Name ______________________________

Partner(s): ______________________________

Experiment I – Kinematics in One Dimension

Note A guide for Logger*Pro* Software is given in Appendix 1 at the end of this lab manual.

Objectives Understand *x*, *v*, and *a* (displacement, velocity and acceleration)
Understand motion graphs (*x* vs. *t*, *v* vs. *t*, *a* vs. *t*)
Be able to interpret motion graphs and to make prediction
Learn how to measure velocity and acceleration
Problem solving skills

Preparation You will be pressed for time during the lab. Since successful completion of all lab activities counts towards your final lab grade it will be important to be well prepared by doing Pre-Lab assignments and reading the entire lab **before** attending the lab.

Pre-Lab Read the Pre-Lab introduction and answer the accompanying questions and problems **before** this Lab.

Points earned today

Pre-Lab	_____
Lab	_____
Challenge	_____
Total	_____
Instructor Initials	_____
Date	_____

Pre-Lab for LAB#1

Intro **1-dimensional motion with constant acceleration**

If all objects either remained at rest or moved at constant speeds in straight lines, the world as you know it could not exist. Objects move in all manner of ways, some quite complex. Objects that do not remain at rest or move at constant speeds in straight lines are experiencing accelerated motion.

A major part of this first lab examines the relationship between motion in a straight line, also called 1-dimensional motion, and the graphical representation of that motion. Consider these quantities of motion: distance traveled, displacement, speed, velocity, and acceleration. Can you write down the definition for each of these quantities? What is the difference between speed and velocity? How about distance traveled and displacement? How are graphs used to show these quantities?

Definitions For motion of an object during a given time interval,

- Displacement is the resulting change of position during the interval.
- Distance is the length of the path the object travels during the interval.
- Average velocity is the change of displacement per unit time during the interval.
- Speed is the distance the object travels per unit time during the interval.
- Average acceleration is the change of velocity per unit time during the interval.
- Displacement, velocity, and acceleration are all vector quantities: these are described in terms of both a magnitude and a direction – direction will become very important when we discuss motion in more than 1 dimension.
- Speed and distance are scalar quantities: these are described in terms of magnitude (but not direction).

Motion is best described and measured relative to a frame of reference and a clock. A frame of reference is a coordinate system. Suppose an object moves along a straight line. Using the straight line as the x-axis of a coordinate system, we take these readings: at time $t_0 = 0$, the object is at position x_0 and travels with velocity v_0; at time t, the object is at position x and travels with velocity v. Equations describing the motion are expressed in terms of the coordinate and clock readings.

Equations **For arbitrary motion along a straight line, these equations apply:**

displacement: $\Delta x = x - x_0$ time interval: $\Delta t = t - t_0 = t$

average velocity: $\bar{v} = \dfrac{\Delta x}{\Delta t} = \dfrac{x - x_0}{t}$

average acceleration: $\bar{a} = \dfrac{\Delta v}{\Delta t} = \dfrac{v - v_0}{t}$

For motion with constant acceleration, *a*, these equations also apply:

$x = x_0 + v_0 t + \frac{1}{2}at^2$ $v = v_0 + at$

$v^2 = v_0^2 + 2a(x - x_0)$ $\Delta x = \bar{v}t = \dfrac{(v + v_0)}{2}t$

Pre-Lab for LAB#1

Question Which of the equations for motion with constant acceleration produce a straight line when graphed? Which produce a parabola?

If we apply the above equations to the case of an object that <u>does not</u> change its direction of travel as it moves with constant acceleration, we find that the object:

- Undergoes a displacement $\Delta x = x - x_0$. Note that displacement is a positive quantity if $x > x_0$ and a negative quantity if $x < x_0$.
- Has average velocity $\bar{v} = (x - x_0)/t = (v + v_0)/2$. Note that velocity has the same sign as displacement.
- Travels distance $d = |\Delta x| = |x - x_0|$. Note that distance is always a positive quantity.
- Has average speed d/t. Note that speed is always a positive quantity.
- Has constant acceleration $a = (v - v_0)/t$. Acceleration may be positive or negative, depending on how velocity changes.

