need to be tested in a wind tunnel.
3. The experiment procedure w/ figure
   1. Test the following at 0 angle of attack:
      1. 1.5” diam sphere, 4” diam sphere with and without turbulent trip, dimpled golf ball
   2. Measure axial force in increments of 5mph from 0-40
   3. Plot Cd vs Re and compare to published values
   4. Test Clark-Y airfoil at free-stream velocity (40 m/s) varying angle of attack in 2 deg increments from -6 to 20 degrees.
4. Theory and equations

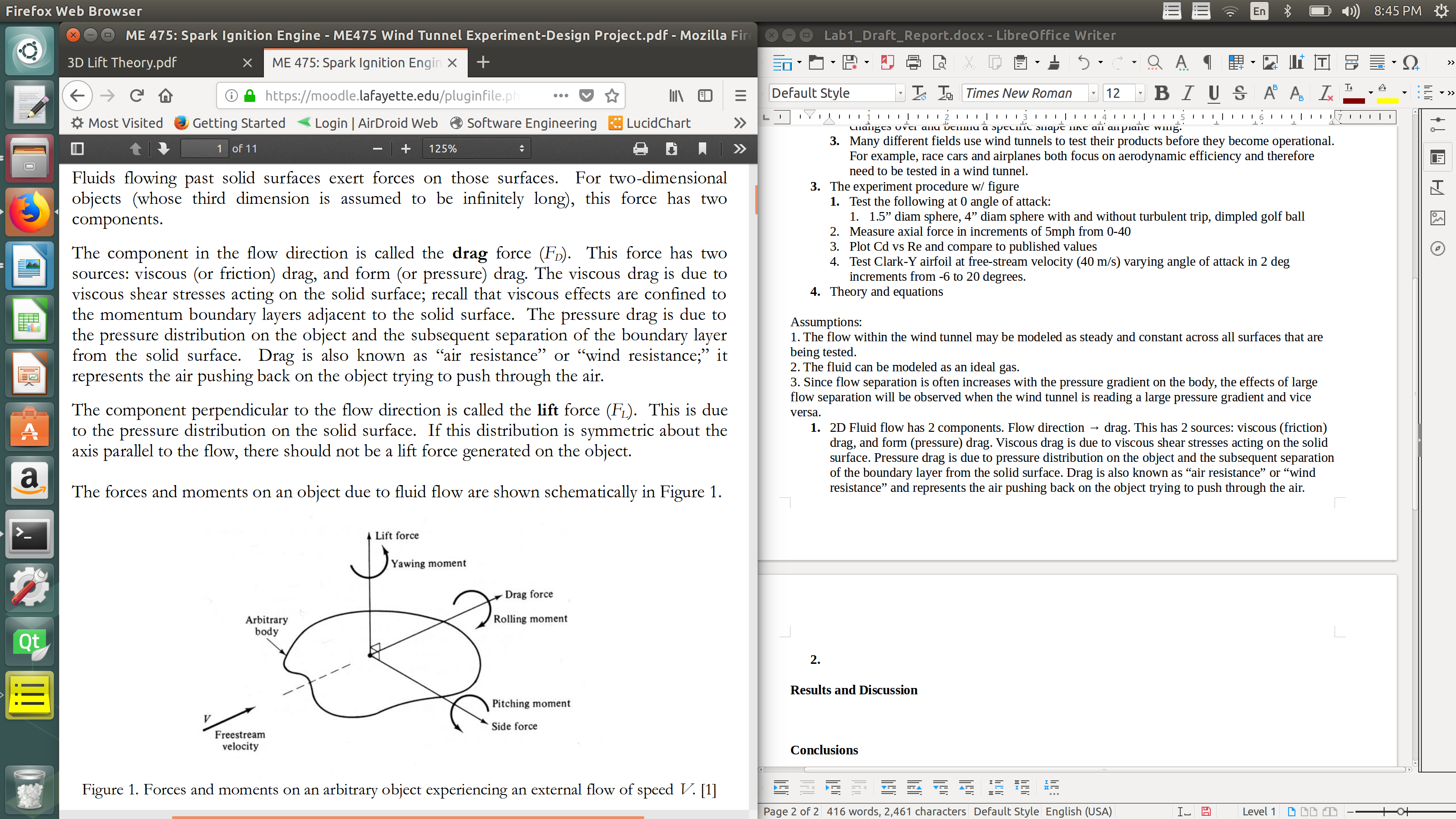
Assumptions:

1. The flow within the wind tunnel may be modeled as steady and constant across all surfaces that are being tested.

2. The fluid can be modeled as an ideal gas.

3. Since flow separation is often increases with the pressure gradient on the body, the effects of large flow separation will be observed when the wind tunnel is reading a large pressure gradient and vice versa.

1. 2D Fluid flow has 2 components. Flow direction → drag. This has 2 sources: viscous (friction) drag, and form (pressure) drag. Viscous drag is due to viscous shear stresses acting on the solid surface. Pressure drag is due to pressure distribution on the object and the subsequent separation of the boundary layer from the solid surface. Drag is also known as “air resistance” or “wind resistance” and represents the air pushing back on the object trying to push through the air.

Figure 1. Forces and moments on an arbitrary object experiencing an external flow of speed V. (Include reference here!)

1. Consider lift and drag can be represented by their non-dimensional coefficients in which the magnitude of the lift/drag force is non-dimensionalized by a measure of fluid kinetic energy.

The following equations are needed in order to determine the lift and drag effects on the bodies that are being tested.

Where Fl,d is the lift or drag force, rho is the fluid density, V is the average free stream flow speed, and A is either the projected frontal area or the plan-form area.

3. Airfoil Theory: Mathematical explanation for lift on airfoils is that the airfoil shape creates a circulation in the airflow as seen by a still observer, much like that around a baseball thrown with backspin. Both the baseball and the airfoil then experience an upward lift force. Drag is a force that resists the object’s motion. Therefore an airplane with lower drag will be able to fly at faster speeds than a higher-drag airplane with the same amount of power. In addition, lower-drag aircraft will require less power to fly at the same speed.

4. 3D Lift and Pitching Moment Theory:

– For airplane wings, pressure distribution at the wing tips result in trailing vortices with induced downwash.

– The vortices expand and travel downwards

**For Rectangular wing planforms:**

**–**

**Results and Discussion**

**Conclusions**

**References**

1. Lab handout

2. 3D lift theory document