PHY151H1F – Experiment 1: The Acceleration Due to Gravity

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Today's Textbook Reference to review before lab:
"University Physics with Modern Physics" 1st Edition by W. Bauer and G.D. Westfall ©2011
Chapter 4 "Force"
Section 4.6 "Applying Newton's Laws"
Pg. 113, **Solved Problem 4.1 Snowboarding:** "A snowboarder glides down a slope with an angle of 22° with respect to the horizontal. If we can neglect friction, what is his acceleration?"

Practices in keeping a good notebook (please keep these hints for future reference):
Everything you do in the lab should be recorded in your lab notebook while you are doing the experiment. It should contain everything that you do, all your rough calculations or preliminary measurements, full details of any error calculations, any comments, records of successes or failures, etc. There is no point in copying information that is already in the guide sheets. Nor is there any point in writing a detailed essay on your procedure; note form is quite sufficient, as long as it is complete and comprehensible to your Demonstrator. Because the lab book is a complete record, taken as the experiment is being done, it will not necessarily be overly neat.

- List the NAMES of all participants on the first page of each experiment write-up. Note if any participants arrived late or left early.
- Put the DATE (including year!) at the top of every page in your notebook.
- NUMBER the pages in your notebook, in case you need to refer back to previous work.
- DO NOT use loose paper for data taking or calculations. All your work should be entered and appear in your lab notebook.
- Diary format means that the record is written in the order in which a procedure, calculation or inspiration actually occurred. You should NOT leave blank pages to be filled in later.
- If you use graph paper (obtainable from the Resource Centre) or have computer drawn graphs, stick or staple them in neatly beside the description of your experiment.
- It is good practice to keep the record of the experiment on facing pages, and any rough work, doodles or scribbles on the back pages (labelled "Rough Work").
- You should also NOT spend much time "tidying up" your notebook, or "rewriting history"; your time is too valuable, and it vitiates the function of the notebook.
- Do not us liquid paper, or big blotchy marks, or torn-out pages to obscure parts of your work. If you have written down something that you later realize is wrong (which happens a lot), simply put a line through it and label it as "wrong". Many times you might figure out later that what you thought was wrong was not wrong and you'll be glad you didn't blotch it out! Also, when someone sees evidence of redaction in a laboratory notebook it puts the scientific validity of the notebook into question.

DATASTUDIO - PRELIMINARY EXERCISE

Before starting with your first compulsory experiment, get a short training in using the DataStudio software to process experiment data. It is also useful to spend some time to study other software installed to your computer in MP 126.

This exercise will allow you to familiarize yourself with the equipment and analysis tools. Briefly record your observations and results in your notebook.

1. Plug the Motion Detector into the interface, with the yellow lead in data channel 1 and the black lead in data channel 2.
2. On the switch on the top of the Motion Detector choose the “wide beam” (🯅 icon) option.
3. Double click on the DataStudio icon to start the program. In the Welcome Window, select *Open Activity*. Open the file *match_position* in the Training folder. A set of instructions in the *Follow the Leader Graphing* window appears. Follow these.
4. Use the pull-down *Data* menu above the graph to display or remove different runs. Make sure that each member of your group gets a chance to test their ability to follow the positiontime graph. The counter on the last graph gives a measure of how well you have managed to follow the graph with your own motion. A score of under 5 is quite good.
5. Exit DataStudio and start it again. In the Welcome Window, select *Open Activity*, open *match_velocity* and attempt to match the velocity-time profile. A score under 10 is quite good.

Experiment 1 Preparatory Questions

Please discuss with your partners and write the answers to these in your notebooks.

1. An object is launched up a frictionless plane inclined at an angle of θ to the horizontal. Make predictions about:
   a) the graphs of position, velocity and acceleration versus time (sketch these).
   b) the acceleration of the cart just after it is launched, in terms of g and θ.
   c) the acceleration of the cart at its highest point, in terms of g and θ.
   d) the speed of the cart when it returns to the point of launch, in terms of its initial speed.
2. Use your calculator to calculate the % difference between θ, $\sin\theta$ and $\tan\theta$ for θ = 0.05 radians. What does this tell you?

Have your Demonstrator initial these Preparatory Questions before you start taking data.

Experiment 1: Acceleration Due to Gravity

First, you must level the air track in two directions. Start by checking that the two stops are fixed to the central portion of the track, about 1 m or so apart. The across-track leveling (at right angles to its length) is not critical, so it is sufficient to use the supplied spirit level and the two leveling screws at one end. Once you have leveled in this direction, **both** of the leveling screws must be given the **same** number of turns in all further adjustments.

Leveling the air track along its length is much more critical. Switch on the air blower, and place a cart on the track. Use the leveling screws to reduce the movement of the cart. If the track is level, the cart should stay in place over an extended period. Occasionally you may find that a track is bent in some way; at these places the cart will tend to move to a local minimum; remember that it is an “average” level between the two stops that you require.

Now design and perform an experiment to check your predictions. Describe carefully what you do, and explain any discrepancies between your predictions and the observations. Take at least 5 readings at different values of inclination of the air track. Then use your data to calculate a value of the acceleration due to gravity, *g*. Quote an estimate of your experimental uncertainty.