Question For the case of an object that <u>does</u> change its direction of travel as it moves with constant acceleration, which of the quantities listed above are different?

Concept Questions Answer the following questions. Indicate your reasoning.

1. Does the speedometer in a car measure velocity, speed, or both?

2. You watch a player on the OSU football team and observe that he runs for 2.62 km. Is the displacement of the player the same as the distance traveled? If not, why not?

3. In the Olympic 200 m race, is it possible for the runner with the greatest speed crossing the finish line to lose the race? Explain?

4. Describe how the velocity of an object changes if it undergoes uniformly acceleration motion. Can its direction change?

Pre-Lab for LAB#1

Problem 1 What is the magnitude of the average acceleration of a skier who, starting from rest, reaches a speed of 8.0 m/s when going down a slope for 5.0 s?

How far does the skier travel in this time?

Problem 2 You are driving your car and the traffic light ahead turns red. You apply the brakes for 3.0 s, and the velocity of the car decreases to +4.5 m/s. If the car's deceleration has a magnitude of 2.7 m/s^2, what is the car's displacement during this time?

Hint: First find the initial velocity of the car.

Laboratory

List of Today's Activities

Check Pre-Lab

Introduction	Introduction to the equipment. What is expected of students.
Lab Activities	The motion detector and kinematics in 1 dimension Record and interpret *a-t*, *v-t*, *x-t* graphs
Lab Challenge	**Cops and Robbers** (Accelerated motion in 1 dimension)

Activity 1 **The Speed of the Get-Away Car (Group Experiment)**

Let's start with a simple example – an object moving along a straight line with constant speed. Your instructor will show you a small, battery operated cart that we call the Get-Away Car because it will be used by the Beagle Boys to escape the police in today's Lab Challenge, but we will get to that later.

Describe here how you would measure the speed:

Your instructor will ask several students to help with the measurement. Why does he or she repeat the measurement several times and asks you to take the average?

Results

1st measurement: speed = ____________ m/s

2nd measurement: speed = ____________ m/s

3rd measurement: speed = ____________ m/s

Calculate the average to get the

Speed of the Get-Away Car ____________ m/s

You will need to use this result later during the Lab Challenge.

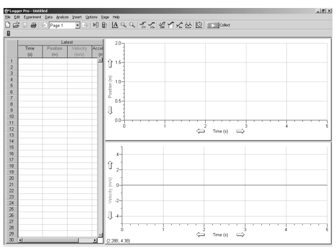
Activity 2 The Computer, the Motion Detector and the Logger*Pro* Software

Many of the lab activities not only today but throughout the entire quarter will use electronic sensors to measure motion, force, rotation etc. In the first two labs we will work with the sonar motion detector that in combination with a computer and the Logger*Pro* software has the ability to measure position, velocity, and acceleration as function of time. The software allows you to display the measurements graphically– for example, as a position vs. time graph.

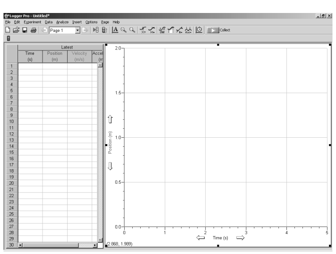
During this activity you will familiarize yourself with the motion detector and learn how to use the software. We do this in two steps; first, your instructor will demonstrate the use of the motion detector and the Logger*Pro* Software; next, your instructor will discuss how to use the graphs.

It's strongly recommended that you take some notes (they could become quite useful when you have to do this on your own).

1. Your instructor will demonstrate how to check the motion detector and start the Logger*Pro* Software.

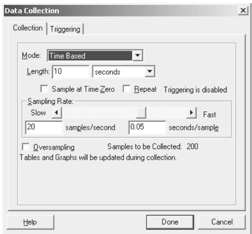


2. A default set of windows will be displayed. Watch how your instructor removes the unwanted velocity graph and enlarges the position vs. time graph.



3. Let's record some data. Your instructor clicks the green **Collect** button at the top of the screen. After about a second, the computer will start generating a graph of the position of an object in the beam of the motion detector. What is this sound you are hearing? What are those numbers that appear in the table in the Logger*Pro* window?

