Bag of Cars – Again

Materials:

- Three toy vehicles: a battery car, a hot wheels car, and a pull-back car
- A ramp made with a board and a few books

Purpose:

What differences do you observe in the motion of these toy vehicles?

Directions:

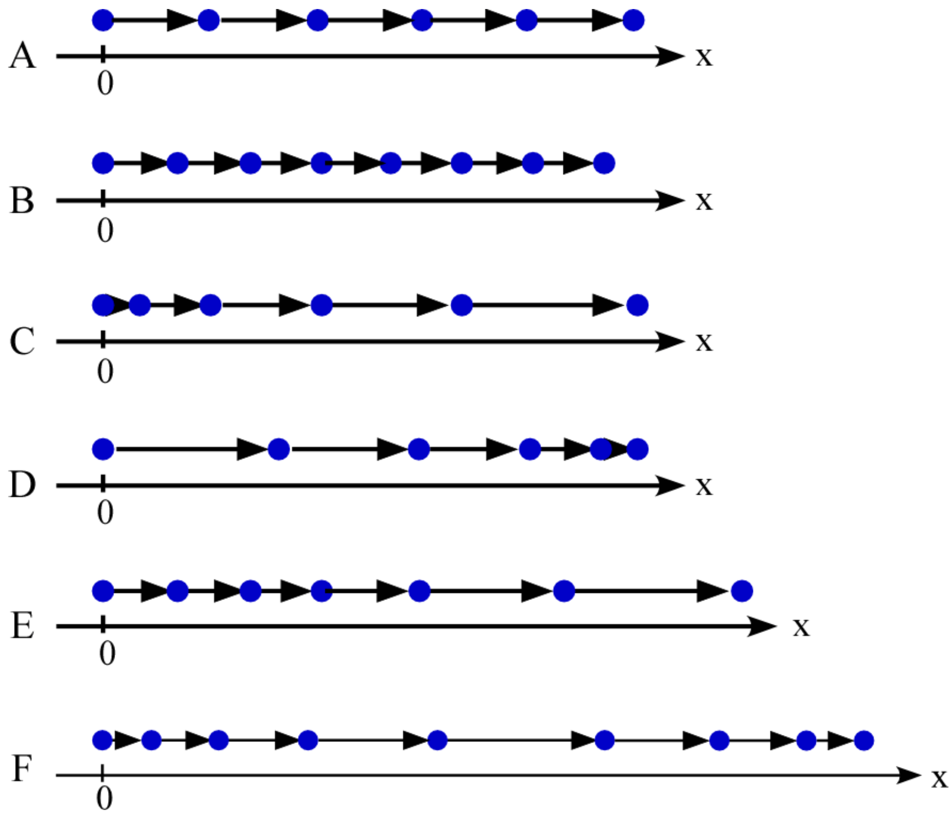
1. Examine the motion of the cars when they travel on a flat surface. Describe the motion based on the concepts that you have learned in the previous unit on uniform motion.

2. Observe the motion of the cars as they travel up and down a ramp, and write a description of the motion of each type of car.

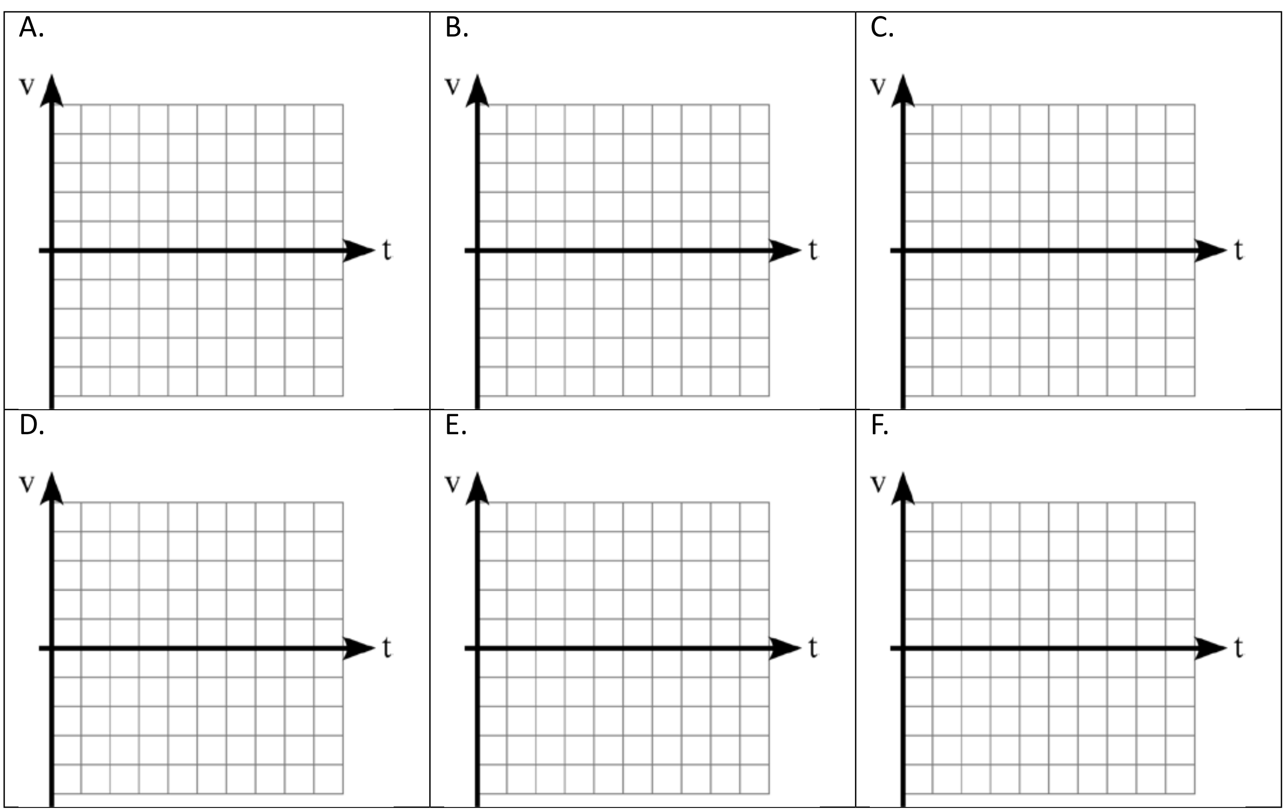
3. List the differences between uniform motion and "slowed-down" or "speeded-up" motion.

4. What do you need to measure to quantitatively describe the motion of the different cars?

5. Match the motion of each of the cars to one of the diagrams below.



6. What do you think the v-t graphs will look like for the 6 situations above?



Post-lab discussion:

7. Summarize what you learned from this activity.

8. Summarize the differences between uniform motion and “slowed down” or “speeded up” motion.

Down the Ramp Lab

Purpose:

What does the x-t graph of car traveling down an incline look like?

