**Inertial Mass**

**I. Introduction**

Before you come to your first laboratory session, review this section and the relevant sections in the course text suggested for this experiment in the *General Information* handout. Additionally, read over the sections “*Computer Usage*” and “*Measurement and Error*”.

1. In this experiment you will study the characteristics of a device sometimes called the “Inertia Balance” and will use it to measure “inertial mass”. You will compare this inertial mass of an object with its "gravitational mass" as measured with a laboratory balance. The concepts of mass as a measure of inertia, as distinct from gravitational mass related to weight, and the empirical equivalence of inertial mass and gravitational mass will thus be demonstrated.

1. The idea of periodic motion and the concept of the period T, the time for one complete oscillation, will be introduced.
2. Data will be recorded and displayed in tabular and graphical forms by hand and also by computer, and graphical analysis will be used to verify empirical relationships.
3. The concepts of errors, standard deviations, and error propagation discussed in the handout Measurement and Error will be used to evaluate your observations. These concepts will continue to be used in the analysis of other experiments during the course of the semester.

**II. Required Equipment**

Provided in the Laboratory:

1. Swinging platform (inertia balance), set of known masses, unknown mass, laboratory balance, photogate, Pasco Signal interface, computer.
2. Graph paper.

You must bring:

1. Laboratory Report Form to record procedures, notes, diagrams, measurements, etc.

**III. Procedure**

Record the identifier number of the computer at your lab bench on your Laboratory Report Form, and names of all lab partners.

Before you begin, make sure that the platform of the Inertia Balance is fastened together tightly but can swing freely through the photogate. *(If the platform comes apart before your measurements are complete, you will have to start all over again.)*  Place a mass *m*= 500g on the platform and fasten it securely in place. Start the platform swinging from side to side. This period will be found to depend on the mass. Does the amplitude of the motion (the size of the swings) also affect the period significantly? You must find that out by running the experiment and observing in a qualitative way what happens. Note your observations on your Laboratory Report form.

The experiment will be performed using the Data Studio program for data recording and the Graphical Analysis program to form a master data table, and to carry out data fitting and analysis. A step by step guide to each of these procedures is provided below; general reference and screen samples may be found in Computer Tutorial.

**A. Data Recording - using the Data Studio Program.** *(Refer to Section 2 of Computer Usage for Additional Information)*

1. To run the experiment, double-click on the Data Studio icon on the computer’s Dock. A Control Window with a Menu Bar across the top should appear on the screen.

2. Double-click on the first (leftmost) channel in the picture of the Pasco interface. From the pop-up menu, scroll down and select “photogate and pendulum”.

3. To create the data table and graph, drag the icons for “Table” and “Graph” from the lower left pane to the “Period” in the upper left pane.

4. Start the inertial balance oscillating, by pulling it sideways several inches and releasing it.

5. Now Click on the “Start” button in the Control Window to begin data recording. The graph will update dynamically in real time as the data taking progresses. Is the period a constant throughout the motion? If not, can you speculate about what causes the variation of period with time? When the period begins dropping off, click on the “Stop” button. Depending upon conditions, you may be able to record 30 to 100 measurements for a given mass added to the platform.

6. Perform the above procedure five times using a different amount mass secured to the platform for each trial. Use the values 0g, 250g, 500g, 750g, and for the final trial use the unknown mass. After these measurements, you should have five “Runs” in your data table.

7. Now remove the platform from the inertia balance fins (keep all bolts, nuts, posts attached). Measure the mass of the platform (the “gravitational” mass) on a lab balance. Estimate the error in this measurement. Similarly, measure the mass of your unknown. Estimate the error. Record these values on your Laboratory Report Sheet.

**B. Data Plotting - using the Graphical Analysis (GA) program.**

1. If Graphical Analysis is not already open, open it by double clicking on the Graphical Analysis Icon on the Dock.

2. For each run in Data Studio, select the data by highlighting it with the mouse, and use the Edit menu to Copy the data for that run.

3. Using the “New Manual Column” command in Graphical Analysis, create new columns to hold the data (if necessary) and then use the Edit menu to Paste the data. Do this for each of the five runs.

1. Remove the “Elapsed time” column for each run. Label the period columns by mass used (e.g. T0, T250, etc.) by clicking on the box at the top of the column.

5. Create a “New Calculated Column.” Use the “Generate values” option to generate at least enough values 1, 2, 3… to correspond to the number of counts in your longest run. Title this column “Index”.

