Acceleration Due to Gravity
These questions need to be completed before entering the lab. Show all workings.

**Prelab 1:**
For a falling ball which bounces, draw the expected shape of the vertical position vs time graph.

**Prelab 2:**
From the position vs time graph of an object moving with constant acceleration, how could you find the instantaneous velocity?
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Part V: Summary
In this experiment you will study the motion of a falling ball which experiences constant acceleration.

You will use a **Motion Detector** to measure the position of the ball as a function of time. The motion detector is connected to the computer through a **LabPro** interface and controlled using **Logger Pro**. You will use this combination of hardware and software to generate graphs of distance, velocity, and acceleration as functions of time. The goals of this experiment are:

- To represent the motion of an object through graphs of position, velocity, and acceleration versus time.
- To investigate the relationship between displacement versus time, velocity versus time, and acceleration versus time representations of a given motion.
Part II: Apparatus

The apparatus for this experiment are:

- Ball
- Balloon
- Motion sensor
- Support rods
- Clamps
Part II: Apparatus Setup

Assemble your apparatus as shown.

The motion detector only records position within a range of 0.15 - 6 m.

Be sure to remain within this range during the experiment.
Part III: Data Acquisition

Make sure that the LabPro is connected to the computer and that the motion detector is plugged into DIG/SONIC 1. Open *Logger Pro* by clicking on the icon below:

![Logger Pro icon](image)

*Logger Pro* should open three graphs:

- position vs time,
- velocity vs time, and
- acceleration vs time.

The time axis should have a maximum value of 3 seconds.

If *Logger Pro* does not contain these graphs, consult an instructor.
Part III: Data Acquisition

Before collecting data:

Zero the motion sensor relative to the table top:

Make sure the path is clear (nothing between the motion sensor and the table top)

Click Experiment then Zero.
Part III: Data Acquisition

Hold the ball under the motion detector at a minimum distance of 0.15 m.

Click the Collect button in Logger Pro.

*Logger Pro* will begin to collect data (collection begins when the detector begins to "click" rapidly).

Release the ball smoothly ensuring it hits the table top after it falls.

*Logger Pro* should now display three graphs representing the ball’s motion: *position vs time*, *velocity vs time*, and *acceleration vs time*.

Do not print your graph yet!

Printing instructions are on the following slides.
Part IV: Data Analysis

Examine your data. Are they reasonable?
If not, repeat the experiment or consult an instructor.

When you are happy with your data, save it!
First switch to LoggerPro, then click File and Save As. Change the
name of the graph to graph1.cmbl and save the file to the Desktop.
Autoscale each graph by clicking on it then clicking

CHECKPOINT: Have an instructor check your graph and initial your lab report.

QUESTION 1: Did the shape of your position vs time graph on LoggerPro match your predicted graph from Prelab Question 1?
Explain any differences.
Part IV: Data Analysis
Print your Graph

Click File then Page Setup.
Click landscape orientation.
Click OK.

Click File then Print.

To select the only necessary page:
Click Pages. Choose Single. OR Choose From 1 to 1.

Click File and Print to print your graph.
Attach your graph to your lab report.
Part IV: Data Analysis

In *LoggerPro*:

Display the coordinates in a box on the graph:

- Click on **each** graph to activate it
- Click **Analyze** then **Examine** or click
Part IV: Data Analysis

On your printed graphs:

On each of all three graphs, identify where the ball hits the table for the first time. **Label this A.**

On the position vs time graph and the velocity vs time graph, circle a region where the ball is in free fall and moving down. **Label this B.**

On the position vs time graph and the velocity vs time graph, identify a region where the object is in free fall and moving up. **Label this C.**

On each of all three graphs, identify where the motion changes from moving down to moving up. **Label this D.**

On each of all three graphs, identify where the motion changes from moving up to moving down. **Label this E.**
Part IV: Data Analysis

Activate the position vs time graph and use the Analyze then Examine function to:

QUESTION 2: Examine your position vs time graph and record the time, $t_1$, at which the ball first hits the table.

Also record $t_2$, the time at which the ball hits the table for the second time.

You may use the Analyze then Examine function to identify co-ordinates on the graphs.

QUESTION 3: What are the position and velocity at time $t_1$? Are these values expected? Comment.

By examining the velocity vs time graph in the region between $t_1$ and $t_2$:

QUESTION 4: What is the maximum upward velocity? What is the maximum downward velocity? Are these two velocities related? Is this result expected?
Part IV: Data Analysis

The vertical displacement of a object in free fall is given by

\[ y_f = y_i + v_{yi} t - \frac{1}{2} g t^2 \]

This may be rearranged:

\[ y_f = -\frac{1}{2} g t^2 + v_{yi} t + y_i \]

where \( y_i \) is the initial vertical displacement, \( v_{yi} \) the initial vertical velocity, \( g \) is the acceleration due to gravity.

You are going to fit your data points to a smooth quadratic curve of the form

\[ y = At^2 + Bt + C \]

The above equations will serve as a guide in analyzing your results.
Part IV: Data Analysis

QUESTION 5: To what physical parameter does $A$ in the fit equation ($y = At^2 + Bt + C$) correspond? Explain or show your workings.

What value do you expect for parameter $A$ (including units)? Record this value in Table 1.

If you are having trouble, refer to the previous slide.
Part IV: Data Analysis

Click on your distance vs time graph to activate it.
Highlight the region between $t_1$ and $t_2$, i.e. the first “bump”.
Part IV: Data Analysis

Click **Analyze** then **Curve Fit**.
Under **Options: Fit Type** select “Automatic”

Select **Quadratic** from the **General Equation** list and click **Try Fit**.

If the fit is satisfactory, click on **OK**. Enter the value of the Automatic best fit parameter **A** in **Table 1**.

Edit the title of your graph to “Distance vs. Time”.
Part IV: Data Analysis

QUESTION 6: How does your expected value of $A$ match the displayed value of the automatic curve fit? Comment on any differences.

QUESTION 7: From your automatic curve fit, what is the value of $g$ and its uncertainty?

Print your graph (with fit parameters) and include it with your lab report.
Part V: Data Acquisition and Analysis (Falling Balloon)

Inflate your balloon until it has a rounded shape (with approximately the same diameter as your ball).

Repeat your experiment using the balloon, i.e., drop the balloon and use the computer to record the position as a function of time.

Use *LoggerPro* to create an automatic fit to the position vs time data.

**Do not print this graph!**

Record your automatic fit parameter $A$ in Table 2.
Part VI: Summary

QUESTION 8: From your automatic curve fit, what is the value of the balloon’s acceleration and its uncertainty? How does this value compare with the acceleration of the ball?

QUESTION 9: Write the range of the value of $g$ found in Question 7. Is it equal to the accepted value of 9.81 m/$s^2$? Comment on any differences.

QUESTION 10: Why do the ball and balloon have different accelerations?

Hint: Think carefully about the forces acting on each object. How do those forces depend on the mass of the objects?
QUESTION 11: List at least 3 uncertainties in this experiment. Classify them as random or systematic.

- Make sure you have answered all Questions completely.
- Check that you have completed all Tables.
- Include your printed graphs from LoggerPro.