Projectile Motion and Conservation of energy
PHYS 1493

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1 Introduction

In this experiment, we test our ability to predict the motion of a small projectile using simple equations. We will carry out a series of trials and perform statistical analysis. We will then compare our data to expected values derived using equations (1), (2), and (3).

Work by Friction
$$W_f = mg(h'_1 - h'_2) \tag{1}$$

Initial Velocity
$$v_0 = \sqrt{\frac{10}{7m}(mg(h_1 - h_2) - W_f)} \tag{2}$$

Projectile Motion
$$V_x(t) = V_0 cos(\theta), \quad V_y(t) = V_0 sin(\theta) - gt \tag{3}$$

2 Method

a. Estimate the work done by friction

    (a) Adjust the ramp angle adjustment screw such that when the sphere is released at the release point, the sphere makes it just to the edge of the ramp before reversing direction.

    (b) Record measurements h'_1, and h'_1.

    (c) Use equation (1) to derive work done by friction W_f. Note that the mass of the sphere is not necessary. Calculating $\frac{W_f}{m}$ will suffice since m will be canceled out in equation (2).

b. Conduct Trials

   (a) Adjust the ramp angle adjustment screw such that:

$$h_1 - h_2 > 2(h_1' - h_2') \tag{4}$$

   (b) Use the new measurements of the ramp h_1, h_2, h_3, D, L and the equations (1), (2), and (3), to predict where the sphere will land.

   (c) Release the sphere from the release point and confirm if the prediction is accurate.

   (d) Place a sheet of white paper on the floor where the sphere is predicted to land.

   (e) Place a sheet of carbon paper on top of the white paper. Tape both down.

   (f) Draw crosshairs on the sheet through the point where the sphere is predicted to land.

   (g) Release the sphere 20 times and record the results.

c. Repeat the procedure for a different set of measurements, h_1, h_2, h_3, D, L and a different sphere.

3 Data

x(cm)	z(cm)
1.90	-0.10
2.45	-0.15
2.55	-0.35
2.75	-0.35
2.80	-0.45
2.55	-0.05
2.70	0.00
2.95	-0.20
3.20	-0.30
2.30	0.30
2.40	0.25
2.45	0.10
2.60	0.20
2.65	0.20
2.70	0.30
2.85	0.05
3.00	0.40
2.60	0.05
2.65	0.05
2.70	0.10

Table 1: Metal, Trial 1

x(cm)	z(cm)
1.65	3.25
2.00	3.10
1.80	3.05
1.90	2.85
2.15	2.85
2.40	2.80
1.85	2.65
2.05	2.65
2.90	2.70
1.80	2.60
1.70	2.40
1.95	2.55
2.10	2.50
2.00	2.35
2.00	2.80
2.10	2.80
1.90	2.60
2.05	2.60
2.20	2.60
2.10	2.50

Table 3: Metal, Trial 2

x(cm)	z(cm)
3.15	1.45
2.70	1.80
2.65	1.90
2.55	1.95
2.40	0.20
3.15	2.00
3.75	2.15
2.60	2.25
1.80	2.20
1.40	2.35
2.35	2.45
2.40	2.45
2.70	2.50
2.95	2.70
3.25	2.65
2.45	2.95
2.60	2.90
2.75	2.75
2.80	3.00
2.90	3.00

Table 2: Plastic, Trial 1

x(cm)	z(cm)
-1.65	-2.85
-2.35	-2.80
-3.00	-2.85
-1.90	-2.40
-0.70	-2.30
-1.40	-2.25
-2.40	-2.15
-1.65	-2.45
-1.60	-2.10
-1.30	-1.70
-1.40	-1.50
-1.55	-1.45
-1.85	-1.25
-1.80	-1.45
-2.80	-2.00
-2.45	-2.10
-2.65	-1.85
-2.60	-1.65
-2.35	-1.45
-2.20	-1.70

Table 4: Plastic, Trial 2

Sphere	Trial	h_1' (cm)	h_2' (cm)	h_1 (cm)	h_2 (cm)	D (cm)	L (cm)	h_3(cm)
metal	1	118.2	116.0	120.6	114.6	27.3	29.2	105.9
plastic	1	120.4	114.6	127.0	109.7	26.5	29.2	103.2
metal	2	118.2	116.0	127.0	109.7	26.5	29.2	103.2
plastic	2	120.4	114.6	124.7	111.4	27.2	29.2	104.3

Table 5: Measurements of each trial

4   Data Analysis

We calculate the mean and the errors as described by equations (5), (6), and
(7).
Mean

$$\bar{x} = \sum_{i=1}^{N} x_i \tag{5}$$

Sample Standard Deviation

$$s = \sqrt{\frac{\sum(x_i - \bar{x})^2}{N - 1}} \tag{6}$$

Standard Error

$$\sigma_x = \frac{s}{\sqrt{N}} \tag{7}$$

Sphere	Trial	$\bar{x} \pm \sigma_x$ (cm)	$\bar{z} \pm \sigma_z$ (cm)
Metal	1	2.637 ± 0.062	0.003 ± 0.054
Plastic	1	2.67 ± 0.11	2.28 ± 0.15
Metal	2	2.030 ± 0.060	2.710 ± 0.052
Plastic	2	-1.98 ± 0.13	-2.01 ± 0.11