Materials:

- CPO or other track with car or cart
- Spark timer with tape
- Masking tape, electrical tape or duct tape to hold spark timer at top of track.

Pre-lab discussion

1. Set up the inclined track. Make sure that the track is stable.

2. Let the car/cart roll down the inclined rails and make observations. Record all observations.

3. Which observations are measurable, and what information do you think you obtain from these measurements?

4. Can you measure speed directly? If so, how?

5. Predict the motion diagram and the x-t graph of the object as it travels down the rail/track.

Directions:

6. Practice releasing the car/cart a few times so that you get smooth motion starting from the top of the run, and the car/cart rolls straight and does not get hung up on the sides of the rails.

7. Attach the spark timer to the top of the track. Thread the spark tape through the timer, and attach the free end of the spark tape to the car/cart with masking tape. Choose whether you want the spark timer to mark the position of the car/cart every 1/10 or 1/60 sec (set the switch to 10 Hz or 60 Hz, respectively).
Have one person start the spark timer, and have another person let go of the car/cart after the timer starts.

8. Design an experiment to study the position of the car/cart as a function of time. Time should be the independent variable.

a) The Experimental Question:

b) IV:

c) DV:

d) Constants:

e) Hypothesis:

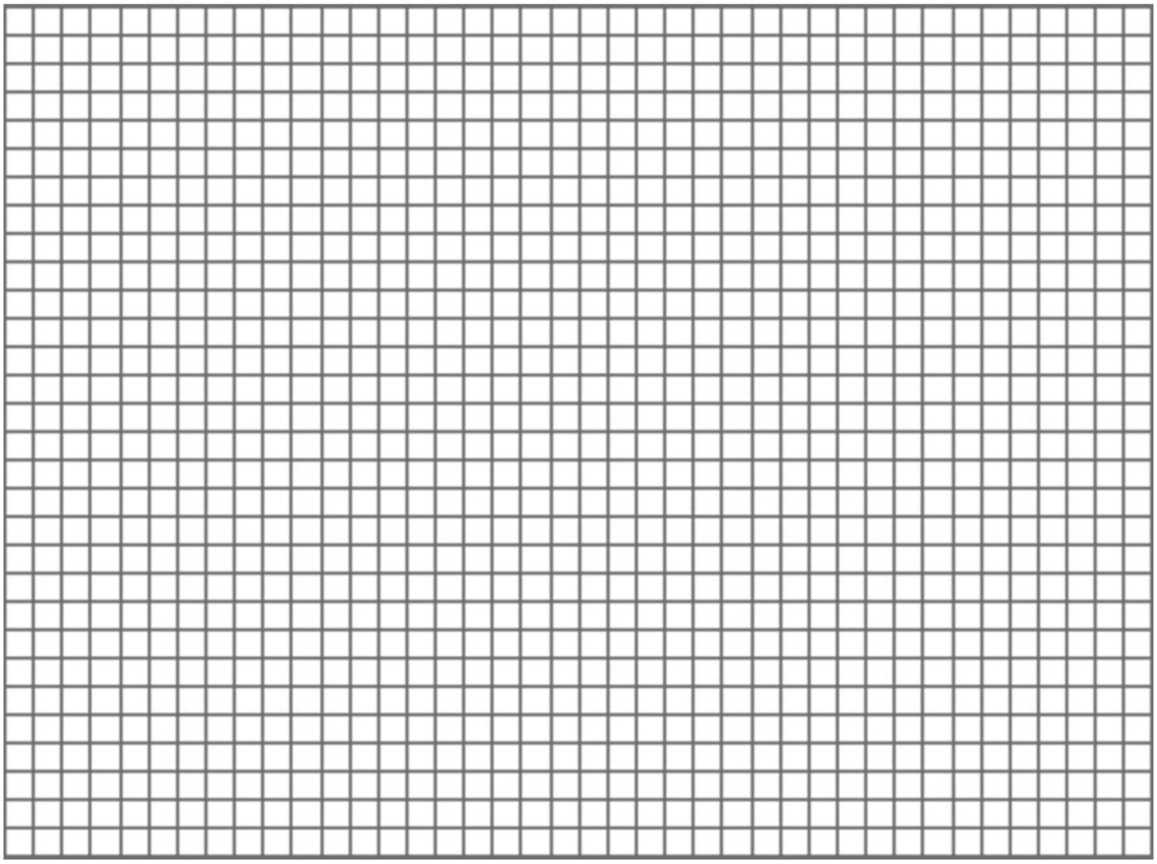
f) Materials List:

g) Procedure:

h) Data table:

i) Plot your data, and draw a smooth line through data points:

Title of graph:



Post-lab discussion:

9. Analysis: Since you are familiar with uniform motion:

a) How does a uniform-speed x *vs.*t graph compare with the graph you obtained from this experiment?

b) Sketch a v *vs* t graph that you would expect for a car/cart traveling at a uniform speed. What do you think would be different in a v *vs* t graph for the experiment you just conducted?

c) Could you use the slope of the x *vs* t graph to figure out how the velocity changes with time? Explain.

10. Draw a motion diagram for the car/cart in this experiment.

11. Save this data- you will return to it and reanalyze it.

Down the Ramp Lab analysis: using the *x-t* graph to get a *v-t* graph

Purpose:

How do I get a *v-t* graph from the *x-t* graph of the Down the Ramp lab, and develop its mathematical expression?

Materials:

- *x-t* graph from Down the Ramp activity

Directions:

1. Using the *x-t* graph from the Down the Ramp lab (call it graph 1), draw secants at several (at least 8) different clock readings and determine the slope of each secant.