4. Almost everything you see on the screen can be changed. Take notes as your instructor changes the



Collection time

Axis labels and Scale (Auto-scale)

Add/remove additional graphs

Your instructor will demonstrate how to use the motion detector and the Logger*Pro* software to measure the speed of the Get-Away car from Activity 2. How can you extract the speed from the slope of the position vs. time graph?

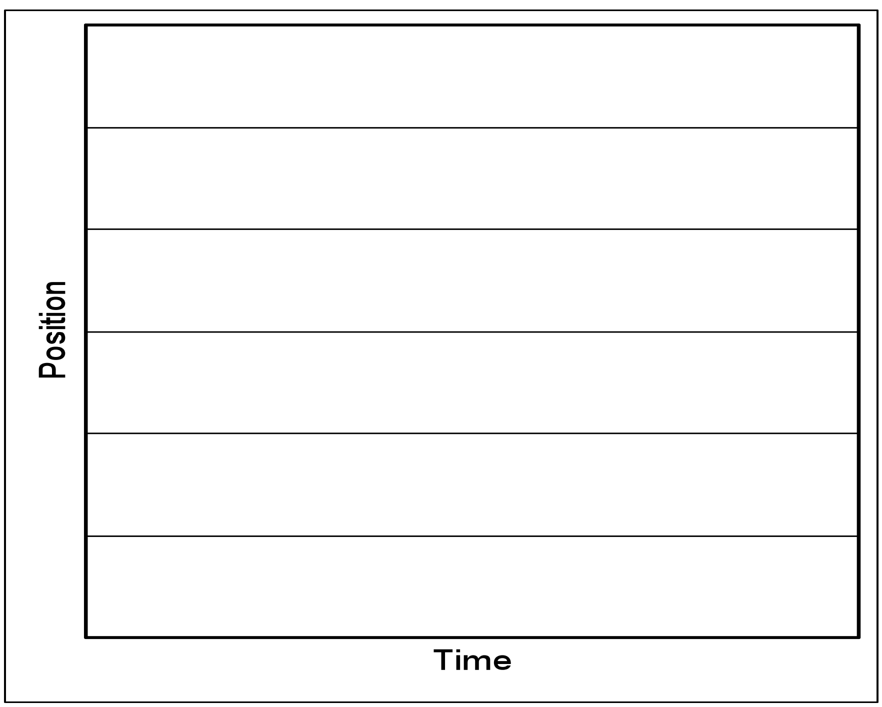
Activity 3 **Now you are on your own: Record and Understand Position vs. Time Graphs**

Now that you are familiar with the motion detector and the Logger*Pro* software you can answer the following questions. Write your answer in the space provided, then do the experiment and copy the *x-t* graph from the display (just a sketch will do but remember to add units and labels to your graphs). Hint: Holding your lab manual in front of your body while you are walking toward or away from the motion detector results in much nicer graphs.

Note You do not need to clear your data between exercises. When Logger*Pro* begins to take new data, the old data is erased. Any data that has been saved is not erased.

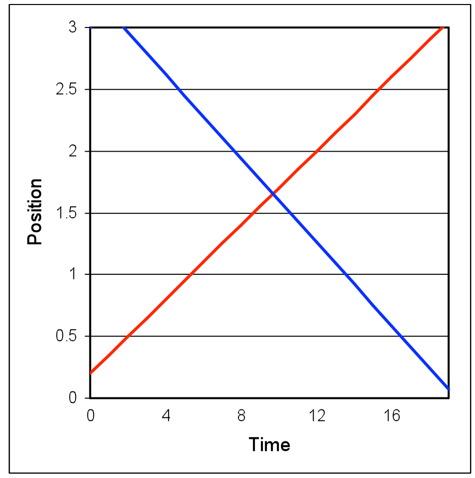
Exercise 1 What do you have to do to create a horizontal line on a position vs. time graph?
Answer:

Now let's try it with the motion detector. One of you stands in front of the detector and the other clicks **Collect**. Can you produce a horizontal line? You can try it more than once. Copy your best result to the plot below.

