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## Experiment P-35



# Velocity of Free Falling Objects



### Objectives

- To measure the velocity of falling objects at a minimal air resistance.
- To examine whether two objects with different masses have the same velocity while falling.

### Modules and Sensors

- PC + NeuLog application
- USB-200 module 
- NUL-209 Photo gate logger sensor 

### Equipment and Accessories

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|---------------------|
| ▪ Utility stand     |
| ▪ Right angle clamp |
| ▪ Thin plate        |
| ▪ Thick plate       |
| ▪ Soft material     |
- The utility stand and right angle clamp are included in the NeuLog Mechanics kit, MEC-KIT.
  - The plates' size should be around 10 cm X 10 cm.

## Introduction

The position (or displacement) of a moving object is marked by the letter  $x$ . The object's velocity is marked by the letter  $v$ . The velocity is determined by the ratio between the change in position and the time it takes for the object to move. The formula is:

$$v \text{ (average)} = \frac{x \text{ (final)} - x \text{ (initial)}}{t \text{ (final)} - t \text{ (initial)}}$$

When the velocity is constant it can be described as in the formula above. When the velocity changes with time, dividing the change in position by the time will give us the object's average velocity. In order to calculate the object's instantaneous velocity ( $v(t)$ ), we divide a very small section of the position change by the time difference.

These concepts will help you understand the principles of falling objects.

One of the classic questions in physics is: If we throw two objects (one with a mass of 100 g and one with a mass of 1000 g) from a tall building, which one will hit the ground first?

The intuitive answer is that the heavier object will hit the ground first. 300 years ago, Galileo proved that the two objects will hit the ground at the same time.

When an object falls, it always increases its velocity towards the ground due to gravity, thus it has gravitational acceleration ( $9.8 \text{ m/s}^2$ ). This acceleration is the same for all falling objects. This law is correct as long as there is no factor that influences the falling object such as air (this topic is examined in experiment P-1, Falling Objects).

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The following equation describes the velocity of a moving object with a constant acceleration:

$$\mathbf{v} = \mathbf{v}_0 + \mathbf{a}t$$

This is relevant for a free falling object (when the air resistance is minimal). The object moves with a gravitational acceleration ( $a = g = 9.8 \text{ m/s}^2$ ) and in this case the initial velocity is 0, therefore:

$$\mathbf{v} = \mathbf{g}t$$

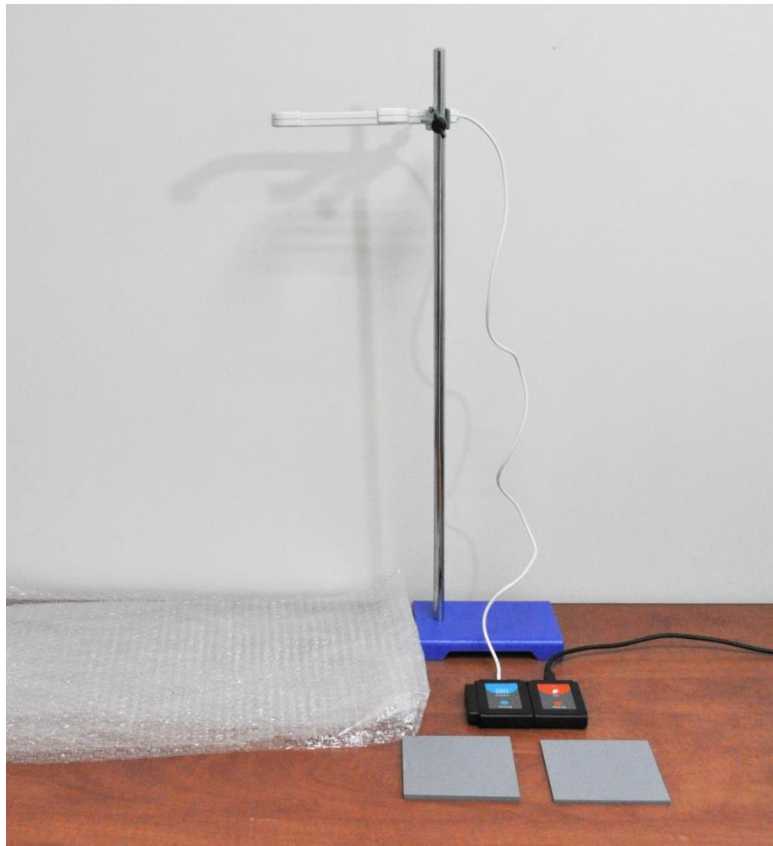
Every second, the object gains 9.8 m/s to its velocity while falling. For example after 2 seconds,  $v = 9.8 \text{ m/s}^2 * 2\text{s} = 19.6 \text{ m/s}$ .