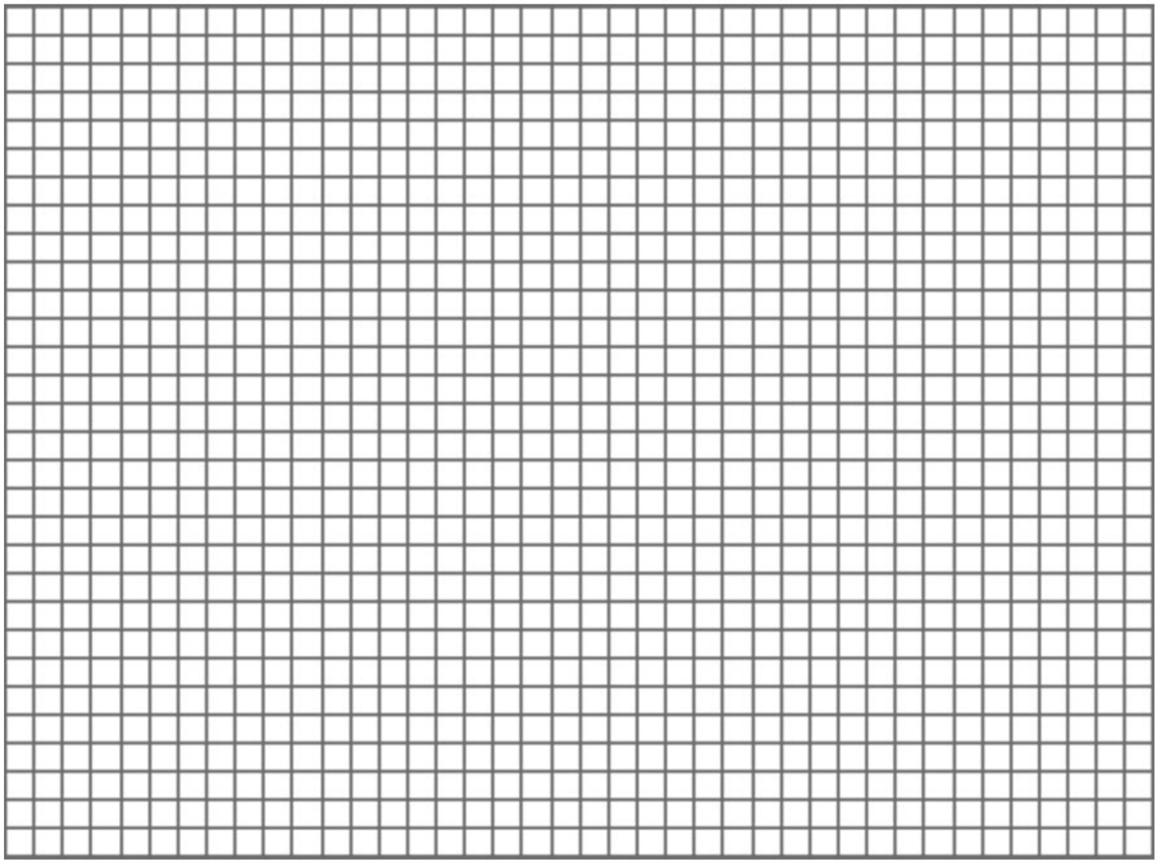
   a) How do you know that you have drawn a secant to the curve?

   b) What are the units of the slope? What do the slopes represent?

   c) If you were to make a table of clock reading and slope, what clock reading would you assign to each slope?

   d) Make a table of clock reading and slope of the secant. Then plot the slope of the secant vs. time (clock reading). Use the same time scale graph 1. Call this graph 2.

Title of graph:



2. Analyze the graph:

a) What is the shape of the curve in graph 2? What does that shape indicate?

b) Calculate the slope of graph 2. What does the slope indicate? What are its units?

c) What does the vertical intercept of graph 2 indicate?

3. Developing a mathematical relationship from graph 2 for v vs t:

a) From the slope of graph 2, develop a mathematical relationship between the beginning and ending velocities (often called the initial and final velocities, respectively), the time interval, and the slope.

b) What do you think the name of the slope might be?

4. Drawing the motion diagram:

From the x-t and v-t graphs, draw a motion diagram that indicates both the position and velocity of the car/cart.

Know your Equipment –Timer and Photogates Activity

This activity introduces you to the equipment needed for the Motion along an Incline Photogate Lab. (for Vernier and Pasco photogates, see appendix)

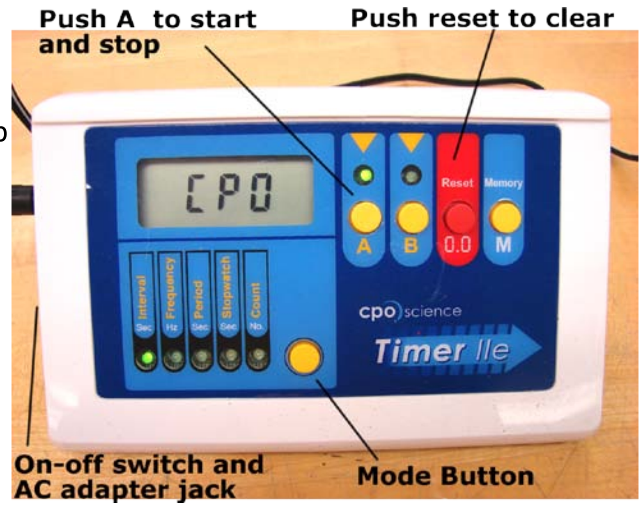
Part I. Using the timer as a stopwatch:

The electronic timer allows us to make accurate, precise measurements of time. The timer performs many different functions. The first function to try is stopwatch. Use the mode button (1) to move the light under the word stopwatch.

A stopwatch measures a **time interval.** The stopwatch is started and stopped with the "A" button (2). The display shows time in seconds up to 60 seconds, then changes to show minutes: seconds for times longer than one minute.

1. The time it takes a signal to go from your brain to move a muscle is called **reaction time.** Reaction time varies from person to person and can be affected by factors like tiredness or caffeine intake.

   a) Try this out: Design a method to measure the reaction time of a person:



Set timer to stopwatch

Start and stop the stopwatch with the "A" button

Reset the stopwatch to zero with the "0" button

Use the method you designed to take measurements with the stopwatch on three students. Your data:

2. Estimate the approximate reaction time of an average student.

Part II. Mixed units for time

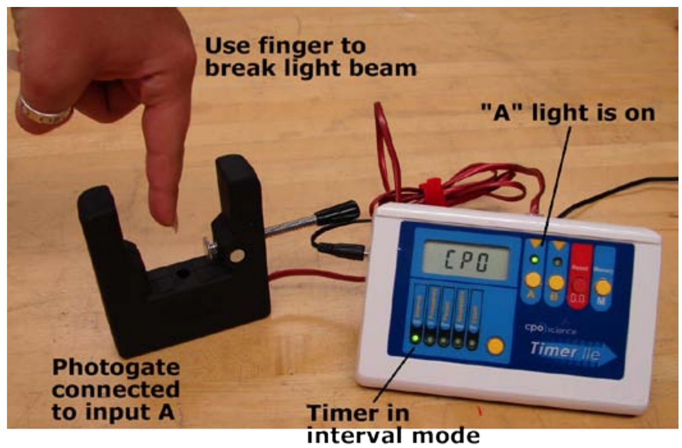
3. Time is often given in mixed units including hours, minutes, and seconds. Mixed units are often written as shown in the diagrams below.

a) Convert each one (a-c) to seconds.

b) Arrange the times from smallest to largest:

Part III. Using Photogates

A photogate allows us to use a light beam to start and stop the timer. When the timer is in interval mode, it uses photogates to control the clock.



