Physics Lab 5: More Motion

Goals: Improve communication and teamwork capacities**;** Improve confidence in hands-on work with equipment; Improve ability to make, describe, and record observations; Improve ability to use a data logger with a motion detector to measure motion

References for today's activity: Physics Lab 3 lab notebook, LoggerPro tutorials 01 Getting Started, 04 Motion Measurement, 07 Viewing Graphs, 09 Curve Fitting, available under LoggerPro, File: Open: Tutorials.

Equipment: You will be oriented to the location and proper use of the equipment for this lab. At the end of the session, return the equipment to its original configuration and location.

Data Management: Create a usefully named folder in the Workspace. Each LoggerPro file should have a useful name, and the best data run in each file should also have a useful name.

Part 1: Getting Started

a) Gather your equipment. Do NOT place your motion detector on your track until the appropriate time. Assemble your track, end stops, cart with spring bouncer, etc. Make sure the track is reasonably level. Check to make sure the cart rolls relatively freely along the level track. As needed, adjust the track level.
b) Start the cart at the opposite end of the track so that when you push it, the spring bouncer acts to smoothly rebound the cart. Make sure not to push the cart so fast that the rebound is rough or that the spring overly compresses. Does the motion of the cart match what you might expect?
c) Lift up the end of the track opposite the bouncing end slightly to create an incline; this doesn't have to be carefully measured – a book under that end of the track would be sufficient. Release the cart from rest at the top of the incline so that it rolls to the bottom of the track so that the spring bouncer acts to smoothly rebound the cart. Make sure you haven't released it so high that it moves so fast at the bottom that it overly compress the spring (you can release it from a lower height as needed). Does the motion of the cart match what you might expect? Return the track to be level.

Part 2: Cart on level track – measuring motion

a) Prepare the system so that the motion detector can be used to measure the motion of the cart as it moves horizontally on the level track. This might involve removing one of the safety end stops, so be careful to **make sure that the cart does not collide with the motion detector**; **both cart and motion detector should be treated with care**.
b) **Set the sample rate to 25 samples per second**. If your data is not smooth even after adjusting your physical set-up, you can adjust this sample rate; don't set it below 10 or above 30. Make sure to record the sample rate you use. **Reverse Direction** on the motion detector so that towards the detector is positive (by default, away from the detector is positive). If you don't know how to set the sample rate or reverse direction on the motion detector, ask, then make sure to write the steps down in your lab notebook.
c) **DRAW A SKETCH** of your experimental set-up. The sketch does not have to be very artistic, but it should show the important **features of your set-up**: track, cart, bouncing end, motion detector. Given what you know about the coordinate system set by the motion detector, carefully draw the appropriate **coordinate system**, making sure to **clearly indicate the positive direction**.
d) Start collecting data; **by hand**, move the cart back and forth over the entire length of the track to see what the useful measuring range of the motion detector is. You should be able to adjust the setup (likely by slightly repositioning and swiveling the motion detector) to measure the motion of the cart over the entire range of the track, except for the dead zone near the detector itself (the motion detector can't detect objects which are too close).
e) **MAKE SURE NOT TO LET THE CART COLLIDE WITH THE MOTION DETECTOR**. Obtain **several good position vs. time graphs** for the cart moving away from the motion detector, rebounding, and moving towards the motion detector, storing each run.
f) **Check with Krishna, Diane, or Julian to make sure your data is acceptable. Rename your best run**. **Save your LoggerPro file with a useful name. Start a new LoggerPro file.**

