PHYSICS 121 ____ Experiment 2

Acceleration

The purpose of this lab is to measure the gravitational acceleration constant g by measuring the rate at which a falling object increases its speed. We learn the use of computerized lab equipment, helpful for later experiments too.

Equipment

1 computer for data taking
1 photo gate
1 interface box
1 plastic ruler
1 masking tape

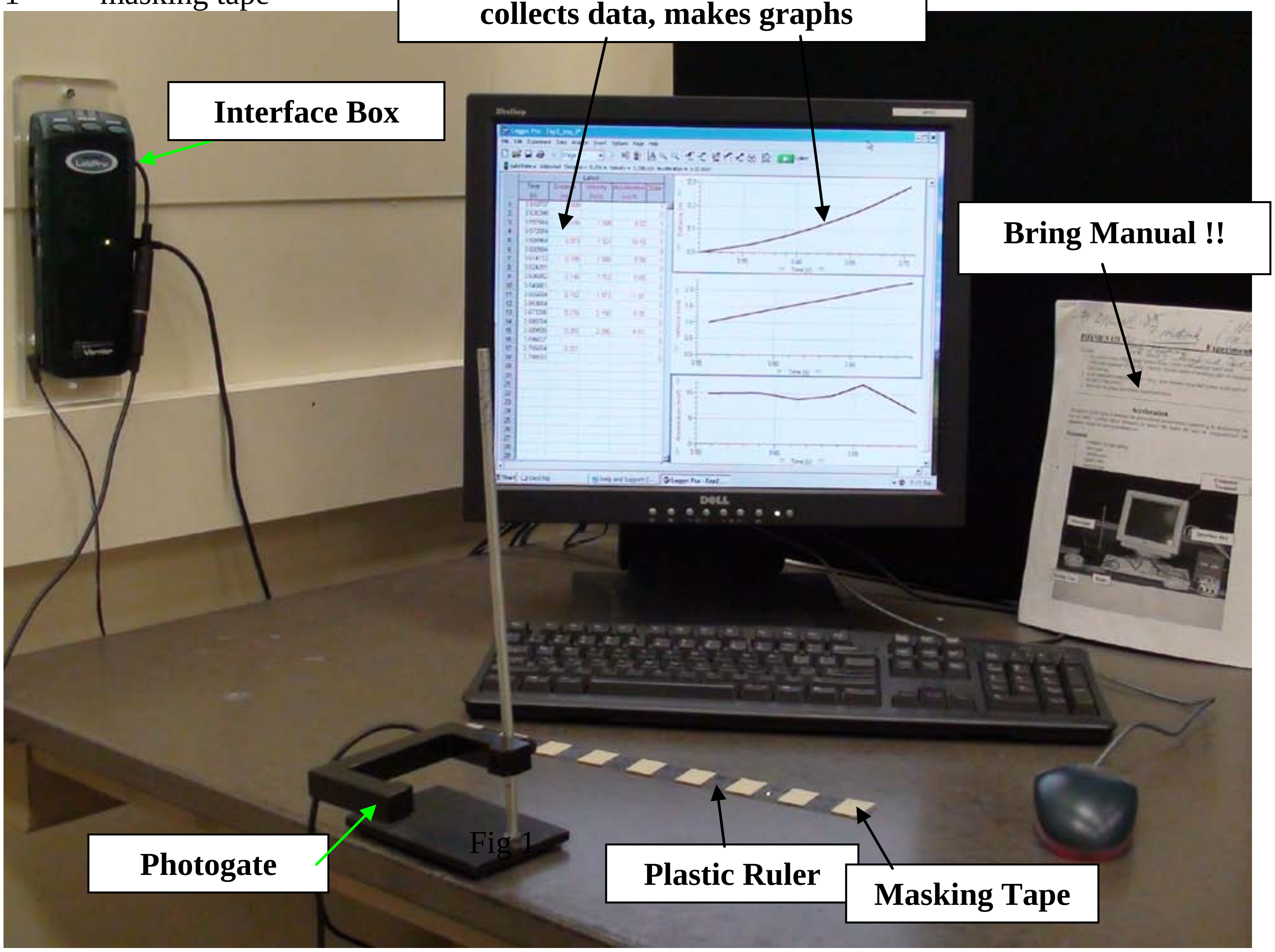


Fig 1.

Introduction

It is apparent that when we drop an object it falls to the ground. What may not be obvious is that the object is in fact accelerating, i.e. its velocity is continuously increasing. This acceleration is due to the earth's gravitational force.