4. Connect a single photogate to the "A" input with a cord.

a) Select **interval** on the timer.

b) Push the "A" button and the "A" light should come on and stay on.

c) Try blocking the light beam with your finger and observe what happens to the timer. Because it is used for so many measurements, you need to figure out how the photogate and timer work together. Try your own experiments until you can answer the questions.

d) Exactly what do you do to start and stop the clock? Be very specific in your answer.

e) If you block the light beam several times in a row, does the time add or does the timer start at zero every time you break the beam? Provide observations to back up your statements.

f) What happens if you use three fingers rather than one?

g) What happens when you move one finger rapidly through the photogate as compared to when you move it slowly?

h) So what is the photogate measuring? How can you use this information to calculate speed?

Part IV. Two photogates

The timer can be used with two photogates. Photogate A is connected to the A input and photogate B is connected to the B input. What the timer shows depends on the lights above the buttons. Pushing the A or B buttons toggles the A or B light on or off. Do your own experiments until you can fill in the table below.

A light	B light	How do you start the clock?	How do you stop the clock?	What time interval does the clock measure?
On	Off			
Off	On			
On	On			
Off	Off			

Part V. Thinking about what you observed

5. Describe a way to measure the speed of a toy car using two photogates and a meter stick.

6. Example: A car has a flag of width 2 cm. As it passes through a photogate, it blocks the light beam for 0.032 sec, as indicated on the timer connected to the photogate. What is the speed of the car?

Answer: The distance traveled by the car in 0.032 sec is 2 cm. Therefore the speed of the car is

$$v = \frac{\text{distance traveled}}{\text{time taken}} = \frac{2\text{ cm}}{0.032\text{ s}} = 62.5\text{ cm/s}$$

b. Describe a way to measure the speed of a toy car using one photogate and a meter stick.

c. What does the red Reset button do?

Motion Along an Incline – Photogate Lab

Materials:
- Track, car(s), two photogates and timer
- Stand to hold track at an incline

Purpose:

How can we experimentally compare a v-t graph obtained from x-t measurements, to v-t measurements? How does the v-t graph change for different inclines?

This lab has three parts. In Part I, x-t data is obtained for a car/cart that travels down an incline, and v-t data is calculated from the x-t graph. In Part II, v-t data is measured for the same conditions. In Part III, v-t data is compared for different inclines.

Pre-lab discussion:

1. Observe how the track is attached so it is at an incline, and how it is set up so that it is stable. Remind yourself about how to set up photogates. Have the car travel down the track, starting from rest at the top of the incline.

2. The goal of the first part of this activity is to take *x-t* data as the car moves down the track. Discuss the factors you will measure, and those that you will keep constant. Write your ideas in your books, and then on your whiteboard.

3. In this lab you will take at least 8 data points (4 or 5 cm apart). You could stick masking tape along the side of the track and mark the cm points where you set up the photogates. Set the first photogate as close as possible to the starting point (the edge of the car's flag) so the clock measures t=0 as close as possible at the point where the speed is zero

4. After you finish the first part and analyze the *x-t* data to get *v-t* data as for the car/cart lab, you will directly measure the speed of the car at the same *x*-values that you used for the *x-t* data. Write below how you plan to set up the experiment to take data so that all the requirements above are satisfied.

Directions:

Part I: Obtaining *x-t* data for the motion of a car along an incline.

5. Design an experiment to study the position of the car as a function of time.

   a) The Experimental Question:

b) IV:

c) DV:

d) Constants of the experiment:

e) Hypothesis:

f) Materials List:

g) Procedure:

h) Data table:

i) Draw a graph on graph paper with fine grid (5 or 10 to the cm. Use the long side for the horizontal axis). Draw a with smooth line through data points.
Although you have used position as the independent variable, plot time on the horizontal axis of the graph, and position on the vertical axis . What do you think is the justification for doing so?

6. Analysis of *x-t* data: Use the slope technique that you used in the Down the Ramp Lab to obtain the instantaneous velocity at 8 different clock ticks.
Plot your *v vs t* data on a separate graph using the same intervals for *t* as you did for the x-t graph. As in the *x-t* graph, use the long side of the paper for the time axis, and place the time variable on the horizontal axis.

Part II: Obtaining *v-t* data for the motion of the car using photogates:

7. Remember that photogates can also be used to measure the speed of the car as it passes the photogates.

a) Notice that the car has a little flag that blocks the photogate's light beam as the car passes through. How can you use this information to measure the speed of the car as it passes the photogate?

b) Which timer function will you use? What is the width of the flag? What will the units of the speed be?

8. Designing the *v-t* experiment:

a) If you wanted to measure the instantaneous velocity v at different positions along the track, and to also measure the time t it took to get to that position on the track, what would you have to do? How many photogates should you use? What timer settings must you keep track of?

b) The goal of this experiment is to compare this *v-t* data with the *v-t* graph that you obtained from the slopes in part I. What factors must you hold constant between this experiment and the previous one?

c) How would you conduct an experiment to obtain the v-t graph discussed above?

9. Conduct an experiment to study the velocity of the car as a function of time.

a) The Experimental Question:

b) IV

c) DV:

d) Constants of the experiment:

e) Hypothesis:

f) Materials List:

g) Procedure:

h) Data table:

i) Draw a graph with smooth line through data points – use another sheet of graph paper: as in your two previous graphs, place t along the horizontal axis, and use the long edge of the paper for t. Use the same time intervals as your two previous graphs.

10. Analysis of *v*-*t* graphs:

a) What comparisons can you make between the two v-t graphs from part I and part II? How are they similar and how are they different? What are the reasons for these similarities/differences?

b) What conclusions can you draw from the two *v*-*t* graphs?

c) What are the shapes of these graphs?

d) What do you think the slopes indicate? What are the units of the slope? Is the slope constant for each curve? If so, what does this constant slope indicate?

Part III. Comparing v-t slopes for different inclines

11. Producing a graph with a different *v-t* slope:

a) What factors could you vary to change the slope of the *v-t* graph, and how would it change the slope? Explain your reasoning.

b) Discuss the factors with your group and your class, and choose one factor that your group will change. Repeat the experiment(s) and obtain a new set of *x-t* and *v-t* data. How is it possible to obtain both *x-t* and *v-t* data in one experiment rather than make separate runs? You may plot the new *x-t* and *v-t* sets on the same sheets of graph paper as in Parts I and II above.

