Terminal Velocity for Objects of Different Surface Area and Constant Mass (Motion Sensor)

Mechanics: Terminal velocity, different surface area	*DataStudio* file: **22A Terminal Velocity 1.ds**

Equipment List

Qty	Items	Part Numbers
1	PASCO Interface (for one sensor)	
1	Motion Sensor	CI-6742
3	Paper shapes to be dropped	

Introduction

The purpose of this activity is to investigate how shape affects an object's terminal velocity. Each shape will be made from a single piece of paper, so the mass will remain constant.

Use the Motion Sensor to measure the motion of falling objects that have the same mass but different surface area. Use *DataStudio* to record and display the data.

Background

When an object falls through the air, how does shape affect the velocity?

A hang glider cannot remain in the air forever. Once a hang glider takes off from the top of a mountain, its begins to slowly fall.

Why is it that some objects when they are dropped fall very slowly and others fall very quickly? For instance, a hang glider moves very differently from a rock.

Terminal speed (or terminal velocity) is defined as the speed for a falling object when the drag (air resistance) on the object equals the object's weight (the pull of gravity on the object). The drag depends on cross-sectional area of the falling object, the density of air, and the coefficient of drag (an empirically determined constant).

SAFETY REMINDER

- Follow directions for using the equipment.

THINK SAFETY
ACT SAFELY
BE SAFE!

Prediction

What shape should the paper be in to have the greatest acceleration? Explain.

Setup

1. Set up the PASCO Interface and computer and start *DataStudio*. Connect the Motion Sensor into the interface.
2. Open the *DataStudio* file: **22A Terminal Velocity 1.ds**

- The *DataStudio* file has a Graph display of Velocity versus Time. Data recording is set at 50 Hz for the Motion Sensor. The delayed start condition is set to begin recording data when the object is 1.50 m above the sensor, and the automatic stop condition is set to end recording data when the object is 0.5 m above the sensor.

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3. Place a motion sensor on the ground and make certain that the sensor is facing straight up. The range of the motion sensor should be set at ‘FAR’ (person).

4. Hold the largest shape slightly higher than 1.5 m above the motion sensor.

Procedure

- NOTE: The procedure is easier if one person handles the falling objects and a second person handles the computer.

1. Click the start button and release the shape. Data will not begin to be collected until the position is below 1.5 m. Data recording will stop when the shape is 0.50 m above the sensor.

2. Repeat the procedure for each shape.

Analyze

1. Analyze the velocity-time trials. Use the ‘Smart Tool’ to determine the velocity of each shape at 0.25 seconds. Record in the Data Table in the Lab Report section.

2. As the shape is falling, what is happening to the acceleration? Use the ‘Slope Tool’ on the velocity-time graph to evaluate the acceleration for each shape.

Answer the questions in the Lab Report section.

Lab Report: Terminal Velocity for Objects of Different Surface Area and Constant Mass

Name: ______________________________

Prediction

What shape should the paper be in to have the greatest acceleration? Explain.

Data Table:

Trial	Shape	Velocity of Shape (m/s)
Run #1	Large	
Run #2	Medium	
Run #3	Small	

Questions

1. As the shape is falling, what is happening to the acceleration?

2. What is the significance of the decreasing acceleration and how this relates to the net force on the shape?

3. In this activity, what aspect of shape determines how fast it will fall in air?

4. How would the aerodynamic shape of an object affect the velocity-time graph? (Hint: Aerodynamic shapes are those that minimize the surface area of the object, relative to the air moving past it.)

5. Was your prediction correct? Why or why not?

Terminal Velocity for Objects of Constant Surface Area and Different Mass (Motion Sensor)

Mechanics: Terminal velocity, different mass	*DataStudio* file: **22B Terminal Velocity 2.ds**

Equipment List

Qty	Items	Part Numbers
1	PASCO Interface (for one sensor)	
1	Motion Sensor	CI-6742
12	Coffee filter	

Introduction

The purpose of this activity is to investigate how mass affects an object's terminal velocity. Each object will have the same surface area, but different amounts of mass.

Use the Motion Sensor to measure the motion of falling objects that have the same surface area but different mass. Use *DataStudio* to record and display the data.

Background

When an object falls through the air, what happens to the object's velocity? Does mass have an effect on the velocity?

Objects are always falling: parachutist from a plane, apples from a tree, raindrops from the clouds. We know that when objects fall they accelerate due to the Earth's gravity.

Raindrops fall from large heights and have the opportunity to accelerate for a long period of time due to the force of gravity. So why are raindrops not traveling at extremely high velocities when they reach the Earth's surface?