Part I Measurement of the gravitational acceleration g by measuring velocity vs. time :

In this part, a ruler will be dropped through a photo gate. From this we can infer the rate at which the ruler will accelerate due to the earth's gravitational force. The clear plastic ruler will be marked at regular intervals with a masking tape that will block the light beam of the photo gate and turn on and off the timer which sends the results to the computer. The times are recorded by the computer and displayed on the monitor. Using the distance between successive pieces of masking tape and these times, the computer will perform the calculation of the average velocity of the ruler in these intervals during its fall. The results can be displayed graphically on the monitor in various instructive ways.

Procedure

We need to get the interval *d* (Fig.2) between two successive leading edges of the tape pieces, i.e. one piece of tape and one blank spot. To be more accurate, measure the distance *D* from the first leading edge to the last one on the ruler and divide it by the number of intervals *d* between them. Record your measurements in your **REPORT SHEET**.

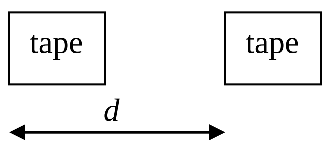
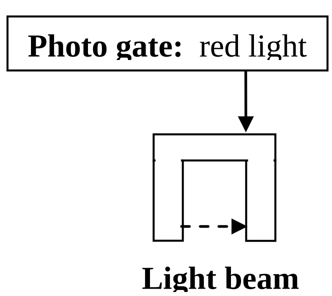


Fig. 2

The distance *D* is the **difference of two position measurements**, one at the begin and one at the end of *D*. Assume that at each end you have an absolute error of $\pm 1/2\ mm$ (this is $\pm 1/2$ of the distance between the incremental markings on the yard stick), $\pm 1/2\ mm$ for the beginning and $\pm 1/2\ mm$ for the end of *D*. From these errors, derive the absolute error for the distance *D* by applying expression (6) (valid for the propagation of the absolute errors in a difference of variables) in **"Error and Uncertainty" (EU)** and record it in your **REPORT SHEET**. Then obtain the absolute error of the interval *d* in Figure 2 using equation (1) in "EU" (valid for the multiplication of a variable with a constant factor, in your case the number of intervals *d* contained in the distance *D*). Record *d* and its error in your **REPORT SHEET**.

Now, connect the photo gate output to the interface box by plugging its cable into the **top** socket (labeled "DIG/SONIC 1") of the black interface box ("LabPro"). Test the photo gate: block the photogate beam with your finger and see the red light on the cross bar of the photogate turn on:



Get the **computer ready** for data taking:

Turn on the computer and check the system by following these instructions: double click the icon "**Exp2_xva_t**". A window with a spreadsheet on the left (having "Time, Distance, Velocity, Acceleration" columns) and empty graphs on the right (distance, velocity and acceleration vs time) comes up. On top is a window "**Sensor Confirmation**". It should show:

Sensor Specified In File:	**Sensor To Set Up:**	**Where:**	**Use:**
✓ Photogate	Photogate	DIG1 on LabPro	✓

Click OK.

[If you don't see the above do:
Click Experiment->Set Up Sensors->Show All Interfaces->DIG/SONIC1: you can check the photogate by blocking it and seeing "Unblocked' go to "Blocked".
Click "Close"]

Enter your value for the distance *d* in Fig. 2 above into the program: Click Data->User Parameters: the window "**User Parameters**" comes up and should show:

Name:	**Value:**	**Units:**	**Places:**	**Increment:**	**Editable:**
PhotogateDistance1			4	1.0000	✓

enter your value of *d* in meters here

Click OK.

Click Experiment->Start Collection. You should see "Waiting for Data" on the right hand side graph. If you waited too long before dropping the ruler and the message has disappeared repeat the start. Any time you want to repeat your measurement simply restart.

While the message "Waiting for data" is on hold the ruler just right above the photogate (with the first masking tape edge closely above the light beam) and then drop it through the photo gate so that the tape on the ruler interrupts the light path of the photo gate. Make sure that the ruler is aligned vertically before you drop it, such that it is oriented perpendicular to the light beam during its fall. After the ruler has fallen through the photogate you see the collected data on the screen: Time, Distance, Velocity, Acceleration. After a little while the corresponding graphs appear on the right.

You should have **at least 5 velocity values** and a straight line velocity - time graph without a kink on the right. If not repeat the measurement. Copy both time and velocity values into Table 1 in your **REPORT SHEET.**

Make sketches of distance vs time, velocity vs time and acceleration vs time in the grids supplied in your **REPORT SHEETs.** Label **axes, units** and **scales**. Make sure your vertical axes start their scales at zero. If needed click on the graph that doesn't , click Options->Graph Options and choose "Autoscale from 0".

Analysis:

Analyzing Table 1 **neglect the error in time *t*** and assume that the **relative error** of the interval ***d*** is equal to the **relative error** of the velocity ***v***. (This can be done since $v = (1/t)\, d$, and $(1/t)$ with t being error free is a constant factor. Then expression (3) in "EU" tells us that v and d have the same relative error.) Calculate the **absolute** error of v using the expression (4) in "EU" and fill in the last column of Table 1 for further analysis later.