In this experiment we will measure and compare the average velocities of two plates with different masses. We will use a photo gate sensor for our measurements.

## Procedure

### Experiment setup



1. Set up the experiment as shown in the picture below.



2. Attach the photo gate to the utility stand using the right angle clamp.
3. Place a material under the photo gate for softening the plate's fall.

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## Sensor setup



4. Connect the USB-200 module  to the PC.
5. Check that the photo gate sensor  is connected to the USB-200 module.

### Note:

The following application functions are explained in short. It is recommended to practice the NeuLog application functions (as described in the user manual) beforehand.

6. Run the NeuLog application and check that the photo gate sensor is identified.

## Settings

7. Click on the **On-line experiment** icon  in the NeuLog main icon bar.
8. Click on the **Experiment setup** icon .
9. The following menu should appear. Set the configuration as explained below:



## Testing and measurements


### Note:

The photo gate sensor has a light source and a light detector. The sensor can detect the motion of an object moving between them (this resembles a gate). A timer starts when the object begins its pass through the photo gate and ends when the object is no longer blocking the light, i.e. when it has already passed through it. The length of the object is inserted into the software.


The software can calculate the average velocity at the measured time difference by this equation:

$$v(\text{average}) = \frac{x(\text{final}) - x(\text{initial})}{t(\text{final}) - t(\text{initial})} = \frac{\text{Lenth of the object}}{\text{Measured time difference}}$$

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10. Click on the **Run Experiment** icon  to start the measurement.
11. Hold the thin plate a few centimeters above the photo gate and let it fall. Make sure that the plate is not touching the photo gate while falling.
12. The first measurement should appear in the digital window and the table:

Time[sec] Avg :	0.062	Velocity[m/s] Avg :	1.613
	0.062		1.613

13. Place the plate in the initial position and repeat the measurement (do not click on the **Run Experiment** icon  again).

14. The second measurement should appear in the table (as sample 2):


Time[sec] Avg :	0.0617	Velocity[m/s] Avg :	1.621
0.062		1.613	
0.0614		1.629	

15. Repeat the measurement three more times (for a total of five measurements).
16. Your data should be similar to the following:

Time[sec] Avg :	0.0635	Velocity[m/s] Avg :	1.577
0.062		1.613	
0.0614		1.629	
0.0664		1.506	
0.0633		1.58	
0.0642		1.558	

17. The time it took the plate to pass through the photo gate in each measurement appears in the first column.
18. The calculated average velocity of the plate (while passing through the photo gate) in each measurement appears in the second column.
19. The average velocity of all five measurements appears in the top of the second column.
20. Save your data.
21. Insert the average velocity value into the following table:

	Thin plate	Thick plate
Average velocity [m/s]		

22. Click on the **Erase Experiment** icon  in order to erase the data in the table.
23. Repeat the five measurements, using this time the thick plate (make sure you do not change the initial position of the plate).



## Summary questions

1. What was the difference between the average velocities of each plate? Explain.
2. How will the results change (time and velocity) if we repeat the experiment, starting at a higher initial position?
3. Use the following equation to calculate the time it took for one of the plates to reach the point where the middle of it is detected by the photo gate.

$$v = gt$$