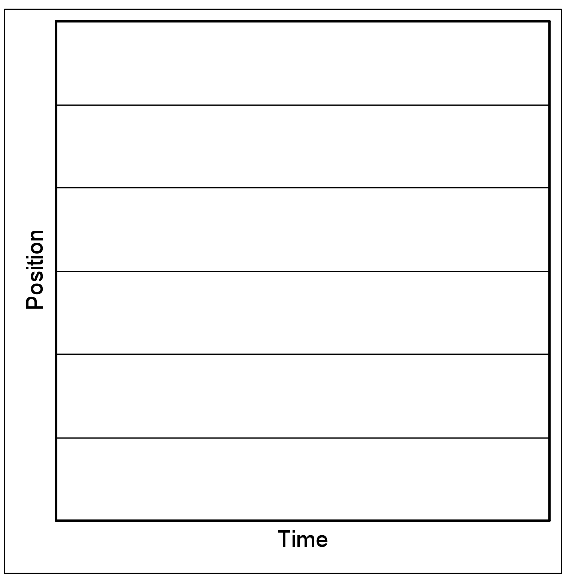


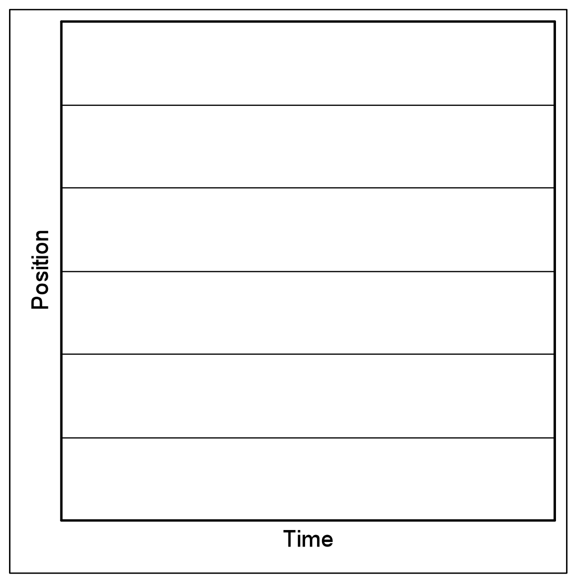
Exercise 2 How do you have to walk to create a straight line that slopes up? How do you have to walk to create a straight line that slopes down?

Answer:



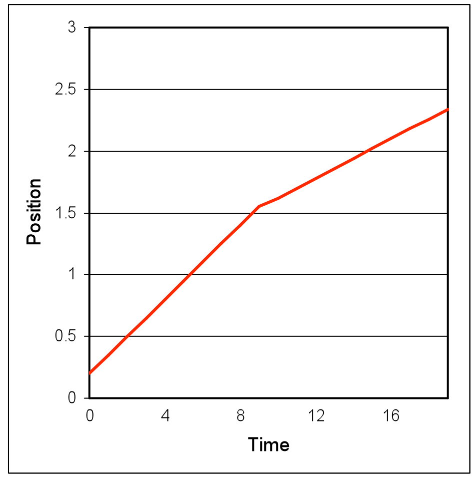
Now use the motion detector and walk in a way that the position vs. time graph looks like one of the lines in the figure. Repeat the experiment trying to produce a graph that looks like the other line. Copy your best results into the 2 diagrams below:



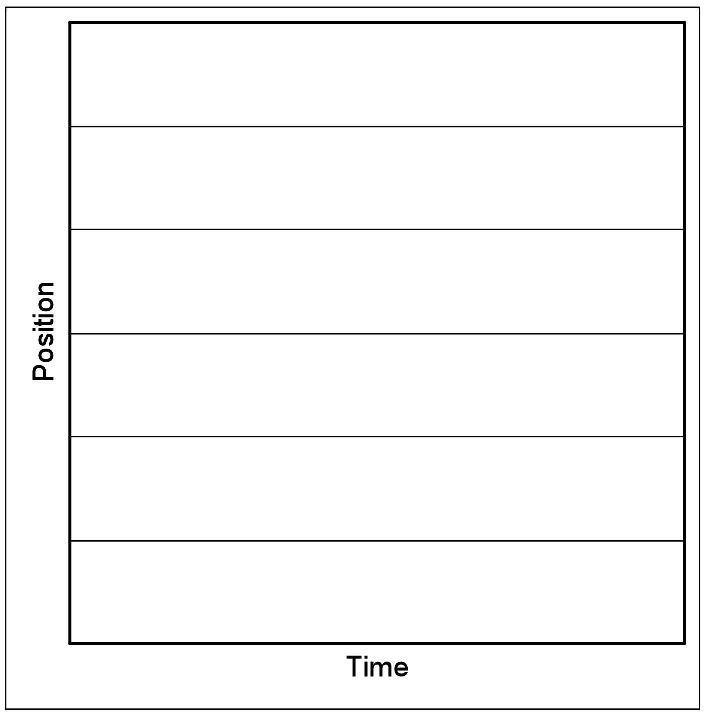


Exercise 3: How do you have to move so that the graph goes up steeply at first, and then continues up less steeply? What causes the change in the slope of the position vs. time graph?

Answer:



Reproduce the position vs. time graph with the motion detector and show your best results:

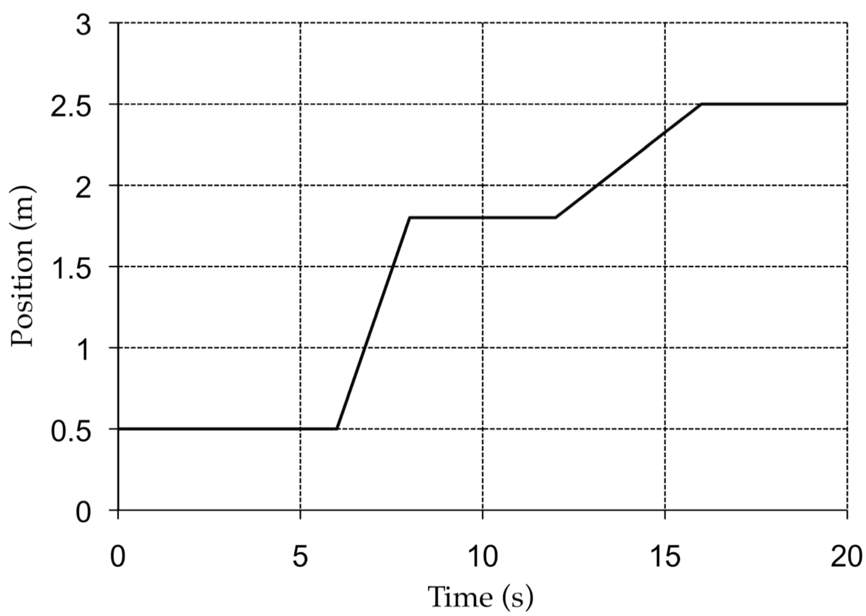


Exercise 4: **Matching a Position Graph**

In this activity you will attempt to match a position graph shown on the computer screen.

1. Display a position graph on the screen
   - Pull down the **File** menu.
   - Choose the **Open...** command. Locate and open the Physics 1200 Logger*Pro* file. [Or look for the file on the desktop]
   - **Double-click** on the file named **Lab1_Graph** to open it. Before the file opens, a dialog box will appear to ask if you wish to save any changes – click **No**.

   The following graph will appear on your screen.



2. Try to match the position graph shown on your computer screen. Figure out how to move to duplicate the data on the **Lab1_Graph** graph. You may try a number of times; do not be discouraged if you do not succeed on your first attempt: you will find that it is quite difficult to match the graph completely, so don't try for a perfect match. Work as a team. Each person should take a turn.

Question How did you move differently to produce the two differently sloped parts of the graph from $t = 6$ s to 8 s and $t = 12$ s to 16 s that you just matched?

