**Terminal Velocity Simulation Conducted on a Spreadsheet**

**Objective:** To write a program that will calculate terminal velocity for various objects on a spreadsheet given their cross-sectional area, mass, and drag coefficient.

**Discussion:** Students are often taught to disregard air resistance in any problem involving freefall. For massive objects at low speeds, this assumption is good. However, in reality air resistance begins affecting the motion of objects at relatively low speeds and must be considered to accurately model the motion of an object in freefall. When an object encounters air resistance as it falls, its acceleration begins to drop below 9.8 m/sec2.

As a falling object’s velocity increases the drag force it experiences increases and approaches the weight of the object. When these two forces become balanced (drag force = weight) and the object stops accelerating. When this happens, the object has reached its **terminal velocity**.

 **Predicting Terminal Velocity:**

1. **Before inputting the values** given in the table on the next page, try to guess the terminal velocity of each of the items. You can guess **1m/s, 10m/s or 100 m/s**. You will not be penalized for incorrect predictions. Estimate as best you can and write your guesses into the table in the “Predicted Terminal Velocity” column. Then use the spreadsheet to determine the actual according to the model (step 2)
2. **Only one object can be viewed at a time**. Now enter the data for a single object from the table of objects, their masses, cross-sectional areas, drag coefficients and time increments which are to be entered into cells A2 thru D2 on the spreadsheet to determine the terminal velocity. Scroll down to see the velocity level off and when it is holding constant it is an acceptable result. Or you may simply go to the bottom cell (B95) and look at that value. Observe the progression of the net force and acceleration columns as the object is speeding up over time.
3. Record the actual terminal velocity for each item in the table below (from cell F2)

**Table 1.1**: Objects to be simulated falling through air to reach terminal velocity. **Guess first and record in the predicted column. Then input the object specs and observe the actual terminal velocities and record each one in the table below.**

| Falling Item | Mass (kg) | CSA (m^2) | Drag Coefficient | Time Increment (sec) | Predicted Terminal Velocity (m/sec) | Actual Terminal Velocity (m/sec) |
| --- | --- | --- | --- | --- | --- | --- |
| Skydiver | 95 | 0.6 | 0.55 | 0.5 |  |  |
| skydiver (head first dive) | 95 | 0.18 | 0.55 | 1 |  |  |
| skydiver (open parachute) | 95 | 25 | 1.4 | 0.1 |  |  |
| Feather | 0.001 | 0.002 | 0.55 | 0.02 |  |  |
| Javelin | 0.8 | 0.0004 | 0.45 | 1.5 |  |  |
| penny (sideways) | 0.003 | 0.0000019 | 0.5 | 1 |  |  |
| penny (facing down) | 0.003 | 0.0002834 | 0.55 | 0.1 |  |  |
| piece of paper | 0.005 | 0.0616 | 0.6 | 0.01 |  |  |
| Bullet | 0.013 | 0.0000785 | 0.45 | 0.5 |  |  |

**Analysis Questions:**

1. ***Observe:***  Why does a skydiver travel different speeds in different positions/orientations?
2. ***Experiment:*** Test the effect of increasing or decreasing each of the following (a-c) on an object's terminal velocity holding other factors constant. State a conclusion for each: a) mass b) cross-sectional area (CSA) c) drag coefficient

a)increasing Mass \_\_\_\_\_\_\_ terminal velocity

b)increasing CSA \_\_\_\_\_\_\_ terminal velocity

c) increasing drag coefficient \_\_\_\_\_\_\_ terminal velocity

1. **The Returning Bullet:**  If a bullet was fired straight up, it would slow down to a velocity of zero and fall back toward earth. Would it be as deadly on its way down if it left the gun at 350 meters per second? *Hint: you modeled its terminal velocity already.*
2. **Reasoning:** The actual terminal velocity of a rotating penny changes as it falls. Why?
3. **Interpreting graphs:** Copy and paste a graph of the terminal velocity of a skydiver of your choosing below. Label the part of the graph that is constant velocity and the part that is accelerating. ***Choices for the two blanks:*****constant velocity *or* accelerated**

**The horizontal line is \_\_\_\_\_\_\_\_\_\_\_\_\_\_. Everything before that (the curved line) is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.**