Free Fall

We say an object is in *free fall* when the only force acting on it is the earth's gravitational force. No other forces can be acting; in particular, air resistance must be either absent or so small as to be ignored. When the object in free fall is near the surface of the earth, the gravitational force on it is nearly constant. As a result, an object in free fall accelerates downward at a constant rate. This acceleration is usually represented with the symbol g.

Physics students measure the acceleration due to gravity using a wide variety of timing methods. In this experiment, you will have the advantage of using a precise timer connected to a Free Fall Apparatus. When the ball is released it falls on the Target Pad and the timer measures the time of fall. You will vary the distance the ball falls and measure the time of fall. This data can be used to plot graphs of position vs time, and velocity vs time. The velocity graph is then used to determine the acceleration of the ball. Finally, this acceleration will be compared with the known acceleration due to gravity.

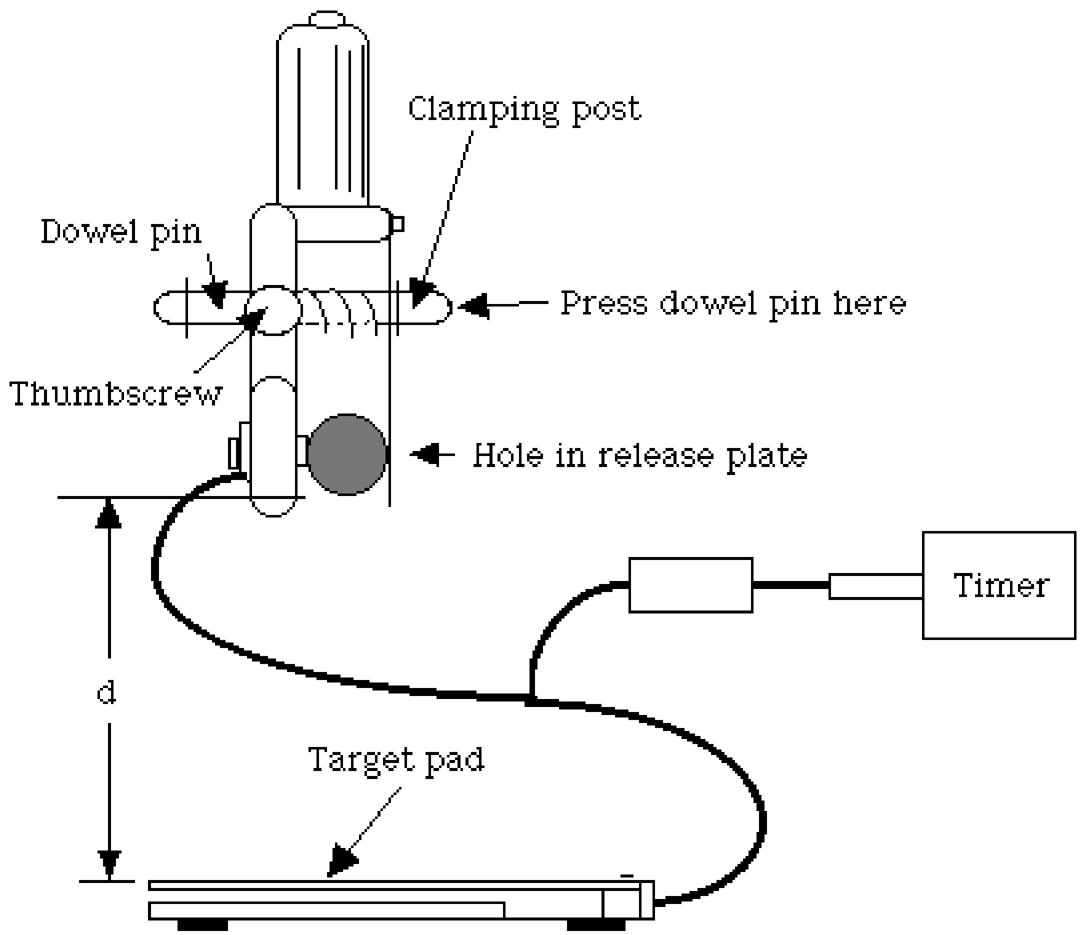

Figure 1

MATERIALS

- Free Fall Apparatus
- Table Clamp and Rod
- Steel Ball
- Meter Stick and Ruler
- Smart Timer

PROCEDURE

1. Set up the apparatus as shown in Figure 1. The Target Pad should be placed directly below the ball. Start with the bottom of the ball approximately 10cm from the Target

Pad. Set the Smart Timer to Stopwatch mode. You must do the following in the order indicated below:

   a. Put the ball in the release apparatus, pull the dowel pin, and tighten the thumbscrew to hold the ball in place.

   b. Press the Start/Stop button on the Timer. When a * is displayed the timer is ready.

   c. Tap the Target Pad a few times.

2. Loosen the thumb screw to release the ball. When the ball hits the Target Pad the Timer shows the time of fall. Obtain the average of three trials for the time of fall.

3. Increase the distance between the ball and the Target Pad by 30cm and repeat step 1. Keep increasing the distance till you have six or seven data points. Clearly organize your data in data tables.

4. Decide whether you want to designate "up" as positive or negative. Clearly indicate this choice in your report.

5. Construct a data table for displacement ($x-x_0$) vs time (t) consistent with your choice of positive and negative direction.

6. Use Logger Pro to construct a graph of position vs time. **Be sure to include (0,0) as a data point.** What type of function best describes the relationship between position and time? Use the Curve Fit feature of the software to fit your data with the expected function. Start the "time" axis from 0, and adjust the "position" axis to clearly see the shape of the curve. Print this graph and include it in your report.

7. Use the printed graph and by hand determine the instantaneous velocity of the ball at t=0.25s. Clearly show all your calculations and reasoning.

8. Use the following process to find the maximum uncertainty in your data points.

   a) On the position graph displayed on the computer screen find the data point that is farthest from the best-fit-curve. Also find the same data point in the data table.

   b) Put the cursor on that data point. Notice you can read its coordinate on the bottom left corner of the graph. Using these coordinates, figure out how much the point must move horizontally to be on the best-fit-curve. This is the absolute uncertainty in "time". Similarly, figure out how much the point must move vertically to be on the best-fit-curve. This is the absolute uncertainty in "displacement".

   c) Convert these absolute uncertainties to percentages and add the percentages together. This is the overall uncertainty for the acceleration you will calculate below.

9. Use the Tangent feature of Logger Pro to determine the instantaneous velocities at five different points. Double click on the graph and select "Interpolate" to use the whole curve fit. Double click on the "Time" column, click on the "Options" tab and set the precision to 2 decimal places. Record instantaneous velocity vs time data in a data table.

10. On a graph paper, construct a graph of velocity vs time. **Be sure to include (0,0) as a data point.** Then use the graph to determine the acceleration. Does this acceleration agree with what you expected to get? To answer this question you must compare %uncertainty with %error to see if the calculated value falls within the range of uncertainties.