Patterning the World – Winter 2014 Name:______________________________________

Partners' Names:______________________________________

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; Improve your ability to use LoggerPro software to analyze kinematics data; Gain more experience with graphical representations of motion; Use slopes of (linear regions of) position vs. time graphs to determine velocity for constant velocity situations; Use slopes of (linear regions of) velocity vs. time graphs to determine acceleration for constant acceleration situations; Use quadratic fits to position vs. time graphs for constant acceleration to determine acceleration.

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.

Groups: For today's investigation, you will work in groups of 3; your instructor will facilitate group formation.

References: LoggerPro tutorials 01 Getting Started, 04 Motion Measurement, 07 Viewing Graphs, and 09 Curve Fitting, available under LoggerPro, File: Open: Tutorials.

Lab Notebook: Update your Table of Contents. General Lab Notes guidelines apply.

Data Management: Create a usefully named folder in the Workspace using the Lab 5 folder. Each of your group's LoggerPro files should have a useful name, and the best data run in each file should also have a useful name.

Part 1: Getting Started

a) Take notes during the equipment orientation.
b) Observe the motion of the cart when the track is horizontal. The cart starts from the opposite end of the track as the spring so the spring acts to smoothly rebound the cart. The cart is not pushed so fast that the rebound is rough or the spring overly compresses. Observe the motion a few times, and then draw your best prediction for the position vs. time and velocity vs. time graphs of the cart's motion.
c) Observe the motion of the cart when the track is slightly inclined, with the bouncing end at the bottom. The cart is released 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. The cart is not released so high that it moves so fast at the bottom that it overly compress the spring. Observe a few times, and then draw your best prediction for the position vs. time and velocity vs. time graphs of the cart's motion.

Part 2: Cart on level track – measuring motion

a) Gather your equipment. 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. 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. **Make sure the cart does not collide with the motion detector**.
b) If your group doesn't know how to do any of the following, ask and then record the steps. **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. If you don't like having your position measurements have negative numbers, **Zero** the detector on the other side of the track to set that as the origin (by default the detector is the origin).
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.
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 four but as many as you can) 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) – e) with a known angle close to 10^o.

Analysis (if needed, finish after class to prepare for discussion in Tuesday's Lecture. You can access Logger Pro from any computer on campus. Make sure to save your group LoggerPro file to your own cubbie before making any changes)

a) Make sure each graph shows individual data points that are the same size. Zoom in as needed.
b) Examine the position vs. time and the velocity vs. time graphs for the level track data. 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. Identify the turn-around point on the position vs. time graph and the velocity vs. time graph. Discuss how the two graphs are related in the 3 parts of the cart's trip.
c) 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. Use a curve fitting procedure to determine the velocity of the cart as it moves freely **away** from the motion detector (don't include the time when it is in contact with the spring). Repeat to find the velocity of the cart as it moves freely **towards** the motion detector.
d) Examine the position vs. time and the velocity vs. time graphs for the low angle track data. It might help to zoom in on the first few up-and-down trips. Identify the three parts of an up-and-down trip (these parts repeat): 1) when the cart is moving freely up the ramp, 2) while the spring is being compressed and expanding during the rebound phase, and 3) when the cart is moving freely down the ramp; these up-and-down trips repeat. 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 graphs?
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. 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 line to the velocity vs. time data, and record the slope (along with units).
f) For the same highlighted region, fit a quadratic to the position vs. time data. Record the value for. Show that the units for A must be m/s^2 by looking at the curve fit formula. Save your graphs with fits and values, copy/print/cut/paste/label into your notebook, etc.
g) Repeat d) – e) for two other bounces for the low angle track data.
h) Repeat this analysis for several individual up-and-down trips for the other angle (graphs, fits, and values in notebook).
i) Organize your results into a table, with columns: angle, "bounce number", slope, A value (and leave room for more columns).
j) Based on your data/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.
k) 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. Note that one of these columns should seem repetitive. Are the two results for acceleration consistent for a given angle?

Extensions

- Examine the angled track data. Does the time between bounces change? If so, does there seem to be a pattern to that change? If so, can you determine a mathematical model for that pattern?
- Examine the angled track data. The maximum position decreases for each successive bounce. Does there seem to be a pattern to that change? If so, can you determine a mathematical model for that pattern?