Lab 03: Constant Acceleration

The Objectives

The purpose of this exercise is to observe and analyze one-dimensional motion with constant acceleration:

What is the acceleration of an object in free fall?

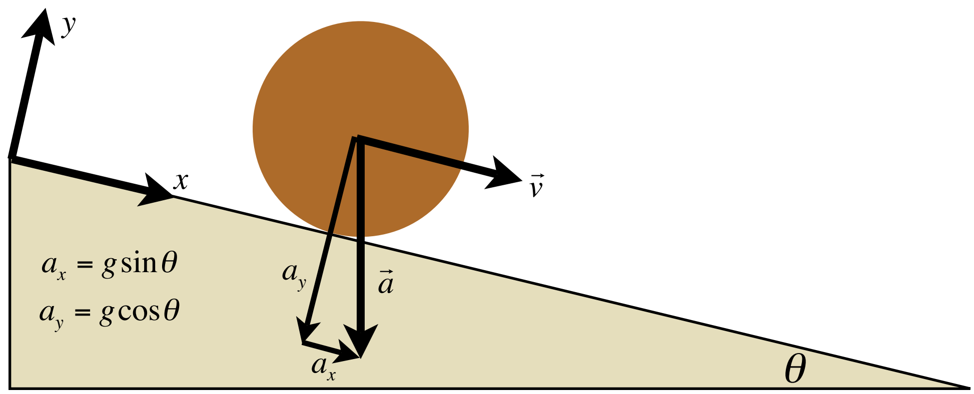
Some specific objectives:

- Observe motion with a constant acceleration
- Use the LoggerPro to measure and record motion data accurately
- Relate the kinematic equations for constant acceleration to their graphical representation
- Prepare detailed graphs, and use them to determine the acceleration of the object
- Determine the accuracy of the results by calculating a standard deviation and a percent error

The Procedure

The acceleration of an object is free fall is the acceleration due to gravity:

$$\vec{a} = \vec{g} = 9.8\,\tfrac{\text{m}}{\text{s}^2}\downarrow$$



We will measure this directly by releasing an object from rest and recording its position as a function of time. It can also be shown that the acceleration of an object moving down (or up) an inclined plane is directly the result of gravity as well. By measuring the position as a function of time of an object released from rest on an incline, we will have a second method for verifying the value of **g**.

Specifically, we will be using the Motion Sensors attached to the LoggerPro (connected to the computer) to automate the data collection. There are several general techniques that we will always use with the motion sensors:

- The LoggerPro software should automatically detect the motion sensor.
- The object must be at least 40cm (about 16 inches) from the sensor for accurate data to be recorded.
- The sensors are, well, *sensitive*. They will pick up extraneous motion. You will have to practice releasing objects in order get a clean release.
- You may adjust the length of the Data Collection interval to suit the actual trial, but you should not set the collection rate to more than 30 data per second. A higher collection rate will not be accurate.

Position the basketball under the sensor and release it from rest. Coordinate with your lab partners so that you do not release before the data collection has begun. Allow the basketball to bounce untouched until the collection interval expires.

Position the motion sensor at the end of the track, and stabilize the track on an incline. Record the incline angle. Release the ball from rest at the top of the incline, making sure to stop the ball before it strikes the sensor. When you have good data, save it and repeat, except this time start with the ball near the bottom of the incline. Give it a push to start it rolling up the incline, then stop it when it comes back down (before it strikes the sensor!) Re-position the incline to a different angle and repeat the experiment for three different angles of incline.

The Data

After you have completed several trials, and are confident that you can perform a clean release, you should start keeping your data sets. You may save your LoggerPro worksheet on the hard drive, using the appropriate Desktop→PHYS1410→Section# folder for your file. Your raw data consists of the tables of position and time values. The remaining columns are calculated values, and therefore part of the data reduction (and the graphs are part of the analysis).

You should have data for both experiments in the same file, so you should name the data sets to distinguish between them. You should have three separate data sets for the three distinct incline angles you tested.

The Reduction

Because the velocity values are calculated and the velocity vs. time graph is automatically generated for you, there are no required calculations of velocity.

Use your v vs t graph to find the acceleration of the ball in free fall. Since acceleration is constant,

$$a = \frac{\Delta v}{\Delta t}$$

which is the slope of your v vs t curve. If your data includes several bounces, you should find the acceleration of each. Record each of these individual values. This means that you will highlight and curve fit only a selected portion of your data, then highlight and fit the next portion, until you have fit each of the segments.

For the ball on the ramp, your graph will probably be a little messier to look at. By comparing the x vs t graph to the v vs t graph, you should be able to identify the time interval over which the ball was accelerating down the ramp. Find the slope of this portion of the graph, and record it. This is the acceleration in the x-direction, a_x. The value for g can then be calculated:

$$g = \frac{a_x}{\sin\theta},$$

where θ is the angle of the incline you previously recorded. Find the acceleration of the ball and value of g for each of the inclines you tested.

The Analysis

Calculate an average value for g based on the values you obtained for each individual trial. The experimental uncertainty of this average value must be found by calculating the standard deviation:

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(g_i - \overline{g}\right)^2}$$

where g_i is each individual value, and $\overline{g}$ is the average value.

Compare your average to the known value of g, and calculate your percent error.

The Conclusions

You should think about and answer these questions in your notebook as preparation for your quiz next week:

1. For the free–falling basketball, what is the shape of the position vs time graph? Relate this to the kinematic equation for position as a function of time.
2. Explain how you would know, without having observed the experiment, that the basketball had bounced. What do your graphs have to tell you about this?
3. What would your graphs look like if you had started by throwing the ball up and letting it fall back down, instead of just letting it drop from rest?
4. Why is the slope of the v vs t graph negative for the ball, regardless of whether it was rolling up or down the incline?
5. Do you get a more accurate result with the freely falling ball, or with the ball on the incline? Can you think of any reason why one technique might be more accurate than the other?
6. How could you improve the results of the incline experiment?
7. Why do we need to use the standard deviation to find the uncertainty in our result?