PHYSICS 117 LAB MANUAL

Experiment I: Graphs, Functions and Motion, Part I

A. Purpose

The purpose of this experiment is to study motions which yield displacements which are linear in time, together with their velocities and accelerations, and to relate them to straight line graphs of constant slope.

B. Challenge I: Constant and Linear *vs.* Graphs

Challenge I of this experiment is first to use the motion detector and the computer's data handling capacity to generate simple horizontal and sloped straight-line distance vs. time graphs describing actual zero velocity and constant velocity motions of oneself. Secondly, one is to confront his expectations for these velocity vs. time graphs with the computer's $x(t)$ curves, which it calculates by computing the slope of $x(t)$ at each point.

1. Computer and Detector Operation

When booting up your computer check that the motion detector is plugged into port 2; turn on the ULI computer interface box; click ok (not cancel) in the Novell Client log-in box; wait for the computer to do what it has to do – do not rush the hourglass. (Getting this wrong may compromise your access to the hardware, the program or the printer.

Turn on the computer and activate Logger Pro: <File/Open/Probes and Sensors/Motion Detector/Motion Detector.MBL>. Three blank graphs will appear on your screen: *x vs. t*, *v vs.* t and *a vs. t.* Stand about one meter in front of the "motion detector" and have another group member click the <COLLECT> button on your upper screen with the mouse. When the motion detector begins to operate (you will hear a clicking), warm up by moving towards or away from the detector and observing the pattern that appears on the screen. Be creative. Aim the detector at a nearby wall or at the ceiling. See how the graphical patterns you create are related to the sequence of distance measurements which the probe sends to Logger Pro. Each group member should take several turns.

Besides recording the distance at the time of each detector click, Logger Pro also produces and graphs an estimate of the velocity by calculating the slope of the position, $x(t)$, as the ratio of the differences between two nearby positions, $x_2(t_2)$ — $x_1(t_1)$, and the corresponding times, $t_2 — t_1$:

$$v(t) = \frac{x_2(t_2) - x_1(t_1)}{t_2 - t_1}, \qquad (1)$$

If the times at which the measurements are made are close enough together, then this computed estimate provides a good approximation to the actual instantaneous velocities. In the same way, Logger Pro computes and plots an estimate of the instantaneous acceleration as the slope of the velocity vs. *t*, using its computed velocities:

$$a(t) = \frac{v_2(t_2) - v_1(t_1)}{t_2 - t_1}, \qquad (2)$$

2. Motions Which Yield Constant and Linear x *vs.* t Graphs

When you have acquired a feeling for the operation of the position detector, discuss with your partners what you expect to see on the screen for $x(t)$, $v(t)$ and $a(t)$ when you (a) remain at a fixed distance from the detector, and (b) when you approach the detector in a steady walk. Make sketches of your expectations.

When your expectations are clear, <COLLECT> position data while you stand at rest a fixed distance (more than 0.5 m, and less than 2.0 meters) from the detector. Then <COLLECT> data as you walk towards the detector at a steady rate. Print and label copies of both graphs for your report.

[Note that the limited distance range (0.5 ¡ *x* ¡ 2.0 m) of the detector may require you to shorten the (10-second) time interval over which Logger Pro collects data. To do this, click </Setup/Data Collection Sampling> to obtain a box where the "Experimental Length" can be altered.]

Also note that various individual features of any graph, such as title, x-variable, y-variable, scale end values, can be changed by clicking on the item and selecting the new values desired. Also </View/Autoscale Once> or </View/Set Axes to Autoscale> will choose x and y-scales to accommodate your data, once or on a continuing basis, respectively.

C. Challenge II: Quadratic *x vs. t* Graphs

Challenge II is to use the constant force of the fan cart propeller to cause a constant acceleration, and thereby to exhibit the qualitative quadratic dependence of $x(t)$ upon time, *t*, which occurs in general for the case of constant acceleration. In particular, we wish to contrast this quadratic $x(t)$ with the linear $x(t)$ curves of the (zero acceleration) cases of Challenge I. (In Expt. II we shall return to study this constant acceleration/quadratic displacement case in more detail.)

Use the fan cart to generate a curved-line graph of distance vs. time by placing it in front of the detector arid turning on the fan. However, prior to carrying out this experiment, predict what the distance vs. time graph will look like. **[Note the fan carts easily role off the lab tables to their deaths. Set the cart on its side when you are not using it.]**

In using the fan cart, you should push the fan cart away from the position detector (located against the wall) while its propeller force is pulling it back towards you. With a few tries you can get the cart to move almost to the bumper (which stops it from falling off the table), slowing as it goes. Then it comes momentarily to rest (without striking the bumper, please.. those collision forces are a complication you don't want to deal with!), and begins to accelerate back towards the detector. The resulting $x(t)$ curve should be qualitatively distinguishable from the straight line $x(t)$ curves of the unaccelerated constant speed motions of Challenge I. Within a conical field emanating from the motion detector it will take data on whatever is closest whether it be your hand, belt buckle or lab partner – so keep people and random objects out of the beam!

Once you obtain a good distance vs. time curve, print a copy and describe in words the motion that you observed, the motion described by the graph, and the motion which you had predicted in advance.

In these fan cart experiments, one should find that Logger Pro computes a non-zero estimate of the constant acceleration, at least on the average. (But this estimate sometimes fluctuates irregularly due to the fact that the computation of small differences of a measured quantity tends to magnify its relative experimental error and thereby to introduce substantial random fluctuations. Since the acceleration estimation requires two such differences, its random fluctuating component is generally larger than that of the velocity, and may sometimes become rather large.)

D. Report

Review the recommendations for LABORATORY REPORTS at the beginning of the lab manual, write up your brief [Title/Purpose/Data/Summary and Conclusions/Critique] report and hand it in to your teaching assistant before you leave. If you have some spare time, you may wish to explore the Logger Pro Menu to get familiar with the things that Logger Pro can do for you.