## Experiment #0

## Data Analysis

Date:_____

Name:_____ Section:_____

**Purpose**

To learn how to use data for analysis: conversion of units, plotting data, re-plotting data to obtain a straight-line graph, finding the slope of a straight-line graph, using the slope of a graph to find a physical quantity, calculating a percent error.

**Exercise 1.** Table 1 shows the data for a baseball, initially at rest, falling straight down in air. The distance was measured with an ultrasonic ranger placed above the ball.

**Table 1. Freely falling baseball**

| Time, $t$ (s) | Distance from the detector (m) | $t^2$ ($s^2$) | Displacement, y (m) |
|---|---|---|---|
| 0 | 0.872 | | |
| 0.10 | 0.922 | | |
| 0.20 | 1.061 | | |
| 0.30 | 1.287 | | |
| 0.40 | 1.635 | | |
| 0.50 | 2.079 | | |

1. Fill in the $t^2$ and displacement columns. The displacement is the distance of the ball that traveled from its initial position at $t = 0$.

2. Plot displacement $y$ vs. time $t$. (This means that $y$ is the ordinate (vertical axis) and $t$ is the abscissa (horizontal axis)).

3. Plot $y$ vs. $t^2$. Draw a best-fit straight line to the data. Find the slope of the graph with units. (Show calculation with units together with your graph on a graph paper.)

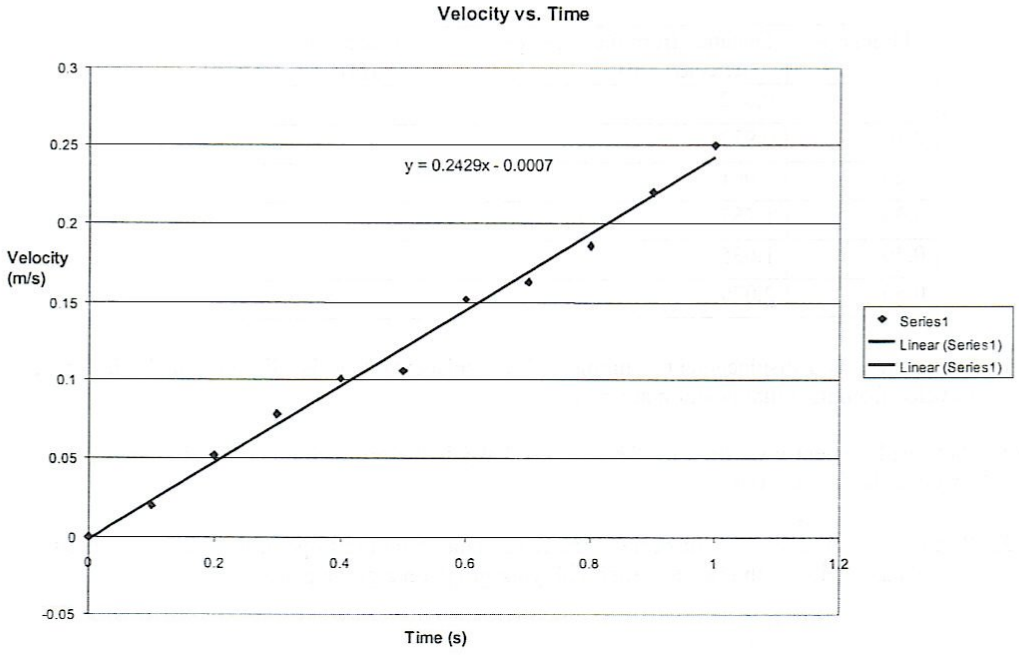
   Slope = (units)

4. What physical quantity (velocity, acceleration, etc.) does the value of the slope of the graph indicate? ( Hint: The displacement of a freely falling body with the initial speed zero is given by $y = \frac{1}{2}gt^2$ .)

5. Determine the experimental value of $g$ from the value of the slope of your graph.

6. Find the percent error of the experimental value of $g$ using $g$=9.81 m/s$^2$ as the accepted value.

**Figure 1. Example of a graph with a best-fit straight line**



**Exercise 2.** Table 2 shows the acceleration of a car on an air track (frictionless surface) under a constant force.

**Table 2. Acceleration of a car under a constant force**

| Total mass, $m$ (g) | Acceleration, $a$ ($m/s^2$) | Total mass, $m$ (kg) | $1/m$ ($kg^{-1}$) |
|---|---|---|---|
| 50 | 15.72 | | |
| 100 | 8.37 | | |
| 200 | 4.02 | | |
| 400 | 1.98 | | |
| 800 | 1.03 | | |
| 1600 | 0.47 | | |

1. Convert the unit of the total mass from grams to kilograms and write the results in the third column.

2. Calculate the inverse of the mass (in $kg^{-1}$) and fill out the fourth column.

3. Plot $a$ vs. $m$

4. Plot $a$ vs. $1/m$. Draw a best-fit straight line to the data and find the slope of the line. (Show calculation with units together with your graph on a graph paper.)

   Slope = (units)

**Exercise 3.** The period of pendulum $T$ is given by

$$T = 2\pi\sqrt{\frac{l}{g}} \tag{4}$$

where $l$ is the length of the pendulum and $g$ is the gravitational acceleration, $9.80 m/s^2$.

The table shows the data of the period of a pendulum as a function of length.

| Length, l (m) | Period, T (s) | $T^a$ ( ) |
|---|---|---|
| 0.200 | 0.91 | |
| 0.400 | 1.26 | |
| 0.600 | 1.58 | |
| 0.800 | 1.80 | |
| 1.00 | 2.08 | |
| 1.20 | 2.22 | |

a. Plot $T$ vs. $l$.

b. Replot the graph to straighten it out, *i.e.*, plot $T^a$ vs. $l$ where $a$ is the exponent to be determined from Equation 4.

c. Find the slope of the graph (with units).

***Technical physics***

**Exercise 4.** The number of radioactive nuclei decreases exponentially with time as shown by

$$N = N_0 e^{-\lambda t} \tag{5}$$

where $N$ is the number of nuclei present at time $t$, $N_0$ the original number of nuclei present (*i.e.* at time $t = 0$), and $\lambda$ the decay constant of the process, *i.e.*, the probability that any single nucleus will decay in one second. This function can be also straightened out as follows. First, dividing both sides of the equation by $N_0$ gives

$$\frac{N}{N_0} = e^{-\lambda t} \tag{6}$$

Taking the natural logarithm of both sides of the equation yields

$$\ln \frac{N}{N_0} = -\lambda t \tag{7}$$

The $\ln \frac{N}{N_0}$ vs. $t$ graph will be a straight-line graph. The slope will be *negative* ($-\lambda$), showing the time *decay* of the nuclei.

a. Calculate N for t = 0 to t = 10.0 minutes in increment of 2.0 min (convert to seconds). with $N_0 = 5.0 \times 10^{22}$ and $\lambda = 5.66 \times 10^{-4}\ s^{-1}$. (This is the probability that any single ${}^{11}_{6}C$ nucleus will decay in one second.) The exponent must be dimensionless. Since $\lambda$ is in $s^{-1}$, time $t$ must be in seconds.

b. Plot $\ln(N/N_0)$ vs. $t$.

c. Find the slope of the line (with units). What physical quantity does the slope indicate?