Statement of Problem: Determine the minimal height and wind speed that can be used to separate 30%-40% of paper falling from a certain height that is uniformly distributed with cardboard.

Parameters of the Device: The simple device is a rectangular chamber which has an opening at the top of the chamber which allows the uniformly distributed paper and cardboard to fall which will begin the recycling process. The chamber is 1.5 m wide and is a certain height up. The fan has a dimension of 0.75 m which also has an opening going horizontally across from it. The fan is powerful enough to provide a uniformly distributed wind speed as it influences any object falling on it.

Rules:

(1) Have at least 30%-40% of the paper recycled from the paper-cardboard mixture.
(2) Find the minimum height possible to separate 30-40% of the paper.
(3) Find the minimum wind speed possible that can be used to separate the paper from the cardboard.

The Object of Interest: The object of interest which was determined experimentally was the paper. After some time, it was observed that half of the paper was attached to the cardboard while half of the paper was separated from the paper and was alone in its journey downward. The dimension of the paper used was an 8.5 in by 11 in by 0.003 in computer paper since it is commonly used and discarded. The mass of the paper recorded was 0.005 kg. A free body diagram of the paper was developed and displayed in figure 1. The paper is also falling rigidly.

Figure 1. Diagram of Simple Device
From this free-body diagram, Newton’s second law of motion was developed, and the external forces were summed to develop a differential equation model (1) The cardboard is considered solely in freefall as it is dense enough to bypass the fan.

\[
m_{p,c} \frac{dv}{dt} = m_{p,c} \cdot g(0,1,0) - C_{D} \cdot \rho \cdot \frac{v^2}{2} \cdot A(1,1,0) + A \cdot P \cdot C_{D}(1,0,0)
\]

(1)

\(V(t)\) is the velocity of the paper in m/s, \(\rho_{\text{air}}=1.225 \text{ kg/m}^3\), the force of gravity is 9.81 m/s\(^2\), the coefficient of drag of air is 1.1, \(v\) = velocity of the object, and \(P\) is the wind pressure. The cross-sectional area of the paper is 0.01015 m\(^2\).

**Our Approach:** To find the minimal height, we wanted to find the terminal velocity in which the paper will reach after some time. Once we know the initial velocity and the terminal velocity we could use a kinematic equation to find the time it took for the paper to reach the terminal velocity. Then once the time was known, another kinematic equation could be used to solve for the displacement the paper undergoes as it travels from the initial velocity to the terminal velocity. This is equal to the height that the paper undergoes and what we assumed in the minimum height required. We know from observation that the cardboard will travel faster than the paper which tells us that we can find can ignore the cardboard and most of the paper that attaches to it when it is in freefall.

Once the paper reaches the terminal velocity, we modeled the paper once it reached the fan. We developed several models and scenarios to explore the trajectory that the paper would take. We did return some interesting results but did achieve a reasonable result. We choose to ignore the Bernoulli force that the paper would experience since that would complicate the model extremely since it would take unexpected turns and curls. The cardboard used in some scenarios were assumed to be all identical which was 18in by 12in by 6in.