Table 6: Observed Means and their uncertainties

In figure 1, even though all the distributions are roughly bell-shaped, only the
first trial of the metal sphere has a distribution that centered around the ex-
pected value. In the remaining trials, the overall shift in the points is evident of
systematic errors. There are many factors that could have caused this shift. Two
possible factors include the presence of wind in the room toward one direction,
and a error in the direction of the release ramp during setup. Furthermore, in
each trial, the degree of spread in the x and z directions are very similar. How-
ever, the trials for the metal sphere had significantly smaller spread than those
of the plastic balls. This could be attributed to the fact that the metal balls
have more mass, and thus their trajectories are less prone being affected by the
random changes in the wind. Additionally, the plastic is not a conductor, which
means that it is able to hold a charge. The plastic's trajectory may be affected
by electromagnetic forces. Altercations to reduce spread include performing the
experiment in a vacuum, getting rid of static electricity, using denser spheres
such as those made from lead.
If instead, a hollow plastic sphere was used for the experiment, its moment of
inertia would increase and its mass decreases. This would cause v_0 to decrease.
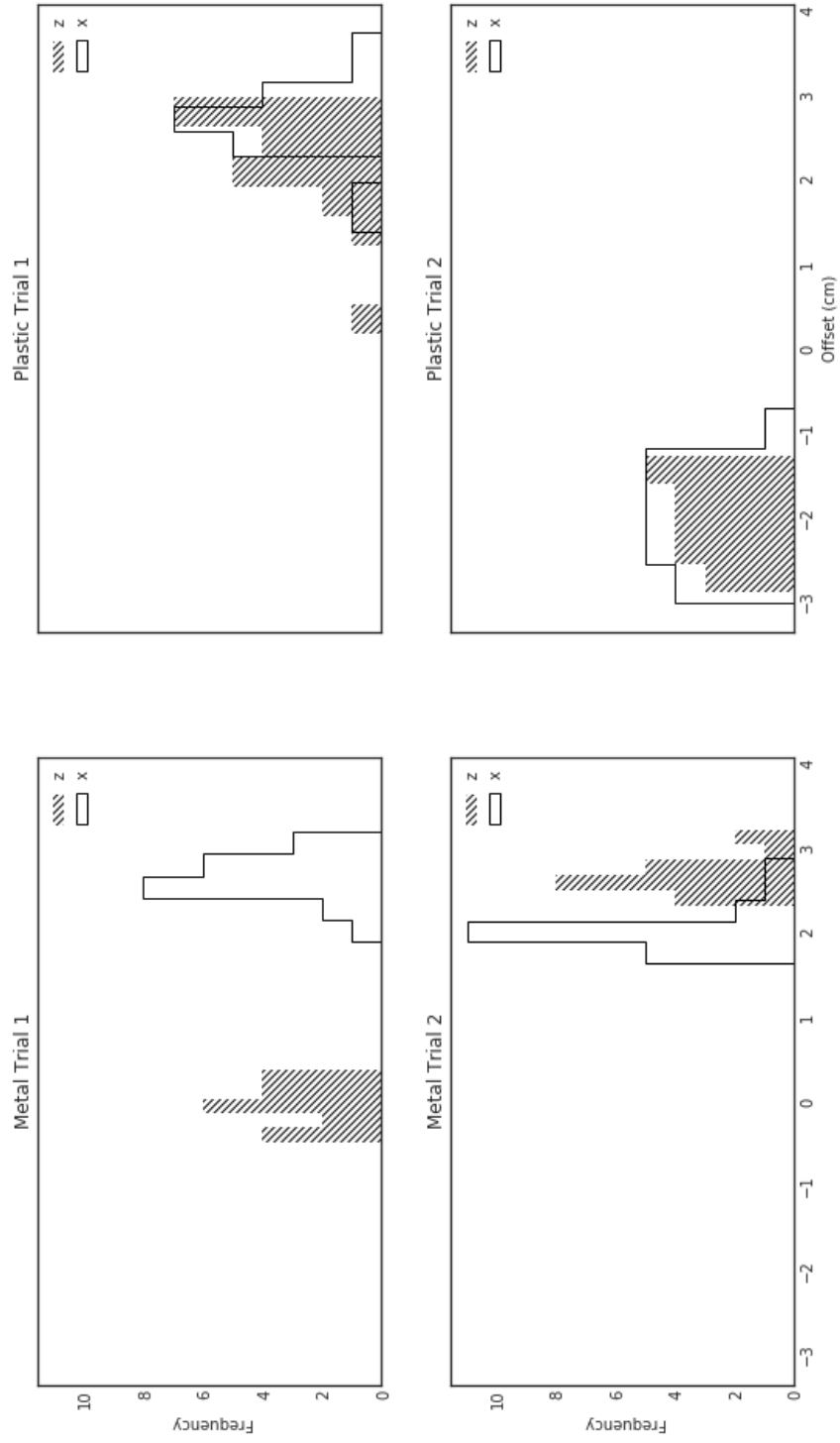Thus, mean distance would decrease, and spread increases.

Figure 1: Difference between actual and expected positions

5 Conclusions

The accepted value (periodic table) is $24.3\,\mathrm{g\,mol^{-1}}$?. The percentage discrepancy between the accepted value and the result obtained here is 1.3%. Because only a single measurement was made, it is not possible to calculate an estimated standard deviation.

The most obvious source of experimental uncertainty is the limited precision of the balance. Other potential sources of experimental uncertainty are: the reaction might not be complete; if not enough time was allowed for total oxidation, less than complete oxidation of the magnesium might have, in part, reacted with nitrogen in the air (incorrect reaction); the magnesium oxide might have absorbed water from the air, and thus weigh "too much." Because the result obtained is close to the accepted value it is possible that some of these experimental uncertainties have fortuitously cancelled one another. j