**1D Kinematics**

**(One week, In-Person)**

# Notes:

1. This lab will be done in-person with your lab partner(s), in LD011.
2. Turning in your report:
   1. Collaborate with your partner(s) on data collection, analysis, and report.
   2. When working in a group, please turn in only one report and make sure it lists all group members as authors.
   3. Lab reports should be uploaded to Canvas by the deadline in the course calendar.
   4. Do not include your raw spreadsheets in the Canvas submission or final report. You may want to use figures generated from the spreadsheet(s) in your report.
3. Getting help:
   1. Your lab TA can answer questions during the lab or after the lab by email or at their office hour (listed in the syllabus).
   2. You can also ask advice from lab partner(s) and/or other students.

# Objective of this lab:

For this lab, you will refine/design and implement an experiment in which you use two different methods (physical arrangements) to determine the (local) acceleration of gravity, *g*. You will then compare your measured values of *g* with the standard value of 9.8 m/s2.

These are things you will do:

1. Using the Vernier Go Direct® Motion Detector, measure the velocity versus time for two different objects/configurations: cart on a ramp and a dropped ball. Perform multiple runs.
2. Using the Vernier Graphical Analysis™ Software Package, perform a linear regression (for each configuration) to obtain the slope of the velocity data.
3. Using your knowledge of 1-dimensional kinematics, and the slope value from the velocity data, determine the acceleration due to gravity, *g*, for each configuration. Compare this measured value to the “theoretical” value.
4. Investigate if other pertinent data are buried or hidden in your velocity versus time data. Discuss those that you identify.
5. Identify errors that can occur in your experiment. Minimize those errors.

# What you will learn:

Please review the learning goals for the semester in lab in the handout from the first week. In addition, this lab has several specific goals:

1. You will practice keeping lab notes in a paper notebook, computer file, or other format.
2. You will enhance the data analysis skills you learned previously, by applying them to real data.
3. You will learn to distinguish between two types of errors that occur in data: systematic errors and random errors.
4. You will enhance your understanding of how noise arises in data, and how to account for that noise when interpreting experimental results.
5. You will practice scientific communication skills by preparing graphs and writing a formal lab report.

## What goes in my lab notes, and what about my report?

The purpose of lab notes is to enable you or a colleague to reconstruct what was done and why.

* They don’t have to be neat, in complete sentences, etc., but they do have to be useful.
* In a case like this, they should include things like what were the two setups for measuring the gravitational acceleration and what you did while recording data in those setups.
* Did you try other setups or take multiple data sets for same setup?
* If you store multiple files, record what filenames correspond to what conditions.

The purpose of a **report** is to explain what you learned and how you learned it. The sorts of things that belong here are

* A description of each step you did as part of Activity 1 and Activity 2.
* Any graphs to show to your results.
* Explain how you determined your results.
* Explain differences between theory (standard value) and your actual (measured) acceleration due to gravity.
* An analysis of the errors of the in your experiment including an explanation of how calculated average acceleration, found the standard deviation, and determined the standard error.
* Your conclusions about any relevant and useful information you were able to extract from the data.

# EQUIPMENT

For this lab, the following are available for use: dynamics cart, ramp/incline, stacking blocks (or books), rubber ball, ring stand with crossbar, clamps, meter stick, computer, Vernier Go Direct® Motion Detector, and Vernier Graphical Analysis™ Software Package.

**DOs & DON’Ts**

* ***Don’t*** break the equipment -- Make sure the cart does not go too fast. Make sure your ramp is not too high.
* ***Do*** consult with your Lab TA about the various techniques you want to consider as you design your particular experiment.
* ***Don’t*** forget to record your data for each run.
* ***Do*** use your imagination and have fun.

# Sample Set-Ups:

For Activity 1: *Cart on Ramp*, consider using the blocks (books) stacked to height *h*, measure the distance *x* (the underside of the ramp), then you know the angle.

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# *Figure 1. Example set up for Activity 1 “Cart on Ramp”.*

For Activity 2: *Ball Dropped*, consider using the ring stand to position the Vernier Go Direct® Motion Detector above the floor and away from the lab table.

lab table

Motion Detector

free fall

# *Figure 2. Example set up for Activity 2 “Ball Dropped”*

# ACTIVITY 1: Cart on Ramp

* Spend time properly setting up the Vernier Go Direct® Motion Detector and Vernier Graphical Analysis™ Software Package. You will likely have to adjust the position and aim of the Motion Detector several times to get it right (this is not trivial and will take time).
* Practice releasing the cart and making additional adjustments so that you have good data, distance *x* should be around 2 meters and the cart should never be closer than 40 cm to Motion Detector.
* Do practice runs until you obtain good data showing an approximately **constant slope** on the velocity *vs.* time graph during the motion of the cart.
* You can use the Graphical Analysis™ Software Package can fit a straight line to a portion of your data -- use the Linear Fit button, to perform a linear regression of selected data, this will give you the slope.
* Make sure to do multiple runs. How many? You choose -- the more you do, the better your data and thus the experiment.
* Save your data for each run. Use Excel (or similar) to make graphs, do analysis, etc.
* Using what you have learned in lecture about 1D kinematics, fully analyze your experiment. For example, the slope of velocity yields the acceleration *a* (along the incline). Use that to then find the acceleration due to gravity, *g*.
* Recall, you will have the data for multiple runs, compute an average value. Compare your “measured” acceleration due to gravity to the “theoretical” value for *g* of 9.8 m/s2. Discuss and calculate the Percent Error. Explain.
* What other unknowns are possibly buried in your data? Discuss those, as well.

# ACTIVITY 2: Ball Dropped

* Again, plan to spend time setting up the Vernier Go Direct® Motion Detector and Vernier Graphical Analysis™ Software Package. In the Experiment menu, select Data Collection, then set **collection length** to 2 seconds and **sampling speed** to 20 samples/s. You will likely have to adjust the position and aim of the Motion Detector several times to get it right (this is not trivial and will take time).
* Practice dropping the ball and making additional adjustments so that you have good data. Your position graph should be plotting the ball bounces as parabolas, and the associated velocity graph should be linear.
* Do practice runs until you obtain good data showing an approximately **constant slope** on the velocity *vs.* time graph during the drop.
* Use Graphical Analysis™ Software Package to fit a straight line the velocity graph corresponding to the first bounce. Determine the slope of the velocity (versus time).
* Make sure to do multiple runs. How many? You choose -- the more you do, the better your data and thus the experiment.
* Save your data for each run. Use Excel (or similar) to make graphs, do analysis, etc.
* Using what you have learned in lecture about 1D kinematics, fully analyze this part of the experiment, as well.
* Recall, you will have the data for multiple runs, compute an average value. Compare your “measured” acceleration due to gravity to the “theoretical” value for *g* of 9.8 m/s2. Discuss and calculate the Percent Error. Explain.
* Are there other unknowns buried in your data? For example, does the ball ever reach **terminal velocity** in this experiment. Discuss.