12. Analysis of both sets of data:

a) Examine the two sets of *x*-*t* and *v*-*t* data that you have obtained. Compare and contrast them, and explain their differences.

b) Draw motion diagrams for both sets of data. Compare them and explain why they are same/similar/different.

13. Conclusions: Summarize what you learned about motion down an incline.

Two Accelerating Objects - Theoretical Lab

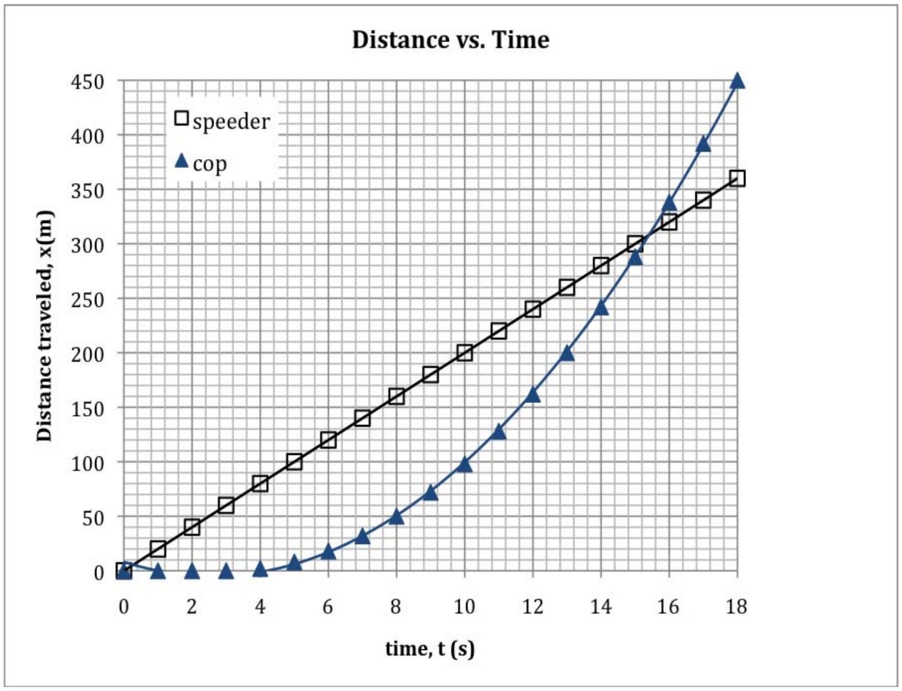
A speeder, who is driving down the road at a constant speed of 20 m/s, passes a cop parked on the roadside. The cop waits 3 seconds, then pursues the speeder, accelerating at a constant 4.0 m/s^2. When does the cop catch the speeder?

a) Do this problem by generating a data table of position values at 1 second intervals for the speeder and for the cop.

b) Plot a graph of the position of the speeder and the cop, and figure out when the cop catches the speeder.

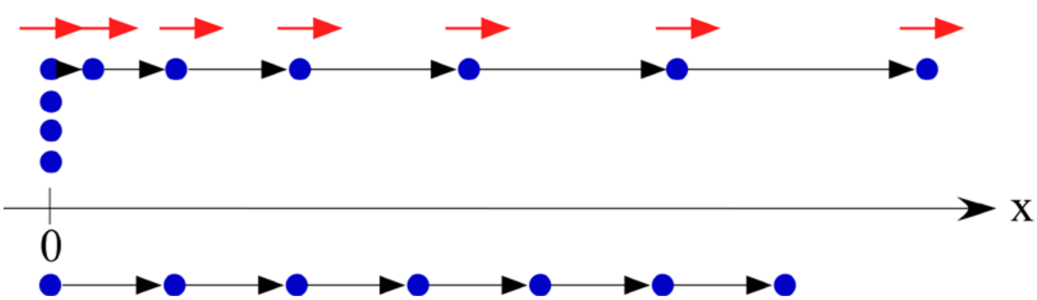
c) Draw motion diagrams of the speeder and the cop.

t (sec)	x (m), speeder	x (m), cop
0	0	0
1	20	0
2	40	0
3	60	0
4	80	2
5	100	8
6	120	18
7	140	32
8	160	50
9	180	72
10	200	98
11	220	128
12	240	162
13	260	200
14	280	242
15	300	288
16	320	338



Solution: The table, graph and the motion diagram are shown. From the graph one can see that the cop catches the speeder 15.4 sec after s/he sees the speeder.

Motion Diagram:

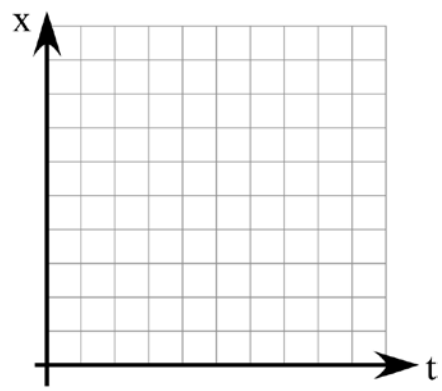


Practice Problem:

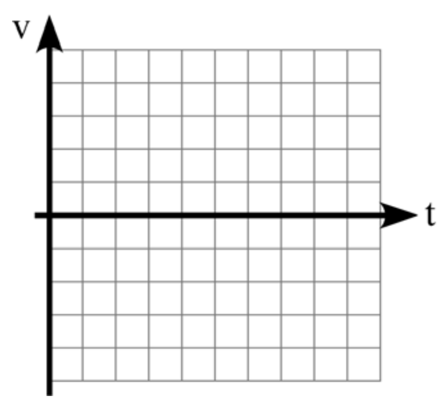
1. Pepper and Matt play football. Pepper stands at the goal line (x=0) and Matt is 20 yards away. At a certain instant, Pepper catches the ball (still standing directly on the goal line). He immediately starts running toward Matt with an acceleration of 6 ft/s^2. At that same instant, Matt heads directly toward Pepper with a steady speed of 15 ft/s.

   a) Draw a physical diagram and label it.

   b) Make a table of position-time data for Pepper and Matt, calculating their positions every second.



   c) Draw a position vs. time graph for both Pepper and Matt.



   d) Make a velocity vs. time for both Pepper and Matt.

   e) Draw a motion diagram for both Pepper and Matt showing their motion from the moment Pepper caught the ball until they meet.