Notes & Hints

- Use spacing blocks placed under the **single** leg of the air track to incline the air track**.**
- Always use MODERATE velocities (i.e. the carts should just make a slight click when they bounce off the stops).
- Note carefully your observations in your notebook; include a sketch, details of the Motion Detector Trigger rate, approximate values of the velocity you used, etc.
- Place the Motion Detector about 15 to 20 cm from one metal stop (the detector doesn’t take any data at less than 15 cm.).
- Set the beam setting (use the button on the Motion Detector) to *narrow*.
- In order to get good results, the Motion Detector must be carefully aligned to point exactly along the air track. If the data is not smooth, i.e. there are spikes in the data, then you have an alignment problem. (**Hint**: observe your reflection in its front face.) The *Delay Start* and *Automatic Stop* in the *Sampling Options* are particularly useful in this experiment (see the *Hints* section of the Preliminary Exercise).
- Display your measurements of position and velocity on a graph, and use the value of the slope from the velocity graph and its error to extract *g*. Read the instructions in the *Hints* section of the Preliminary Exercise for drawing a graph of your calculated data and fitting it on the computer. Of course graphs can always be drawn by hand on graph paper.
- You will need to calculate an error in a quotient (e.g. x/y). Use the appropriate method indicated in the “Propagation of Errors of Precision” section of your Error Analysis Assignment.

Questions.

Your report should include quick answers to the following questions.

1. If “friction” were important, how would it affect a velocity-time graph?
2. Would the effect be the same as the cart moved up the track as when it is moving down? 3. Is the effect of “friction” even observable in your experiment?
4. Does your value of *g* agree with the accepted value for this latitude? If not, why not?
5. If the effect of friction is rather small, what effect is responsible for slowing down the cart?

Additional Measurements on Experiment 1 (If you Have Time):

1) More Accurate Method of Leveling the Air Track

This method also has the pedagogical advantage of testing your understanding of velocity-time graphs and the role of frictional resistance. Before you start, make sure that you understand the answers to the following questions.

> A cart is allowed to move back and forth along an air track, bouncing off metal "stops" at each end of its trajectory. For each of the following three cases, sketch the position-time graph and the velocity-time graph that you would expect to observe for the first two back and forth motions (you may assume Newton's First Law!).

a) The air track is completely level and all friction and air resistance can be ignored.
b) The air track is completely level; friction and air resistance are small but nonnegligible.
c) The air track is **not** completely level; friction and air resistance are small but nonnegligible.

Allow a cart to make several traversals back and forth between the two stops, using the Motion Detector to measure the speed of the cart.

On the Velocity graph, select portions of your data where the cart is moving away from the Motion Detector. Use the *Fit* button to choose a *Linear* fit and note the values of slope (m) and intercept (b) along with their measured errors (*Standard Deviation*). Then repeat the procedure for a portion of the graph where the cart is moving towards the Motion Detector. In your notebook, write down criteria for the values of m and/or b that would satisfy you that the air track is as level as you can make it using this equipment.

It is likely that these criteria will not be met on your first trial. By considering the directions of the gravitational and frictional forces, determine whether the end of the air track near the motion sensor should be raised or lowered and repeat your measurements until your criteria are met. (When adjusting the track, remember to give BOTH leveling screws the same number of turns to preserve the across-track leveling.) When you have obtained a level track, print out the final graphs for pasting into your notebook.

Hint: In order to give a good answer, you should also be able to answer the following question Are the two numbers, 5.1 ± 0.1 and 5.4 ± 0.2 , equal? If so, why; if not, why not?

2) Measurement of Friction

Even on the air track, some residual "friction" or air drag always exists. Using your data from measurements in part **1)** above, you should find it easy to measure the "frictional" acceleration (actually a deceleration) of the cart. Compare its value to g.

3) Resolution of the Motion Detector

An important piece of information is the precision with which the Motion Sensor measures Position. This can be estimated several ways, but the following is a method that will also teach you some of the features of the software. (It is assumed in the following that the uncertainty in the time measurement is sufficiently small that it can be ignored - the manufacturer quotes an uncertainty of 0.0001 seconds = 0.1 ms, so this is a good approximation).

- Use the *Position* data that you obtained to check the level of the air track. Choose a range over which the Position-Time graph gives a good straight line by highlighting it with the cursor. Use the *Fit* pull down menu to give a *Linear Fit* to this data. Notice that a data set for the *Linear Fit* which is the line of best fit now appears in the Data Summary column on the left.
- Click on the *Calculate* button on the main toolbar. In the *Calculator* window, define a variable, let's say R (for residuals), as $R = x - l$ where you will want l to be the corresponding position from a line of best fit and click on *Accept*. The calculator function will ask you to define x and l.
- To define x, click on the appropriate *Run* in the Data Summary column and drag it over the words in the *Calculator* window "Please define variable x" where a dashed box will appear. Release the mouse button. Answer yes when asked if you wish to perform calculations on a single run.
- Similarly, define l by dragging the corresponding *Linear Fit Run* over the words "Please define variable l" in the Calculator window.
- Note that even though residuals are defined for most of the graph they have real meaning only for the portion that you selected above; for this portion the residuals should be small.

  Create a graph of R, select the appropriate portion of the R graph and use the Σ pull-down menu to display the mean and standard deviation of the residuals. The Standard Deviation is a measure of the spread and is thus a quantitative measure of the uncertainty in *Position*.
- Print and paste the resulting graph.

How would you expect the plot of residuals to look? Is this expectation fulfilled? If not, can you give an explanation?

Make sure that you quote a value for the precision of the *Position* measurements, and discuss the above questions with your Demonstrator.