____

____

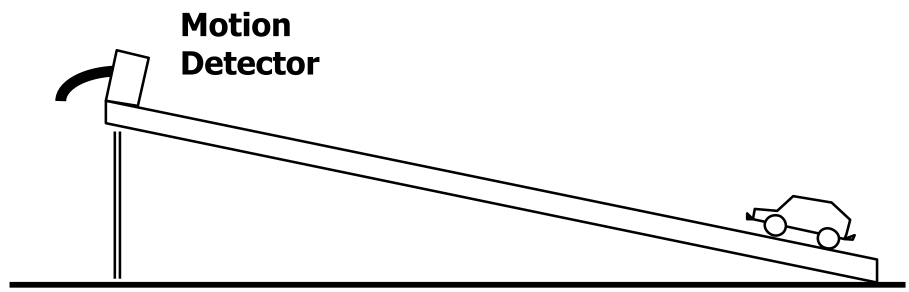
☐ **Show your best match to your instructor. If it's close enough your instructor will let you move on to the next activity.**

Activity 4 **More graphs: Position, Velocity and Acceleration**

For the next activity we need a somewhat more controlled setup. The motion detector is attached to a ramp and we use a cart to study position, velocity and acceleration of the same motion simultaneously.

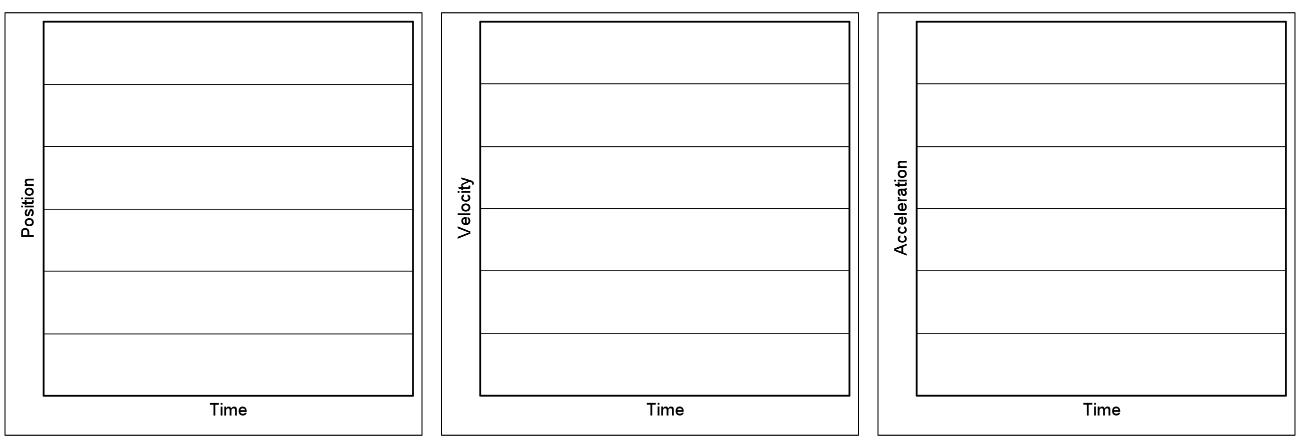
Exercise 1 **Set-up**

Attach the motion detector to the end of the ramp and place the cart at the other end as shown in the drawing.



Exercise 2 **Prediction**

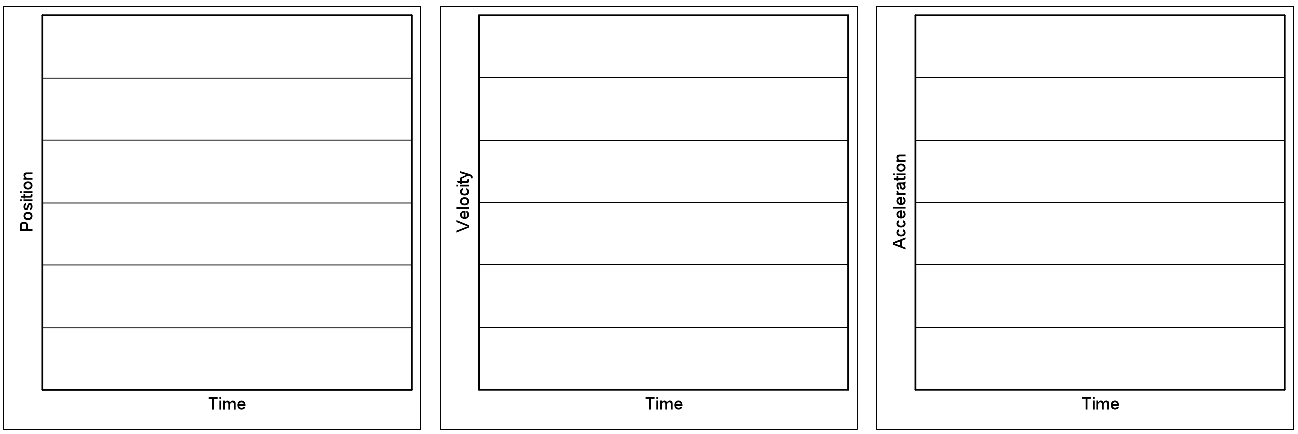
The motion we want to study in this activity is that of a cart rolling up a ramp, coming to a stop and rolling back down again. Just give the cart a quick push (don't let it run into the motion detector) and observe what happens. Use the graphs below to predict position vs. time, velocity vs. time and acceleration vs. time.