Speeding Up and Slowing Down Lab

Materials:

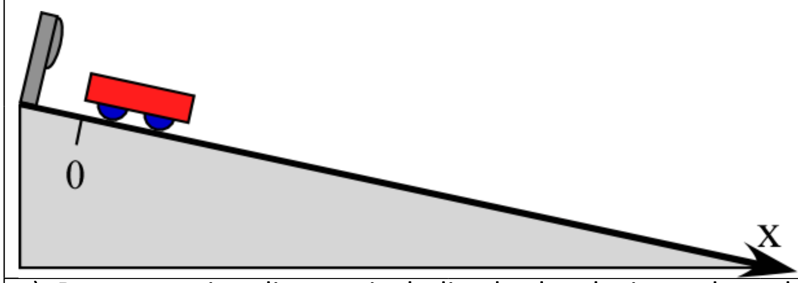
- Motion Detector; Ramp or track

Purpose

How do motion graphs for an accelerating object look?

Directions:

1. Observe the motion of the cart starting from rest and rolling down an incline *without* using the motion detector.

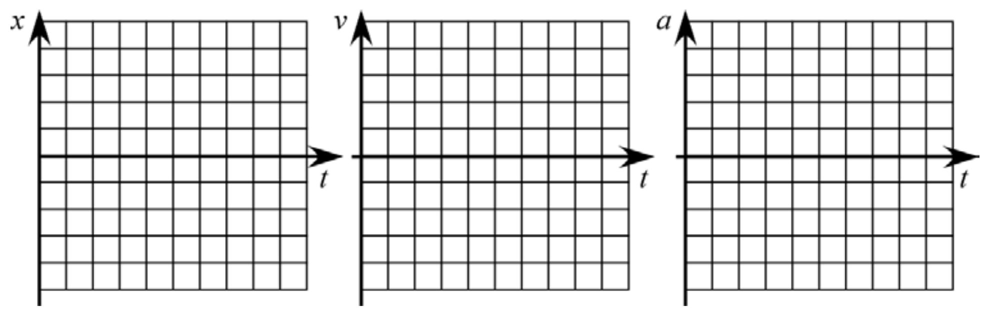


a) Is the velocity positive or negative?

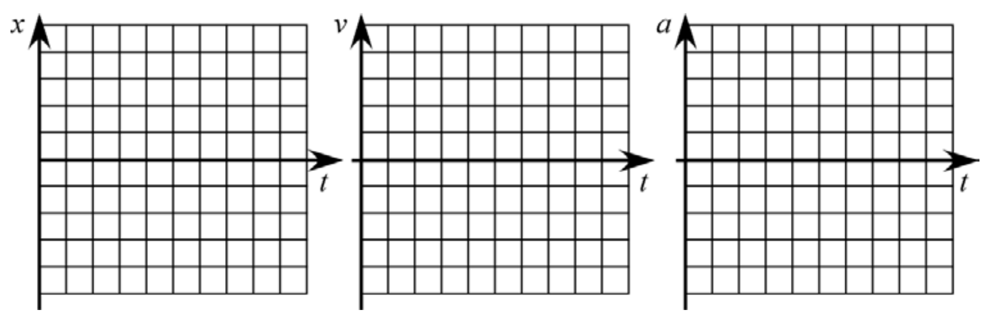
b) Is the acceleration positive or negative?

c) Draw a motion diagram including both velocity and acceleration.

d) Predict the graphs describing the motion

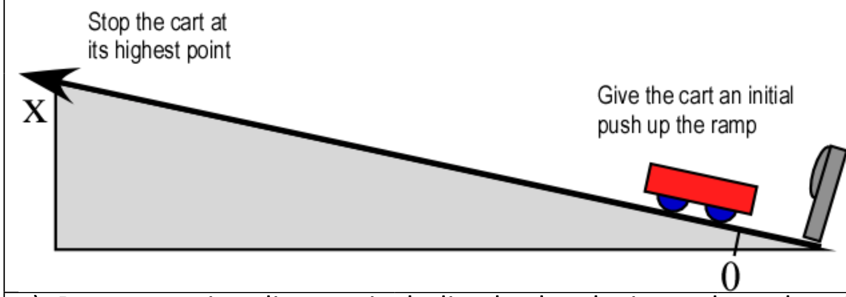


e) Record the graphs observed using the motion detector.



f) For each observed graph,	x-t graph	v-t graph	a-t graph
• Is the slope constant (or zero), increasing or decreasing? • Is the slope positive or negative • What does the slope represent?			

2. Observe the motion of the cart slowing down after an initial push *without* using the motion detector. Answer the following questions for the cart while coasting.

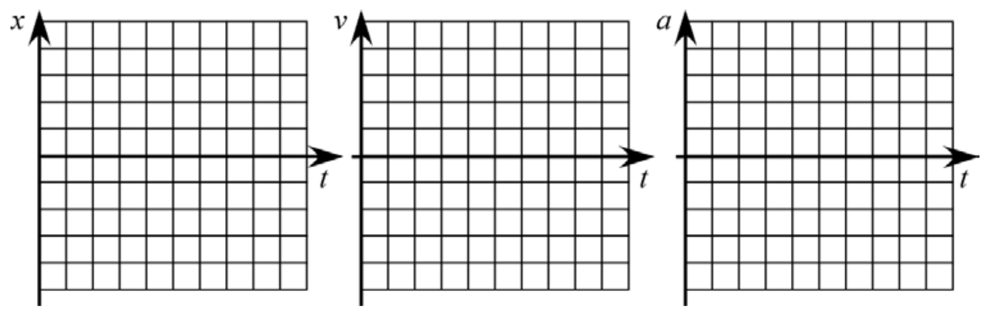


a) Is the velocity positive or negative?

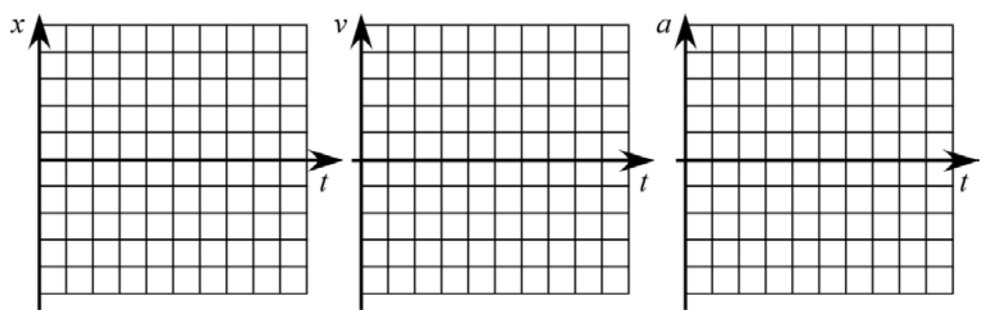
b) Is the acceleration positive or negative?

c) Draw a motion diagram including both velocity and acceleration.

