AP Physics Lab #16: Exploring Air Resistance (Big Idea 3)

3.A.3.1: The student can analyze a scenario and make claims (develop arguments, justify assertions) about the forces exerted on an object by other objects for different types of forces or components of forces.

3.A.3.3: The student can describe a force as an interaction between two objects and identify both objects for any force.

Ask Question: How can you design an experiment to collect data on the terminal velocity as a function of mass for falling objects and use those data to choose between two models for the drag force (i.e., air resistance)?

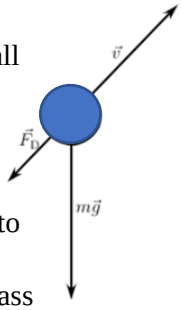
Background: Most of the time we are neglecting air resistance, or drag force, and assuming the acceleration of a projectile is uniform. However, the acceleration is dependent on numerous factors, most noticeably, the object's speed. As objects move faster, they encounter more air resistance, which is always in the opposite direction of the object's velocity. For an object falling vertically, when the amount of upward air resistance is equal to the downward gravity force, the object encounters a balance of forces and is said to have reached a terminal velocity (v_T). Experiments have been done with a variety of objects falling in air. These experiments sometimes show that the drag force is proportional to the velocity and sometimes that the drag force is proportional to the square of the velocity. Mathematically, the drag force can be described using $F_{drag} = -bv$ or $F_{drag} = -cv^2$. The constants b and c are called the drag coefficients that depend on the size and shape of the object. At terminal velocity, the downward force of gravity is equal to the upward force of the air, so $mg = -bv$ or $mg = -cv^2$, depending on whether the drag force follows the first or second relationship. In either case, since g and b or c are constants, the terminal velocity is affected by the mass of the object. Taking out the constants, this means that either the terminal velocity is proportional to the mass, or the terminal velocity squared is proportional to the mass. In this investigation you will have access to coffee filters and any other equipment in our lab. You will need to collect evidence to formulate your claim and to address the overarching question.

P1. Sum the forces for an object that has reached terminal velocity.

P2. For an object falling in the presence of air resistance, sketch a graph for the a(t), v(t), and y(t). For each sketch, label the point where the object has reached terminal velocity (v_T).

P3. Lorenzo tosses a 1.0-kg bocce ball straight up into the air, where it is subjected to an air resistance equivalent to 20 percent of its weight. If the ball reaches the apex of its flight after 2.7 seconds, with what speed does Lorenzo toss the bocce ball into the air? Sum the forces and draw a FBD for this scenario.

P4. Exam the diagram to the right of a bocce ball in the presence of air resistance (F_D). Draw a FBD for the ball resolved into components. At time (t_p), the ball has the velocity indicated on the diagram. Is the acceleration of the ball greater than, less than, or equal to g? Justify your answer. Sketch a diagram showing the magnitude and direction of the acceleration at t_p for the bocce ball.



Research and Evidence: Create a data table to collect your evidence for the lab. At minimum, you will need to manipulate the mass (i.e., number of filters) and collect motion data that will allow you to explore how the velocity changes as a function of time and mass graphically. You will need data that is replicable with each mass trial. Remember you are designing an experiment to collect evidence on the terminal velocity as a function of mass for falling objects and use those data to develop a claim about the two mathematical models for the drag force.

Make a Claim: Write a claim based on the evidence you collected during the investigation. Please explicitly address the question.

Summary and Reasoning: Write your conclusion to explain how your claim is justified. How does the drag force depend on terminal velocity? Justify your answer with your experimental evidence and results. As always, discuss sources of error and how you would improve the lab.