Exercise 3 **Measurement**

Configure the Logger*Pro* software to display position, velocity and acceleration simultaneously: select **Graph** from the **Insert** menu and an acceleration vs. time graph should appear. If necessary repeat this step and change the *y* variable to velocity (remember how to do this?). Use the arrange function to layout the three windows (and the table). Ask your instructor for help if you have problems with the software.

Give the cart a few practice runs so that you can get it repeatedly within approximately 20 cm of the motion detector. Collect your data with Logger*Pro* and sketch your results in the graphs below.



Exercise 4 **Discussion of your results and the motion graphs.**

1. Describe the motion and discuss how position, velocity and acceleration change over time. Do the measurements agree with your predictions?

2. Is there a point along the track where the velocity is 0? Where? How about the acceleration?

3. Does the sign of any of the kinematics quantities change at the point closest to the motion detector?

Exercise 5: Measure the acceleration of the cart

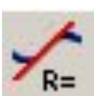
In this exercise we will learn how to use the LoggerPro software to make a quantitative measurement. We will use the graphs recorded in the previous exercise to determine the acceleration of the cart. There are two ways to do this. Obviously, the acceleration can be read from the acceleration vs. time graph. How? Describe your procedure:

The acceleration can also be determined from the velocity vs. time graph. Remember that the acceleration is defined as change in velocity over change in time or $a = \Delta v/\Delta t$. How is this ratio represented in the velocity vs. time graph? Describe your procedure:

LoggerPro

In both cases you have to read of some values from the graphs. Since these are real measurements you can't expect the graphs to be smooth straight lines instead they will wiggle up and down a bit. What you really want is the average; you want to fit the appropriate section of the graph to a line. Fortunately, Logger*Pro* provides you with a simple tool to accomplish this.

Linear Fit



To fit a straight line to your data, select the desired portion of the data by dragging across it. Next, choose Linear Fit from the Analyze menu (or click on the linear regression button on the toolbar – shown in margin). A straight line will be fit to the indicated data, and the slope and intercept information will be displayed in a floating box. Click on the "[" and/or "]" symbols to adjust the fit range.

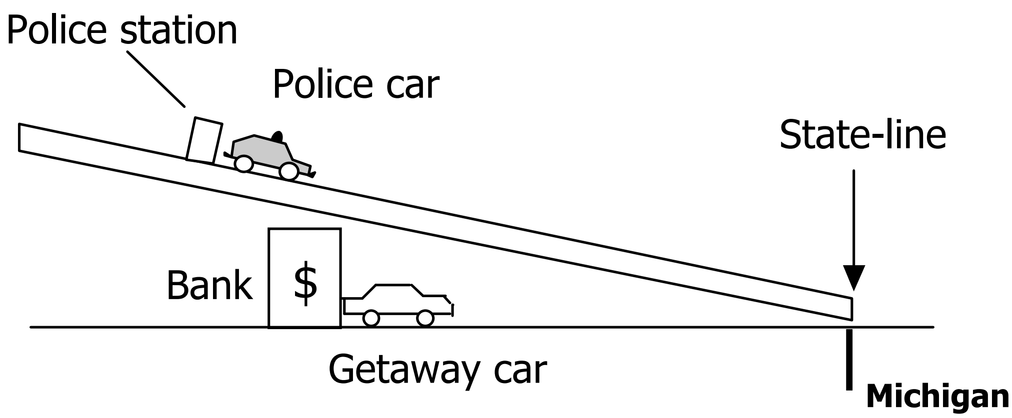
When you fit a segment of the acceleration vs. time graph the acceleration will be given by the intercept information in the floating box.
When you fit a segment of the velocity vs. time graph the acceleration will be given by the slope information in the floating box. (Can you explain why we use the intercept in one case and the slope in another?)