Q1: What are the 3 equations of 1 dimensional motion with constant acceleration for displacement, velocity, and acceleration? (Ch2, sheet 13, 14)

Q2: What is the expected relationship between acceleration vs. time i.e. what is the slope for the acceleration vs. time graph (examine your plot and the equation you wrote for acceleration in Q1)?

Q3: What kind of slope does the velocity vs. time graph have, is it contant or not (examine your plot and the equation you wrote for velocity in Q1)?

Q4: What type of slope is expected for the displacement vs. time plot, is it constant or does it increase or decrease (examine your plot and the equation you wrote for displacement in Q1)?

Plot the values of velocity and time from your Table 1 into the grid provided in your **REPORT SHEET**. Error bars for time can be neglected but be sure to **include error bars** for velocity. Get the **slope *k*** from your graph which best represents a straight line according to expression (10) in "EU" and determine the error of the slope according to expression (11) in "EU". **Do NOT include the point (*t*,*v*) =(0,0)!**

Q5: What is your experimental value of gravitational constant g_{exp} and its error? How is g_{exp} related to the slope of your graph from Q5 and its error? Compare it to the expected value of 9.81 m/s^2.

<u>Part II Repeated measurements of the gravitational acceleration *g* using the computer:</u>

For this part of the lab, we will use the computer program to determine the gravitational constant g by dropping the ruler several times through the photo gate.

Procedure

You are going to drop the ruler through the photo gate as you have done in Part I. You have already one value of *g* from Part I above. In order to get this value from the computer you click the graph, then click Options->Graph Options and check Velocity, click Done. Then click Analyze->Linear Fit: read the slope from the popup window with the fit results.

Which quantity is the slope of the velocity vs time graph ?

Repeat this 4 times and enter your results into Table 2 in your **REPORT SHEET**.

Analysis:

Calculate the average of the accelerations according to expression (5) in "EU". Also calculate its error using expression (5'') in "EU". Compare it to the expected value of 9.81 m/s^2.

<u>Part III Demonstration of non-zero initial velocity :</u>

In this last part, you will see what happens to the initial ("initial" is the time of the first interception of the photo gate beam) velocity v_o if the ruler is dropped from higher up above the photo gate.

Procedure

Hold the ruler a few inches above the photo gate and then drop it through the photo gate. Then look at the computer generated plot of velocity vs. time and record the initial velocity v_o of the graph in your **REPORT SHEET**.

Q6: What is the velocity equation for an object with your initial velocity and your measured value of g from Part II (replace v_o and a with their measured values) ? Is your initial velocity From Part III less or greater than in Part I ?

Q7: In part I Q5, why did we exclude the point (t,v) =(0,0) from the slope measurement ?

PHY 121 **REPORT SHEET (to be signed by instructor)**
EXPERIMENT 2 **<u>Acceleration</u>**

Name: ________________________________ Section:____________

SB#: ________________________ Date: ______________________

Labinstructor:______________________________

Part I Derivation of gravitational constant, g, by measuring velocity vs. time :

Distance *D* (from the first leading edge to the last one on the ruler) including its error (show your error calculation explicitly) and unit: ____

____

____[ ]

Number of intervals between first leading edge and the last one: _______________________________

Distance of interval *d* and its error (show your error calculation explicitly) and unit : __________________

____[ ]

Table 1:

Measurement #	Time (*t*) [ ]	Velocity (*v*) [ ]	Δv [ ]
1			
2			
3			
4			
5			

Δv for measurement #1 above (show calculation explicitly):_________________________________

____[ ]

Distance vs time (label all axes and units):

Velocity vs. time (label all axes and units):

Acceleration vs. time (label all axes and units):

Q1: $x(t)$=______________________________

$v(t)$=______________________________

$a(t)$=______________________________

Q2: ______________________________

____

Q3: ______________________________

____

Q4: ______________________________

____

Velocity vs. Time graph using data from Table 1 (with both axes labeled, error bars, units and ranges of v and t used for the calculation of your slope):

Show explicitly the calculation of slope and its error and units____

____

____

____[ ]

Q5: $g_{exp} \pm \Delta g_{exp}$ =____[ ]

____

____

The expected value of g____

Part II Repeated measurements of the gravitational acceleration *g* using the computer:

Table 2:

Measurement $\#_i$	[ ]
M_1	
M_2	
M_3	
M_4	
M_5	

Average and its error (show both calculations explicitly and units): ____

____

____

____[ ]

The expected value of *g* ____

Part III Demonstration of non-zero initial velocity:

v_0 =____[ ]

Q6: $v(t)$=____

Q7: ____

____