NORTHERN ILLINOIS UNIVERSITY

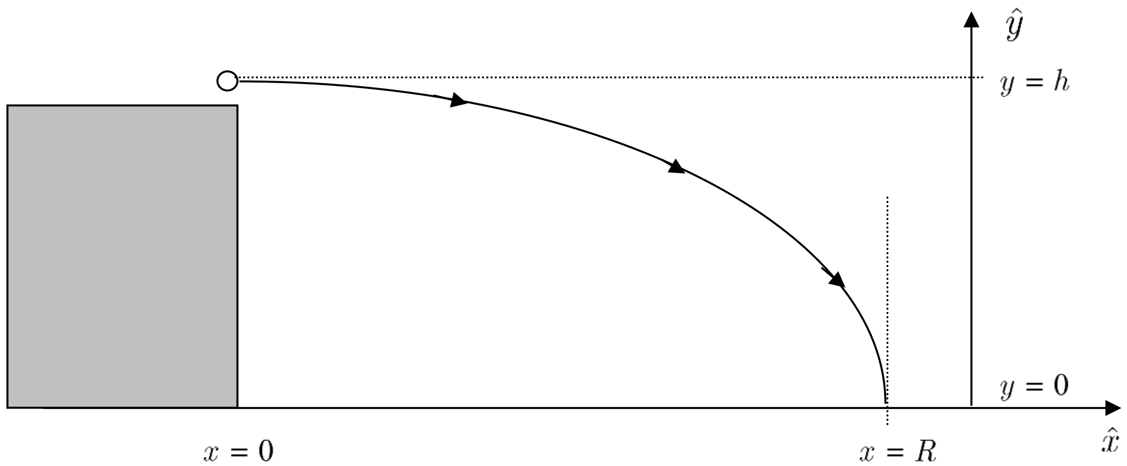
PHYSICS DEPARTMENT

Physics 210 – Mechanics & Heat Spring 2022

Lab #3

Lab Writeup Due: Tue/Wed/Fri, Feb. 15/16/18, 2022
Read OpenStax: Chapter 3, Lecture Notes #2

Projectile Motion



Apparatus

This experiment uses a glass or plastic tube to launch a ball horizontally. Gravity is used to get the ball rolling along a straight long tube. The end of the long tube is a height h above the ground. The ball launches out of the tube with an initial horizontal velocity v_{x0}. As the ball flies through the air it will curve downward due to gravity and strike the floor some distance R away from the end of tube.

Theory

The ball comes out of the tube in the direction parallel to the tube (that is, in the horizontal direction) at some initial velocity v_{x0}. This velocity can be measured by finding the time Δt that it takes to go between two points in the horizontal tube separated by a distance D. The velocity is then

$$v_{x0} = \frac{D}{\Delta t} \tag{1}$$

A projectile in the air is subject to an acceleration a_y downward due to Earth's gravity. The acceleration only acts downward and has no effect on the horizontal motion. Since there is no initial vertical motion for the ball, the distance downward is given by

$$y = y_0 + \tfrac{1}{2} a_y t^2 = h - \tfrac{1}{2} g t^2 \tag{2}$$

where h is the initial height and g is the acceleration due to gravity, $g = 9.8$ m/sec^2.

The time it takes to hit the ground is found by setting $y = 0$ (the ground) and solving Eq. 2 for t

$$t = \sqrt{\frac{2h}{g}} \tag{3}$$

There is no acceleration in the horizontal direction so the forward distance covered when the ball hits the ground, called the range R, is found by substituting the time from Eq. 3 into an expression for distance: $x = x_0 + v_{x0}t + \tfrac{1}{2} a_x t^2 = v_{x0}t$ (since $x_0 = a_x = 0$). Thus, when the ball hits the ground the ***range*** R is found to be:

$$x = R = v_{x0}t = v_{x0}\sqrt{\frac{2h}{g}} \tag{4}$$

The vertical displacement is $\Delta y = y - h = -\tfrac{1}{2} g t^2$ and the horizontal distance is $x = v_{x0}t$. If these two equations are combined to eliminate t, then we get an equation that describes the ***trajectory of the projectile (a parabola)***:

$$y = h - \frac{g}{2}\left(\frac{x}{v_{x0}}\right)^2 = h - \frac{g}{2v_{x0}^2}x^2 \tag{5}$$

Data Collection

When doing measurements, alternate between lab partners for each measurement—no lab partner should do all the measurements (to minimize systematic measurement errors).

(1) Measure the height of the long tube above the floor. This is the vertical distance h that the ball will fall.

(2) Adjust the two *photogates* to be one meter apart. You will use them to measure how long the ball takes to travel one meter. Open the Logger Pro software on the computer. Select **Experiment** from the menu, then select **Set Up Sensors**, then select **Show all Interfaces**. Make certain that *Dig/Sonic1* and *Dig/Sonic2* are set to accept *photogate* sensors. Drop a ball in the tube to test the sensors, and make certain you understand the readings (there should be 4 time readings each time the ball goes by the two sensors—why?). Repeat dropping the ball six times (let each lab partner do a drop), and *record all time information into your lab notebook*, and take an average to use as time Δt.

(3) Calculate the horizontal speeds (six of them) of the ball v_{x0} in the long level portion of the tube with $D = 1$ m using Eq. 1.

(4) Use the height h and the average horizontal speed to predict how far out from the spot on the floor directly beneath the opening of the tube the ball will land using Eq.4. This is the range R.

(5) Now it is time to test your prediction. Tape a sheet of white paper to the floor, and mark an "X" on the sheet of paper where you expect the ball to hit. Next place (*do not tape*) a sheet of carbon paper over the white sheet of paper. Send the ball through the tube ten times letting it hit the paper each time to make a mark on the sheet of white paper (let each lab partner do this).

(6) Measure the horizontal distance from the spot on the floor directly beneath the opening to the edge of the paper.

(7) Measure and *record in your lab notebook* the distance of each mark on the paper from the edge of the paper and find an average.

(8) Add the average distance on the paper to the distance of the paper from the tube along the floor to get the measured range.

Data Analysis

Turn in next week a lab writeup (a Word document) following the guidelines discussed in lab and posted on the Web.

(1) Why was it wise for each lab partner to take turns dropping the ball instead of letting only one person do it all 6 times? Compare each individual time measurement with the overall *average time* by calculating a *percent error*:

$$\%Error = \left|\frac{Experimental - Theoretical}{Theoretical}\right| \times 100$$

where *Theoretical* is your *average time*. How does each individual time measurement compare with the average time (that is, how good a measurement did you do—review Lab #2 for the definition of good and poor *percent error* values)?

(2) Compare your predicted range (*Theoretical*) to the distance you found experimentally. How good was your prediction? (answer this question using *percent errors*)

(3) What effects might account for the different landing positions of the ball on the floor?