Acceleration (from acceleration vs. time): ______________ m/s^2

Acceleration (from velocity vs. time):______________ m/s^2

Which method do you think is more reliable, intercept or slope?

Activity 6: Lab Challenge: Cops and Robbers



Scenario The Beagle Boys have robbed the local bank, and the cops are on the move! Just as the Boys leave the bank, the cops take off from a nearby police station. The Boys are zooming at top speed in their old Ford, while the cops are accelerating as fast as they can. Both are making for the state-line, which is not very far from the bank. Will the Boys escape, or will the cops nab them in the nick of time?

Task The local community, well aware of the Beagle Boys, plans to build a police station to protect the banks. There is money for only one police station and since there are many other needs the mayor wants to build the station as far away from the state-line as possible. He has asked for your help to find the best location. Your job is to place the police station so that the Boys don't escape: the station should be not too far from the state line but far enough away from the state line so that the police can serve other community needs. The front face of a small block represents the "state-line". **To successfully complete this task, the "state-line" must lie somewhere within the region of the front-half of the Police car when the front of the Getaway car reaches the state line.**

Rules Initially, decide on the position of the bank, the incline of the ramp, and the position of the state line. Use the lab jack to adjust the incline of the ramp: set the top of the lab jack so that it is in the range of 12 – 20 cm about the table top. The lab jack should be placed as far as possible from the state-line.

Every group will use the same getaway car. When you have placed the police station on the ramp, your instructor will place the Getaway car and the Police car in front of the buildings, as shown in the drawing. He simultaneously releases both cars and then we'll see what happens. By the way, you won't have access to the Getaway car for any practice runs.

Hint When you do your calculations, don't forget to take into account the length of both the Police car and the Getaway car.

Exercise 1 **Speed of the Getaway Car**

Remember we already measure this speed so all you have to do is to copy the result from Activity 1.

Speed of the Getaway Car ____________________ **m/s.**

Your instructor will announce the length of the Getaway car

Length of the Getaway Car ____________________ **m.**

While we are at it you might as well complete this exercise by measuring the length of the Police car.

Length of the Police Car ____________________ **m.**

Exercise 2 **How long will it take the Beagle Boys to drive from the bank to the state line?**

Since you don't have access to the Getaway car you can't measure this directly but you have enough information to calculate the "escape" time. How do you do this?

Describe your procedure:

Calculate the escape time _________________ **s.**

Exercise 3 **Acceleration of the Police Car**

How long will it take the police car to reach the state line? To answer this question you will need to know the acceleration of the Police car. You will have to measure this.

Acceleration of the Police Car __________________ **m/s^2.**

Exercise 4 **Place the police station**

You now have enough information to place the police station. Okay, you might have to do another calculation using the kinematics equations, but that's all. Good luck and remember the variable that connects the motion of the Getaway car and the Police car is the time – how long can it take the Police car to reach the state line?

Show your work here:

Position of the police station

(Distance from state line) ________________ **m.**

Tell your instructor that you are ready for the challenge; wait for your instructor to bring the Getaway car to your table.

Was your solution correct? For your solution to be correct, the "state-line" must lie somewhere within the region of the front-half of the Police car when the front of the Getaway car reaches the state line.

Yes (The cops thank you, and we give you 2 points.)

No (The Beagle Boys thank you, but we will keep the 2 points.)

Please clean up your worktable for the next class.

End of Lab 1

When you are finished, close both Logger*Pro*. Do not save any changes.