# Laboratory 2: Free Fall Motion – Prelab

## 1 Falling ball on a mystery planet

A ball is held above the surface of a mystery planet and dropped. The vertical position versus time is recorded, giving the following data.

| Time (in s) | Position (in m) |
|---|---|
| 0.00 | 20.0 |
| 0.20 | 19.0 |
| 0.40 | 16.0 |
| 0.60 | 11.0 |
| 0.80 | 4.0 |

a) According to this data, does the ball fall with constant velocity? Explain your answer.

b) Use the data at 0.00 s and 0.20 s to determine the average velocity from 0.00 s to 0.20 s. This represents the velocity midway during this time period, i.e. the velocity at 0.10 s.

c) Use the data at 0.20 s and 0.40 s to determine the average velocity from 0.20 s to 0.40 s. This represents the velocity midway during this time period, i.e. the velocity at 0.30 s. Continue this process to fill out the table.

| Time (in s) | Velocity (in m/s) |
|---|---|
| 0.10 | |
| 0.30 | |
| 0.50 | |
| 0.70 | |

d) Describe *how* you could use the data for velocity to check whether the acceleration of the ball is constant or not.

# Laboratory 2: Free Fall Motion – Experiment

In your physics textbook it is stated that a freely falling object falls with constant acceleration and that the magnitude of this is approximately $9.80\,\mathrm{m/s^2}$. Are these true?

In this laboratory you will record the position of a freely falling ball as time passes and verify facts about free fall motion using the resulting data.

## 1 Experimental Design

You will eventually drop a ball over a sensor which records vertical position as time passes and displays this data in a table. *Before actually doing this experiment,* you will need to consider *how* this data could give you information about acceleration.

a) Identify the *two* main facts about free fall motion that you will try to verify in this experiment.

b) Explain *how* you could use the data for position versus time to determine velocity. Explain *how* you could use this velocity information to assess whether the ball fell with constant acceleration, zero acceleration or changing acceleration. In your explanation, describe explicitly *how* you will manipulate the data obtained from these measurements; the explanation should contain a detailed series of steps and read like a recipe or an algorithm.

c) Suppose that you graphed velocity versus time. Explain *how* you could use this graph to check the main facts that this lab aims to verify.

## 2 Experiment: Falling Ball

a) Connect the motion sensor to the interface; the yellow plug should be in port 1 and the black plug in port 2. Run CapStone and configure it so that it connects to Motion Sensor. Using the Controls palette, adjust the sensor sample rate to 50 Hz.

b) Place the motion sensor facing upwards on the table (placing it on the floor may result in bad data, depending on equipment settings). **Place the protective mesh cage over the motion sensor**; the wire in the cage is too close to the motion sensor to be detected.

c) You will display the data in two ways. Set up the display so that it contains a table and a graph. In the graph click Select measurement on the vertical axis and choose Position from the Motion Sensor II subsection.

d) In the table click Select measurement in the left column and choose Time. Repeat this for the right column of the table choosing Position from the Motion Sensor II subsection.

e) Start data acquisition while one person is holding the ball at rest above the motion sensor. Release the ball shortly after the motion sensor starts. **Try to catch the ball before it hits the cage**. Observe the graph of position versus time to identify whether the detector recorded the freely falling ball correctly. Using this graph, identify the times during which the ball is in free fall (as opposed to before release and after it approaches too closely to the sensor). **Ensure that the instructor checks your answer.**

f) Using your answer for part 2e) identify which of these numbers in the table give a record of the *free fall motion*.

## 3 Data Analysis

a) Copy the *free fall data* that you identified in part 2f) into an Excel spreadsheet. Plot this data and **show the graph to the instructor,** who will verify that the data is correct.

b) Constructing a formula in Excel, calculate average velocity for the intervals between successive data points. For example, use the first and second data points to calculate an average velocity for this interval. Then use the second and third data points to calculate an average velocity for the next interval. Construct a table of velocity vs. time using all successive pairs of marks.

c) Plot velocity vs. time. Your graph should:

   i) use as much of the graph space as possible and

   ii) have axes which are correctly labeled.

d) Does this graph indicate motion with constant or varying acceleration? Explain your answer.

e) Describe *how* one can obtain the acceleration using the graph. Your suggested method must not use only two data points on the graph. Use it to determine the acceleration from your graph. Print your graph and attach it.

f) Compare your result to that stated in your text (or which you learned in class). Does the result presented in class lie within the range of results suggested by the measurements attained by all of the groups in your lab?

g) Can you explain any discrepancies between measured and stated values for $g$ (without invoking "human error")? One example would be the accuracy of the motion sensor. Describe a quick method by which you can check whether the motion sensor reads distance correctly. Use your method to check whether the motion sensor *that you are using* reads distance correctly. Explain how you could you correct the results to account for such errors.

## 4 Rising and Falling Ball

A ball is thrown directly upwards. After it has left the hands and before it is caught, it moves under the influence of the Earth, which presumably determines the acceleration of the ball. The aim of this exercise is to determine the acceleration of the ball at various moments during its motion.

a) Close CapStone.

b) A basketball was thrown directly up above a motion sensor, lying on the floor and pointing upward. CapStone recorded the location and velocity of the ball at various instants during the motion. This data was saved. Retrieve the data by opening the file H:\DOWNLOAD\dacollin\CapStone\freefallball.cap. This will automatically open CapStone and display the data. The remainder of this exercise uses this data. *Note: you do not need to connect and run any sensors to do this exercise.*

c) Use the graph of position vs. time to determine the time at which the ball reached its highest point. Determine the range of times during which it is rising and the range during which it is falling.

d) How do you expect the magnitude of the acceleration of the ball to compare (same, smaller, larger) to $g$ while it is rising, while it is falling and at the highest point?

e) Observe the graph of velocity vs. time. Using the coordinate tool (in the menu bar above the graph), determine the velocities at two moments (preferably several data points apart) during the period while the ball is rising and use these to calculate the average acceleration during that interval.

f) Observe the graph of velocity vs. time. Determine the velocities at two moments (preferably several data points apart) during the period while the ball is falling and use these to calculate the average acceleration during that interval.

g) Observe the graph of velocity vs. time. Determine the velocities at the moments just before and just after the ball reaches its highest point and use these to calculate the average acceleration during that interval.

h) How do the accelerations compare (to each other and $g$) during the three intervals of the three previous parts?

i) Would you need to modify your answers to part (d) based on your observations? If so, provide the modifications.

## 5 Conclusion

With reference to the two facts which you were supposed to verify, what are your conclusions for the lab?

## 6 Exercises

a) Two different groups carry out this experiment and obtain the following graphs of velocity versus time. Describe whether the two groups get (approximately) the same value for $g$ and if not, which group gets the larger value.