

# Projectile Motion

By

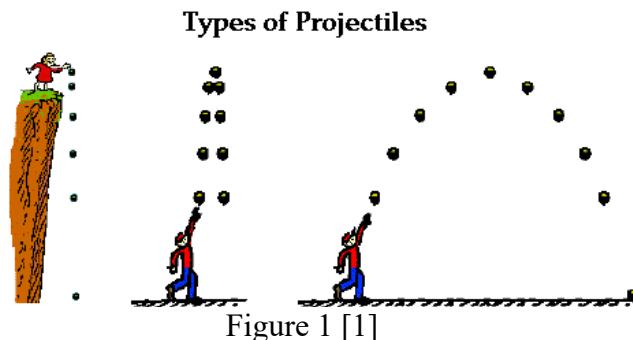
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## I. Introduction

Projectile motion is the two-dimensional (vertical and horizontal) motion of an object that has only one force acting upon it in the form of gravity. The vertical motion is affected by gravity, causing a vertical acceleration. According to Newton's law of motion, an object in motion will remain in motion unless acted upon by force. In the case of the projectile there are no forces acting upon it horizontally; therefore it maintains a constant velocity.

## II. Background

There are many different examples of projectile motion, for example, throwing a rock from a building, kicking a football, or throwing a ball in the air and catching it.



The angle of a projectile plays a big role in the object's motion; if the angle is changed, the motion will change dramatically. A projectile launched at  $45^\circ$  will travel further than if launched from any other angle (if it's launched along the same horizon).

## III. Objective

- Measure the velocity of a car using Photogate and computer software
- Apply concepts from two-dimensional kinematics to predict an object's impact distance
- Compare the theoretical (calculated) versus the computed (from the Photogate) results
- Take into account trial-to-trial variations in the velocity measurement when calculating the impact point

## IV. Equipment List

-Car	-Vernier Motion Sensor
-Ruler	-Carbon paper
-Hot Wheels Booster	-Hot-Wheels Track
-Tape	-Photogate
-PC	-Logger Pro interface

## V. Experimental Procedure:

### Getting the initial velocity

- 1) Place the hot wheels booster on the table, and make sure that the batteries are charged.
- 2) Connect the hot wheels track to the designated part of the booster and place a Photogate at the end of the track and position it so that the car is detected by the Photogate as it passes underneath. Check figure 2 below.

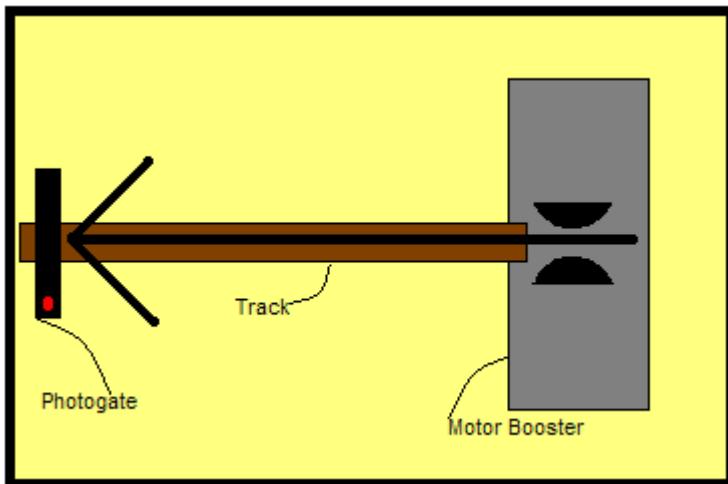


Figure 2 (top view)

- 3) Connect the *Logger Pro* interface to the computer and make sure that it is able to collect data. Then measure the length of the car, so you can calculate the velocity after it passes the Photogate (use  $v = \frac{\text{length of car}}{\text{time}} = l$ ) and record it. Also measure and record the value of the distance, meaning how far from the table the car fell.
- 4) Click collect , turn on the booster so that the rubber wheels begin to spin, then take the hot wheels car and place it in the booster.
- 5) When ready gently push the car into the booster wheels and allow it to be launched from the booster passing through the Photogate; let the car fall from the table and record the distance from the table to the exact dropping spot of the car. Also record the height of the table (y-direction).
- 6) Repeat this procedure five times, collect and record the data.

## VI. Analysis/Questions

- 1) Using what you know about  $v_i$ , determine when the car will hit the ground time  $t(s)$  and the distance of the car where it lands (x-direction). Does it match the measured one (use a ruler)?
- 2) Use your ruler measurements and calculate the initial velocity and compare it with the Photogate velocity. Does it match? Use the formulas below.

<i>x-component</i>	<i>y-component</i>	<i>Vectors</i>
$x_f = x_i + v_{xi}t$	$y_f = y_i + v_{yi}t - \frac{1}{2}gt^2$	$v_{xi} = v_i \cos(\theta)$
	$v_{yf}^2 = v_{yi}^2 - 2g\Delta y$	$v_{yi} = v_i \sin(\theta)$
	$v_{yf} = v_{yi} - gt$	

[2]

First, simplify the equations above and use them interchangeably. What is the value of the initial velocity in the vertical direction ( $v_i$ )? What is the acceleration in the vertical direction ( $a_y$ )?

- 3) Print out or sketch the graph of velocity vs. time from the Photogate analysis. On a separate plot using the equations of projectile motion, starting with  $t=0$  and finishing with  $t=t_{fin}$  (when the projectile will hit the floor) and three different  $t$  values in-between, sketch a graph of theoretical velocity vs. time.
- 4) If there is a difference between the sensor values and the calculated (theoretical) values, what do you think caused it?
- 5) Calculate the average theoretical and the calculated velocity values and find the percent error by using  $\left| \frac{\text{theoretical} - \text{calculated}}{\text{theoretical}} \right| \times 100 = \% \text{error}$ .

### Data Sheet

Photogate Sensor Measurement				
Trial ( $\theta=90$ degrees)	Velocity ( $v_i$ ) (m/s)	Time $t$ (s)	x-direction (m)	y-direction (m)
1				
2				
3				
4				
5				

Theoretical Measurement				
Trial ( $\theta=90$ degrees)	Velocity ( $V_i$ ) (m/s)	Time $t$ (s)	x-direction (m)	y-direction (m)
1				
2				
3				
4				
5				

## References:

[1]	Online: <a href="http://www.physicsclassroom.com/Class/vectors/U3L2a.html">http://www.physicsclassroom.com/Class/vectors/U3L2a.html</a> , web site of physicsclassroom.com.
[2]	Giancoli, Douglas C. <i>Physics: Principles with applications</i> / 5 <sup>th</sup> Ed., 1998
[3]	K. Appel, J. Gastineau, C. Bakken, D. Vernier, Physics with Computers. Vernier Software & Technology, Beaverton, Oregon, 3rd Ed., (2003).