The Power of Wind
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April 21, 2018

Abstract
The purpose of this model is to show the role wind can play in the recycling process. Specifically in such a way to separate paper from cardboard. The current process for this in many recycling plants is to do it entirely by hand which is very time consuming. The research done for this model is to show that dropping a mixture of cardboard and paper from a great height, allowing it to pass through a column of wind created by a fan, successfully separates 30-40% of paper from cardboard.

1 The Question.
The question that our team has chosen of the three given by SCUDEM, Sorting recyclables. This problem asks for a model that shows how to separate paper from cardboard by dropping the mixture from a great height. Then while the mixture falls it passes through a column of wind created by a fan to allow for the separation with a 30-40% efficiency. The end goal being to optimize height and wind speed.

2 The Research Model
2.1 Overview
The research plan that our team created was for us to separate the entire model into three phases: The Drop, The Fan, The Collection Plane. This allowed for a breakdown of the model making it easier to visualize each point in time.

2.2 The Drop
This is the starting phase from the point of release until the point of wind current. The only direction of movement is downward, i.e. free fall. The only condition given on the release is "uniformly distributed" which we defined to mean equal volume of each material, uniform dispersion, and loosely packed. We begin with Newton’s second law of motion.

\[ \sum F = ma \] (1)

allowing us to derive our next equation.

\[ y(t) = -\frac{gt^2}{2} + H_0 \] (2)

and our next equations allowed for us to see the general separation of paper from cardboard was by finding the terminal velocity \( V_T \) by use of the force of drag which is calculated by setting it equal to the force of gravity and solving for velocity

\[ F_d = \frac{\rho C_d A v^2}{2} \] (3)

giving,

\[ V_T = \sqrt{\frac{2mg}{\rho A C_d}} \] (4)
Allowing for us to change equation (2) to this equation for after the object has reached $V_T$

$$y(t) = V_T t + H_0$$

(5)

From the use of all these equations we were able to approximate the minimum amount of distance needed to fall before reaching the second phase to allow for optimal amounts of paper to be blown by the fan. This also allowed for us to calculate a divergence of paper from cardboard since they fall at different rates. This gives us the ability to show a separation of the bulk of paper from cardboard. This will be the paper we are going to try to make cross our S position in phase two.

### 2.3 The Fan

The Fan phase is short in terms of duration as it is only the height of the fan which is a size we assumed to be of 1 m radius. Even though this phase is short it plays a great importance to the overall model as this is where the horizontal separation takes place. Our equation for horizontal displacement is as follows:

$$x(t) = \frac{a(t - t_{1f})^2}{2}$$

(6)

where $a = \frac{A\rho v^2}{m}$ with a lot of the values of this equation coming from the following:

$$\frac{m}{V} = \rho$$

(7)

$$F_w = A\rho v^2$$

(8)

where $v$ is the wind speed and the rest coming from the assumptions that we set in place. We had to find where to set our S value. Our $S = separation$ point this being a point we had assumed as the point we want paper to cross and cardboard to never cross. After that we solved for wind speed giving us a lower bound for our wind speed and then for the upper bound we found a max output for a fan of this size.

### 2.4 The Collection Plane

Overall in this phase; both paper and cardboard are already separated, and moving to the collection plane. The duration of this phase uses equation (2) and (5) whichever one is needed for the assumed height. The height only needs to be great enough to allow for an easy landing but short enough to not allow for a remixing and to not be affected by the wind.

### 3 Findings and variables

Based upon the model created, we have concluded $H_0 = H_1 + 2 + H_3$ which through our calculations we can approximate an optimal height between $5.219m \leq H_0 \leq 6.369m$. Finally from solving for wind speed from our chosen S value and general strengths of fans approximated optimal wind speeds to be $16.55 \frac{m}{s} \leq v \leq 18.96 \frac{m}{s}$.

- F=general force
- m=mass
- a=acceleration
- g=acceleration due to gravity
- t=time
- $H_0$=initial height
- $\rho$=density
- $C_d$=drag coefficient
- A=cross sectional area
- $t_{1f}$=time at end of phase one
- V=volume