Newton's Second Law states that if a net force is acting on an object then it will accelerate. Is a falling raindrop a violation of Newton's Laws?

Terminal speed (or terminal velocity) is defined as the speed for a falling object when the drag (air resistance) on the object equals the object's weight (the pull of gravity on the object). The drag depends on cross-sectional area of the falling object, the density of air, and the coefficient of drag (an empirically determined constant). If the amount of drag on an object is a constant, how does the object's weight determine the rate of falling?

SAFETY REMINDER

- Follow directions for using the equipment.

THINK SAFETY
ACT SAFELY
BE SAFE!

Prediction

What will the graph of position-time and velocity-time look like for a coffee filter falling through air?

Setup

1. Set up the PASCO Interface and computer and start *DataStudio*. Connect the Motion Sensor into the interface.
2. Open the *DataStudio* file: **22B Terminal Velocity 1.ds**

- The *DataStudio* file has a Graph display of Position and Velocity versus Time. Data recording is set at 50 Hz for the Motion Sensor. The delayed start condition is set to begin recording data when the object is 1.50 m above the sensor, and the automatic stop condition is set to end recording data when the object is 0.5 m above the sensor.

3. Place the Motion Sensor on the ground and make certain that the sensor is facing straight up. The range of the motion sensor should be set at 'FAR' (person).
4. Hold three coffee filters slightly higher than 1.5 m directly above the motion sensor.

Procedure

- NOTE: The procedure is easier if one person handles the filters and a second person handles the computer.

1. Click 'Start' button and release the coffee filters. Data will not be collected until the position is less than 1.5 m.
2. For the second trial, use six coffee filters.
3. Continue the procedure for two more data runs, using nine and twelve coffee filters respectively.

Analyze

1. Use the Data menu to view the position graph for the nine coffee filters and analyze the data. Write a description in the Lab Report section of all the information you can interpret from this position-time graph.
2. Use the Data menu to view the velocity graph for the nine coffee filters and analyze the graph. Write a description in the Lab Report section of all the information you can interpret from this velocity-time graph.
3. Analyze the velocity-time trials. Use the 'Smart Tool' to determine the velocity of each shape at 0.30 seconds. Record in the Data Table in the Lab Report section.
4. Slide the 'Slope Tool' along the data curves for the velocity-time graphs and observe the acceleration values. Explain the trend for the acceleration of the stack of coffee filters as it falls.

Answer the questions in the Lab Report section.

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Lab Report: Terminal Velocity for Objects of Constant Surface Area and Different Mass

Name: ______________________________

Prediction

What will the graph of position-time and velocity-time look like for a coffee filter falling through air?

Observation

1. Write a description of all the information you can interpret from the position-time graph for the nine coffee filters.

2. Write a description of all the information you can interpret from the velocity-time graph for the nine coffee filters.

3. Based on the data curves for the velocity-time graphs, explain the trend for the acceleration of the stack of coffee filters as it falls.

Data Table:

Trial	Filters	Velocity of Filters (m/s)
Run #1	Three	
Run #2	Six	
Run #3	Nine	
Run #4	Twelve	

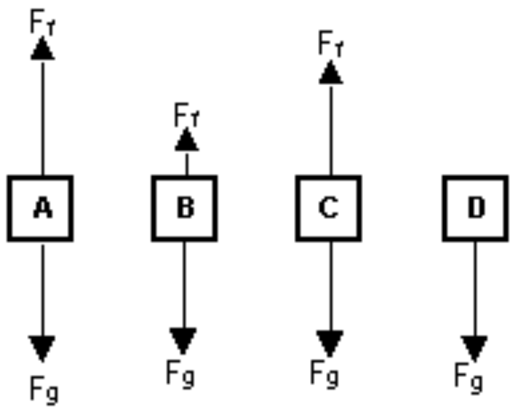
Questions

1. Why is the velocity of the stack of filters negative?

2. How does the final velocity of three coffee filters compare to the velocity of twelve coffee filters?

3. How does the initial acceleration of six coffee filters compare to the acceleration of twelve coffee filters.

Use the diagrams below to answer the next two questions.



4. Which force diagram accurately reflects the initial forces on a stack of three coffee filters as they fall?

5. Which force diagram accurately shows the final forces on a stack of three coffee filters just before they hit the ground?

6. Why does the velocity become constant? (zero acceleration)

7. Why does a higher mass have a corresponding higher final velocity compared to a lower mass?

8. Compare your first prediction to the graphs. Was any part of the prediction correct?

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