Part 3: Cart on angled track – measuring motion

a) While similar to the previous measurement, there are some important differences when the track is inclined: you release the cart from rest so that it rolls down the track; you choose the release position so the cart isn't moving so fast at the bottom that it overly compresses the spring; and the cart will make several trips down and up the ramp. Use the ring stands and clamps as needed. Raise the motion detector end of the track so that the track is inclined at 5 degrees (it doesn't have to be exactly 5^{o}, but measure the angle used).
b) **DRAW A SKETCH as before**, and also include the **angle** of inclination.
c) As needed, adjust your set-up to obtain good position vs. time data. Start data collection, and move the cart up and down the ramp by hand to make sure that you get the full motion of the cart.
d) Choose a release height so that the spring isn't overly compressed during the rebound. Obtain **several good position vs. time graphs** for the cart moving down the ramp (away from the motion detector), rebounding, and moving back up the ramp (towards the motion detector) before slowing down and moving back down the ramp again, **for several (at least three) rebounds from a single release**.
e) **Check with Krishna, Diane, or Julian to make sure your data is acceptable. Rename your best run**. **Save your LoggerPro file with a useful name. Start a new LoggerPro file.**
f) Repeat steps b) – f) with a known angle close to 10^{o}.
g) Repeat with an angle of _____^{o}.
h) Repeat with a fourth angle of _____^{o}.

Part 5: Analysis (if time, begin in lab today, discussing in your lab groups; otherwise make sure to sit with your lab partners in Tuesday's Math Lab to continue with this – you may want to continue this afternoon to prepare)

a) Examine the position vs. time and the velocity vs. time graphs for the level track data. See if you can identify the three 'parts' of the trip: 1) when the cart is moving freely away from the motion detector (after being pushed), 2) while the spring is being compressed and expanding during the rebound phase, and 3) when the cart is moving freely towards the motion detector. It might be easier to distinguish the three parts in one of the graphs as compared to the other. In addition, see if you can identify the turn-around point on both graphs. Discuss how the two graphs are related in the 3 parts of the cart's trip.
b) The manufacturer claims that when the cart rolls freely on a level track, the friction is very low and the cart moves with nearly constant velocity. If this were true, what would the position vs. time graph look like when the cart is moving freely away from the motion detector and when the cart is moving freely towards the motion detector? Do the experimental position vs. time graphs support or refute the manufacturer's claim? Explain your reasoning. If you can, use a curve fitting procedure to determine the velocity of the cart as it moves freely away from the motion detector, and freely towards the motion detector. Describe your approach and your results.
c) Examine the position vs. time and the velocity vs. time graphs for one of the angled track data (your choice). See if you can identify the three parts of the trip (these parts repeat): 1) when the cart is moving freely down the ramp, 2) while the spring is being compressed and expanding during the rebound phase, and 3) when the cart is moving freely up the ramp. In this motion, there are two different kinds of turn-around points: what are they, and what do they correspond to in the cart's motion?
d) Look again at the position vs. time and the velocity vs. time graphs for the angled track data of your choice. Does this pattern look familiar to you – have you seen position vs. time and velocity vs. time graphs that have a similar shape and behavior?
e) Zoom in on the first full up and down part of the trip (first bounce to second bounce) for which you have good data. As you did with the bouncing ball data (hope I didn't give away the answer to part d). Oops – guess I just did), highlight the data in a region centered around the turn-around point at the top of the track and away from the bounce events. Fit a quadratic to the position vs. time data, and record the value for A (along with its uncertainty and RMSE value – what should the units for A be?). Fit a line to the velocity vs. time data, and record the slope (along with units and RMSE). Save your graphs, copy/print/cut/paste/label into your notebook, etc.
f) Repeat for the other angles (graphs in notebook), and organize your results into a table, with columns: angle, slope, A value (and leave room for more columns).
g) Based on your data and analysis, is it reasonable to assume that (at a particular angle) the cart moves with constant acceleration as it moves up and down the ramp (not including the bounce event)? Explain your reasoning.
h) For constant acceleration, the slope of a linear fit to a velocity vs. time graph and the A value for a quadratic fit to a position vs. time graph are each related to the acceleration. How? Add two new columns to your table: acceleration from the velocity vs. time analysis and acceleration from the position vs. time analysis. Are these consistent for a given angle?