iFLY Post Field Trip Activity *Teacher Instructions* Middle Years

Learning Outcomes:

- Use measured data to predict results
- Understand the variables that affect terminal velocity
- Use algebraic reasoning to solve equations
- Discuss possible reasons for error between measured and predicted results

Materials Needed:

- Terminal Velocity worksheets (1 per student)
- Pencils (1 per student)
- Calculators to share
- Measuring tapes to share
- 1 bathroom scale that measures mass in kg

Completing the activity worksheet:

1. Have students work with partners or small groups to complete the exercises on the worksheet. In question #1, allow time for them to discuss the variables in the terminal velocity equation. Before continuing, make sure they can describe what each variable measures in their own words.
2. Students will use the standard value for gravity in their calculations.
3. Students will assume an air density 1.20 kg/m^3. If you have time, you could have them look up what the actual air density is for your particular location and use that value instead.
4. Students will choose a value for the drag coefficient. The human body fairly approximates a cylinder (flying on its side), so use the value of 1.2 in the calculations.
5. Students measure and record their mass in kg using a bathroom scale.

6. Students work with each other to measure their body dimensions and calculate their approximate frontal area.

7. Students use the values they have measured to calculate their predicted terminal velocity in m/s.

8. Students convert their answer to mph and check their terminal velocity against a typical range. If their predicted value lies well outside this range, they may have made a mistake in their calculations.

9. It's rare for the predicted and actual value of terminal velocity to match up exactly. Some possible reasons for errors between the two values are:
    a. Flyers in the wind tunnel hold their bodies in different and varying ways, which affects both their drag coefficient and frontal area.
    b. Air density depends on several factors, including humidity and altitude, and may not be exactly 1.20 kg/m^3.
    c. The drag coefficient of 1.2 was an approximation.

Terminal Velocity Student Worksheet *(middle years)*

During your field trip to iFLY, you recorded the terminal velocities of some different objects in the wind tunnel. In this activity, you will make calculations to predict what *your own* terminal velocity should be in the tunnel.

1. Understand the variables affecting terminal velocity.

   The equation for terminal velocity is:

   $$v = \sqrt{\frac{2 \; x \; m \; x \; g}{p \; x \; Cd \; x \; Af}}$$

   v = terminal velocity
   C_d = drag coefficient
   ρ = air density
   A_f = frontal area
   m = flyer's mass
   g = gravitational acceleration

   With a partner or in a group, discuss these terms. Which ones are familiar and which ones are new? In your own words, explain what each variable measures. In the next exercises, you'll determine what values to use for each variable.

2. <u>GRAVITY</u>
   Gravitational acceleration measures the strength of the Earth's gravity on your body. In step #7 of this activity, we'll use the standard value of:

   $g = 9.81$ m/s^2

3. AIR DENSITY

This is a measure of the mass of air per unit volume. In step #7, use the default value of:

ρ = 1.20 kg/m^3

4. DRAG COEFFICIENT

The drag coefficient expresses the drag or resistance of an object moving through a fluid.

Look at this chart of drag coefficients for common objects:

object shape	$C_!$
sphere	0.5
cylinder	1.2
flat plate	2.0

Based on this chart, choose the drag coefficient best suited for the human body:

$C_!$ = _____

5. MASS

Mass is the amount of matter in an object. Use a scale to measure your mass, m in kg:

m = _____ kg

6. FRONTAL AREA

Frontal area is different from the total surface area of an object. It is the area that the "wind sees". Use a measuring tape and the chart below to calculate the total frontal area of your body.

Body element	Measured Length, l (cm)	Measured Width, w (cm)	Frontal area formula	Frontal area (cm^2)	Multiplier	Total Body Element frontal area (cm^2)
Head (ellipse)			$A=\frac{1}{4}\pi lw$		1	
Neck (rectangle)			$A= lw$		1	
Torso (rectangle)			$A= lw$		1	
Hands (ellipse)			$A=\frac{1}{4}\pi lw$		2	
Arms (rectangle)			$A= lw$		2	
Legs (rectangle)			$A= lw$		2	
Feet (rectangle)			$A= lw$		2	
					Total frontal area (cm^2)	

Divide this total frontal area by 10,000 to find $A_!$ in units of m^2:

$A_!$ = _____m^2

7. Use the space below to calculate your predicted terminal velocity, v in m/s:

$$v = \sqrt{\frac{2 \; x \; m \; x \; g}{p \; x \; Cd \; x \; Af}}$$

8. A middle school student at the iFLY tunnel typically flies at a terminal velocity of 75mph to 110mph. Did your predicted value fall within this range? (Don't forget to convert m/s to mph to compare!)

9. What are some factors that might cause a difference between your predicted terminal velocity and your actual velocity in the wind tunnel?