Projectile Motion of a Ball Bearing Rolling off of a Table

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**Abstract:**

In this experiment, concepts of simple projectile motion will be tested to determine the effect of initial horizontal velocity of a projectile on its displacement. The vertical motion of the projectile was kept constant, so that the relationship between horizontal velocity and displacement could be isolated. The results of the experiment indicated that the relationship is defined linearly, and is defined by the time, which in the experiment was found to be 0.434 seconds.

**Purpose**

The purpose of this experiment is to determine how the displacement by a projectile, which starts at a specific height, varies with the initial velocity given by the slant of a ramp, using ball bearings as projectiles. The experiment will exemplify the separation of horizontal and vertical motion and show that horizontal movement does not impact vertical movement.

**Hypothesis**

The displacement of the ball bearing is expected to be directly proportional to the velocity at which the ball bearing was ‘launched.’ If the velocity that the ball bearing leaves the table changed and ceteris paribus, then the displacement will respond with direct proportion.

Where

The constant of proportionality of this system is expected to be a function of the height at which the ball falls, namely time, so that the final equation will be

in one dimension (horizontal)

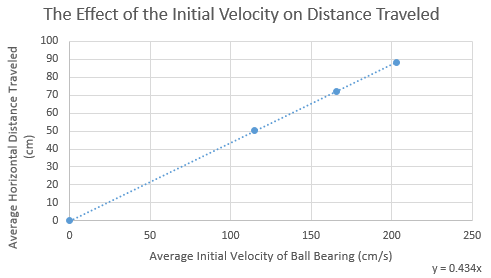
**Procedure**

1. A ramp will be used to give the ball its horizontal velocity, the ramps incline will be what is altered to give a desired velocity. Choose several heights at which the ramp will rest, and determine the horizontal velocity of the ball bearing after it exits the ramp using ‘time gates’ and the displacement between gates, and determine an average using several trials of a single ramp height.
2. Calculate the amount of time the ball will be in the air by solving the kinematic equation for time when initial velocity is zero, initial height is the height of the table, and final height is zero, the floor. Use the time found to calculate the displacement horizontally by the ball bearing, this is the calculated displacement by the ball from the bottom of the table.
3. Place carbon paper near the expected landing point of the ball bearing on the floor so that the ball’s actual landing point can be measured from the table accurately.
4. Execute several trials where the ramp height remains constant, then change the ramp height, and repeat several times.
5. Graph the data and use a line of best fit to determine the slope of that line (the constant of proportionality) and determine its significance.

**Data Tables/Observations**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Projectile Motion Data | | | | |
| Initial Velocity  (cm/s 0.1cm/s) | Displacement  (cm0.1cm) | | | |
|  | Trial 1 | Trial 2 | Trial 3 | Average |
| 115 | 50.3 | 50.8 | 50.4 | 50.5 |
| 166 | 71.6 | 71.5 | 72.9 | 72.0 |
| 203 | 88.3 | 88.2 | 88.0 | 88.2 |

Averages were calculated by summing the values of each trial for a specific velocity, then dividing by the number of trials. For example, the average displacement for the velocity 115 cm/s:



After graphing the data, and assigning a trend line, the function describing the average displacement by the ball bearing is given by . The slope of this line is essentially the average time that the ball bearing fell during this experiment. where , and in this case, rise is in cm, and run is in cm/s, cm cancels and what is left it , . The time can also be calculated by using kinematic equations to determine the time taken for the ball bearing to fall straight down from the height of the table.

This value of t is the ‘predicted’ time taken for the ball bearing to reach the ground. With this, the predicted value of the horizontal displacement can also be calculated.

This is how the following table values were calculated

|  |  |  |
| --- | --- | --- |
| Predicted Displacement and Actual Displacement | | |
| Initial Velocity  (cm/s 0.1cm/s) | Average Actual Displacement  (cm 0.1cm) | Predicted Displacement  (cm0.1cm) |
| 115 | 50.5 | 50.7 |
| 166 | 72.0 | 73.2 |
| 203 | 88.2 | 89.5 |

Observations: The ramp stretched across two tables, and the two tables’ heights were not equal. This was taken into account when measuring the height of the ramp, and the difference was added to the height of the ramp. Observers were rotated out to avoid bias.

**Results/Analysis**

This data supports the hypothesis, the displacement of the ball bearing after falling from the table was shown to be directly proportional to the velocity at which the ball bearing left the table. The data also supported the hypothesis wherein the constant of proportionality was shown to be approximately equivalent to the time, (1.6% error). The percent error was within reason, the smallest percent error was 0.39% for the first velocity (115cm/s), and the highest was 1.6% for the second velocity (166cm/s). Possible sources of error include but are not limited to; difference in height of tables, tables were not a perfectly level surface, error in measuring height of tables, error in measuring height of ramps, and error in measuring displacement of ball.

**Conclusions**

The results of the experiment fell in line with the original hypothesis well, the results can be used to instruct the separability of horizontal and vertical motion, and even in interesting demonstrations, like the time it takes for a bullet fired to reach the ground versus the time for the bullet to be dropped, neglecting air friction. This experiment and its constants were regulated rigorously, because if they weren’t, their results may not be true. One way to improve the experiment would be to test the velocity during the trials instead of prior to, for example, the ball dropped would go through the time gates, and then fall so that its results would be consistent.