d) Predict the graphs describing the motion

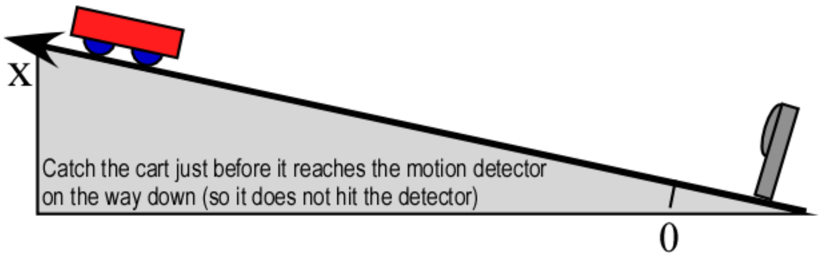


e) Record the graphs observed using the motion detector.



f) For each observed graph, • Is the slope constant (or zero), increasing or decreasing? • Is the slope positive or negative • What does the slope represent?	x-t graph	v-t graph	a-t graph

3. Observe the motion of the cart starting from rest and rolling down the incline *without* using the motion detector.

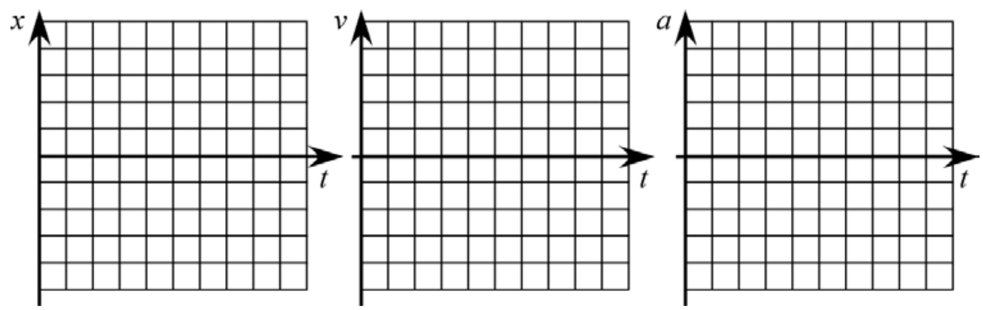


a) Is the velocity positive or negative?

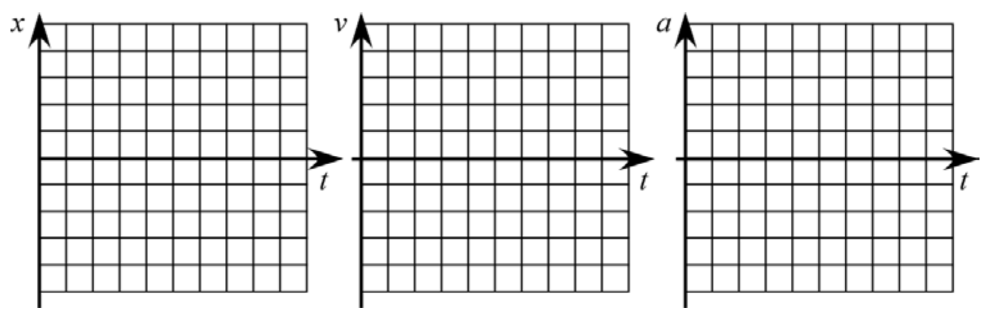
b) Is the acceleration positive or negative?

c) Draw a motion diagram including both velocity and acceleration.

d) Predict the graphs describing the motion

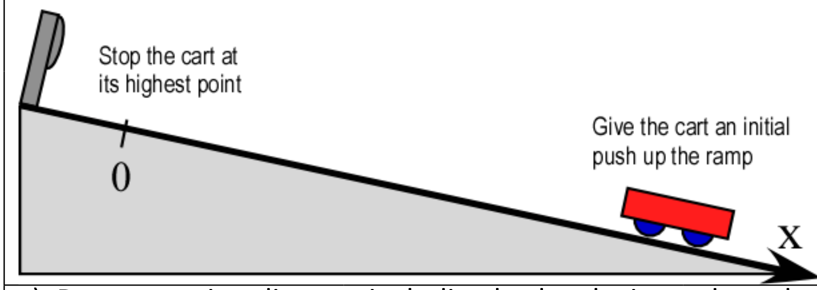


e) Record the graphs observed using the motion detector.



f) For each observed graph, • Is the slope constant (or zero), increasing or decreasing? • Is the slope positive or negative • What does the slope represent?	x-t graph	v-t graph	a-t graph

4. Observe the motion of the cart slowing after an initial push *without* using the motion detector. Answer the following questions for the cart while coasting.

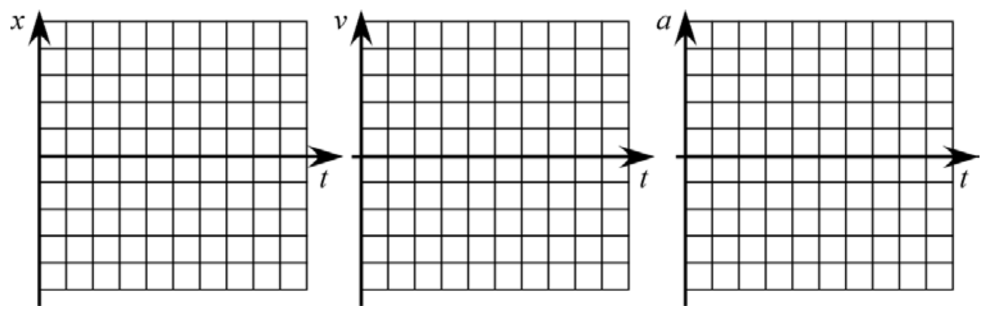


a) Is the velocity positive or negative?

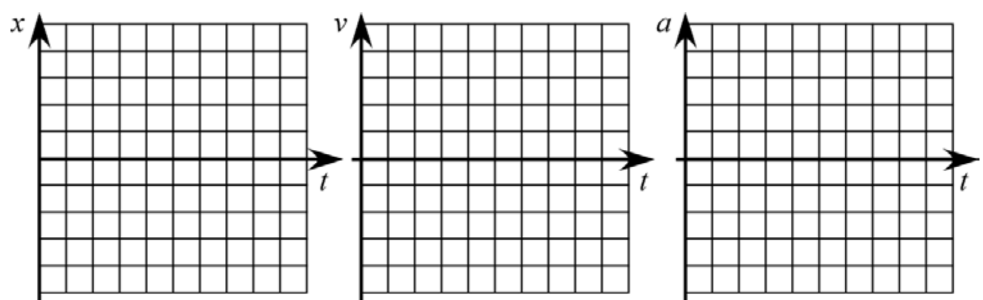
b) Is the acceleration positive or negative?

c) Draw a motion diagram including both velocity and acceleration.

d) Predict the graphs describing the motion

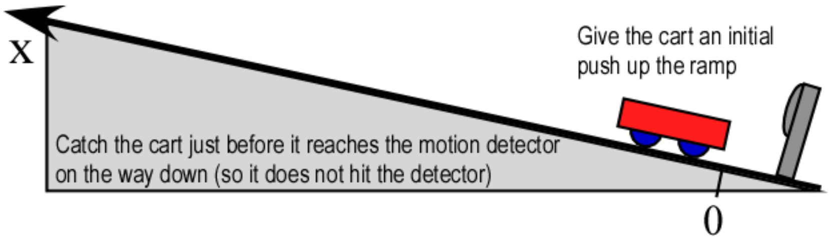


e) Record the graphs observed using the motion detector.



f) For each observed graph, • Is the slope constant (or zero), increasing or decreasing? • Is the slope positive or negative • What does the slope represent?	x-t graph	v-t graph	a-t graph

5. Observe the motion of the cart after an initial push *without* using the motion detector. Answer the following questions for the cart while coasting.