6. If no graph is open, from the Menu Bar, pull down the “Graph” menu and select “New Graph”. A graph will be displayed on the right-hand side of the screen. With the mouse, click and hold on the label on the horizontal axis. Select “Index”.

1. Click and hold the vertical axis label. Select “More…” and in the dialog box, check the boxes for each of your known masses (T0, T250, etc…). The data should look just like it did when you were recording it with Data Studio.

8. To find the mean and standard deviations for each data set, use the “Statistics” command on the “Data” menu, and check each box in the dialog box that appears. Statistics boxes containing the mean and standard deviation should appear on the graph for each of your runs.

7. Fill in the data table (last page of this hand out) in which you can record physical quantities and their errors, for example: mass added to the platform (m, units of grams or kilograms); the best estimate of the period (T, units of seconds); its error (T); the number of measurements (N) of the period ;the square of the period (T2) and its error (T2  = 2 T T).

8. You can now print everything by pulling down the File menu and selecting “Page setup” and choosing “landscape mode” (sideways printing) and clicking on “Ok”. Next from the File menu select “save”. Save to the data folder under a name such as 10.288.ga. Then choose “Print” in the File menu. Print a copy for each member of your lab group.

**IV. Analysis**

**A. Plot a graph of your results.** *(Refer to Section 5 of Measurement and Error for guidance)*

1. Create a new data table in Graphical Analysis. Create four manual columns (m, N, T, and std. dev. of T) and fill them with the values you obtained from the statistics above. Then the error in the mean of T (δT) can be calculated by creating a “New Calculated Column” and dividing the std. dev. of T by the square root of N. Similarly create calculated columns for T2 and δT2.
2. For the first graph, plot T on the vertical axis versus m on the horizontal axis. It is first necessary to choose suitable scales for both axes. Under “Options” choose “Graph Options”. On the “Axes Options” tab you can change the scaling to “Manual” and put in your own values. Also include error bars indicating the ±T values.

2. Print the graph and draw a smooth curve through the data. This curve is your determination of the empirical relationship between mass and period for this "inertia balance" .

3. Use your smooth curve and your values of T and T for the unknown mass to estimate its "inertial mass" and the corresponding error. Compare this "inertia mass" with the "gravitational mass" you measured by weighing the unknown. Compute the difference between the values and the error in the difference. Compute the % difference between the values. Are the values consistent when you consider the errors?

**B. A second graph.**

1. Later in this physics course you will learn that the motion of the inertia balance is called simple harmonic motion or SHM and that there is good reason to believe that T is proportional to , or T2 is proportional to m. If this is true, then a graph of T2 versus m should be a straight line. (As discussed in "*Measurement and Error*", there are advantages to plotting data so that the relationship is a straight line.) Test this by plotting T2 as a function of m. Again leave room for negative values of m. Error bars must be included. Use Graphical Analysis to make a linear fit. Use the fit equation to determine the intertial mass of the unknown, with error. Compare your result with the values you found in part IV.A.3 above.

**C. Comparisons.**

1. The period measured for m = 0 is the period corresponding to the mass of the platform alone. One might then think that the mass on the empirical curve corresponding to T = 0 would be the negative of the platform's mass since it is the negative amount that would have to be added to the platform to make the total mass zero. Try to extend your curve of part IV.A.1 below m = 0 to find the negative value of m where the curve crosses T = 0. Do you feel sure that your extension of the curve is right? Estimate the error in this value of m. Extend the lines on the graph of part IV.B.1 to find the m intercept (the value of m for T2 = 0) and the error in the intercept. Which of these two estimates of m for T or T2 = 0 do you feel to be more reliable? Why? Compare these values of m with each other and with the mass you obtained by weighing the platform. Are they the same within errors? Can you think of any reasons why you might not expect the values to be the same? What do YOU conclude about the hypothesis that the value of m for T = 0 should be the negative of the platform's mass? Why?

2. From the results of this experiment, what do YOU conclude about the relationship between "inertial mass" and "gravitational mass"? Summarize the evidence that leads to your  
conclusions.

DATA TABLE FOR “INERTIAL MASS “ EXPERIMENT

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| m (gm) | T (sec) | N | σT (sec) | (sec) = |  | =  2\*T\* |
| 0.0 |  |  |  |  |  |  |
| 250 |  |  |  |  |  |  |
| 500 |  |  |  |  |  |  |
| 750 |  |  |  |  |  |  |
| unknown |  |  |  |  |  |  |

measured (gravitational) mass of unknown m =