PC and digital camera assisted study of projectile motion

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Abstract

We present a projectile motion experiment with the help of digital camera and PC for data acquisition and processing. In this experiment to study projectile motion with water stream, a photo of the water path is taken and the pixels coordinate of the photo is obtained to measure the length. This method is more effective and accurate than the traditional method. The experiment presents the idea of using digital camera and PC to measure distance and inspires students to look for new methods to solve problems.

1. Introduction

Water stream is commonly used for demonstrating trajectory of projectile motion in introductory-level physics [1-2]. If the trajectory of a horizontal projectile is known, the free fall acceleration can be determined. This is also a method to measure free fall acceleration. The common way to experimentally determine the trajectory in school laboratories is to draw the water path on a piece of paper and measure the lengths using a ruler [2]. This method can impose big subjective errors and complexity in operation when drawing the water path. We employ a digital camera and a computer (PC) to perform this task more effectively and accurately. A photo of the water path is taken. One pixel on the photo represents a certain length. We then get the lengths by reading the pixels directly. The experiment presents the idea of using digital camera and PC to measure distance and inspires students to look for new methods to solve problems.

The motion of a water drop is given by the equations below

$$x = vt \qquad (1)$$

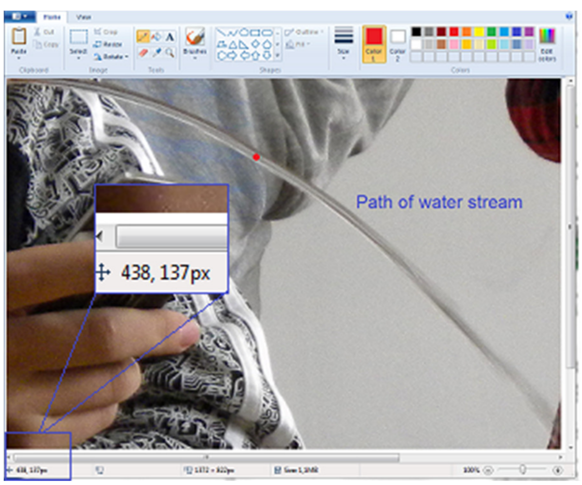
$$y = \frac{1}{2}\, gi^2 \qquad (2)$$

where x and y are the displacements of the water drop along horizontal and vertical directions respectively (thus the coordinate of the trajectory), v is the initial speed of the water flow, g is the free fall acceleration and t is the time taken. By canceling t in eq, the equation for the trajectory is obtained to be

$$y = \frac{g}{2v^2}\, x^2 \qquad (3)$$

Once the trajectory and the initial speed of the water fall are measured, the value of g can then be calculated. The traditional way to decide a few sets of (x, y) values in school laboratories is to draw the water path on a piece of paper and measure the lengths using a ruler. This method can impose big subjective errors when drawing the water path. We employ a digital camera and a PC to perform this task and to process data. A picture of the water path can be taken using the camera (Fig 1). Any simple image-processing application (e g. *Painter*) can be used to determine the pixel coordinates ( ) directly, as shown in Fig 2.

Fig 1. Recorded water path trajectory while demonstrating in a physics class



Putting a ruler or something of known length (a credit card 85.6mm long in our case) in the plane of the water path and counting the number of pixels the side length occupies on the photo, the length represented by each pixel a is obtained. Then,

$$x = n_x a, \quad y = n_y a \qquad (4)$$

Substituting eq. (4) into eq (3) yields,

Take a few data points from the water stream image, whose pixel coordinates can be directly read from the image processing application(for the case of Painter, it is in the bottom of the screen, as shown in Fig 2), and plot graph using MS Office Excel. Then the slope of the graph is $\frac{ga}{2v^2}$. The graph for our experiment is shown in Fig 3. We can see that the graph can be well fitted to a straight line, which indicates that the trajectory of a projectile motion is a parabolic curve. The slope $\frac{ga}{2v^2}$ is found to be 0.000663

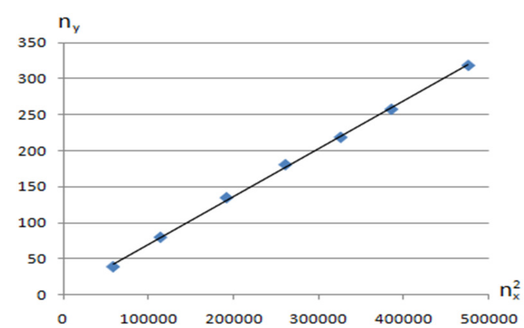


Fig 3. Line of best fit for $n_y \sim (n_x{}^2)$

The initial speed of the water flow v can be determined by measuring the time taken Δt for a small amount of water (volume V) to flow out the pipe with diameter d. The diameter of the pipe d can also be decided by using pixels coordinates (so a vernier calipers is not needed) too. The speed is given by the equation

$$v = \frac{V}{\pi(d/2)^2}\frac{1}{\Delta t} \qquad (6)$$

The free fall acceleration can then be calculated. In our case the value is $9.3\,ms^{-2}$, which is close to the know value $9.8\,ms^{-2}$.

3. Summary

This is a quite interesting experiment or classroom demonstration. It doesn't need any special measurement apparatus such as vernier and it's very easy to perform. The students were also encouraged to do it at home. The experiment can help students get an intuitive understanding of horizontal projection and inspire students to work out convenient methods to solve problems. The idea of using digital camera and PC to measure distance can also be applied to other similar experiments.

Reference

[1] V. J. Ostdiek, D. J. Bord, *Inquiry into Physics,* 6th ed. (Thomson Brooks, Belmont, 2008), p. 62.

[2] W. Winn, *Introduction to Understandable Physics*, (Authorhouse, Bloomington, 2010), V1, p. 3-16.