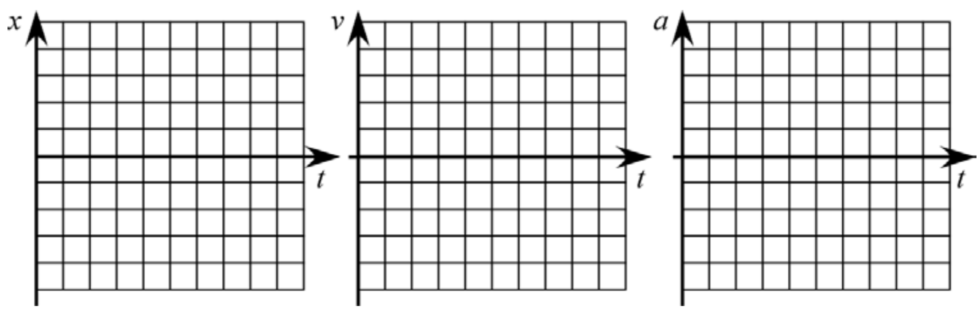


a) Is the velocity positive or negative? Does its direction change?

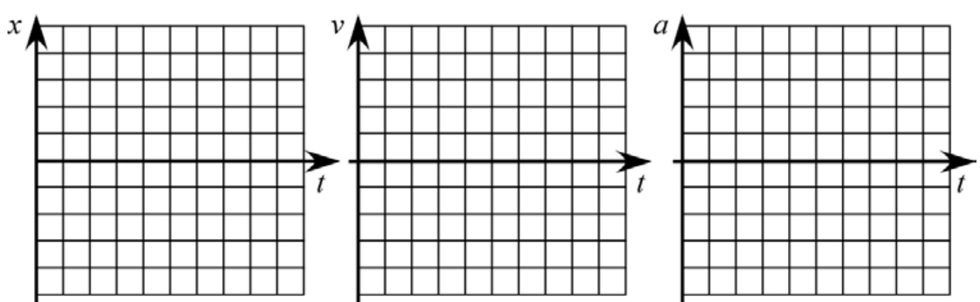
b) Is the acceleration positive or negative? Does its direction change?

c) Draw a motion diagram including both velocity and acceleration.

d) Predict the graphs describing the motion

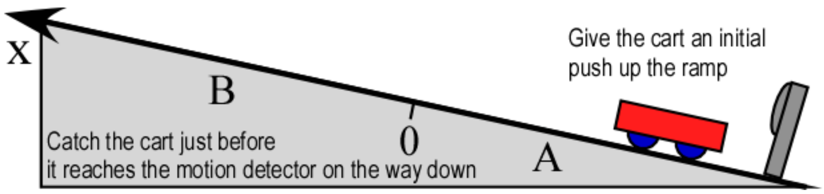


e) Record the graphs observed using the motion detector.



f) For each observed graph,	x-t graph	v-t graph	a-t graph
• Is the slope constant (or zero), increasing or decreasing? • Is the slope positive or negative • What does the slope represent?			

6. Observe the motion of the cart after an initial push *without* using the motion detector. Answer the following questions for the cart.

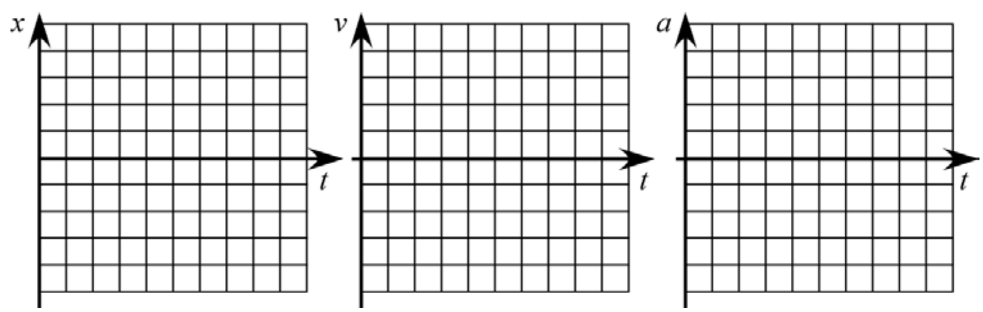


a) Is the velocity positive or negative? Does its direction change? Is position A positive or negative?

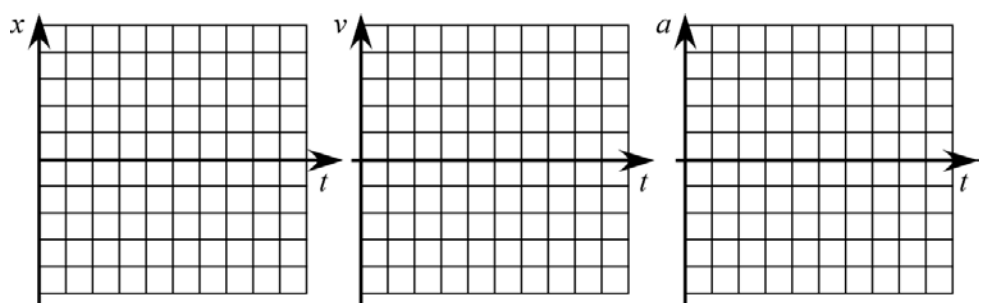
b) Is the acceleration positive or negative? Does its direction change? Is position B positive or negative?

c) Draw a motion diagram including both velocity and acceleration.

d) Predict the graphs describing the motion



e) Record the graphs observed using the motion detector.



f) For each observed graph,	x-t graph	v-t graph	a-t graph
• Is the slope constant (or zero), increasing or decreasing? • Is the slope positive or negative • What does the slope represent?			

Testing Cars – Application lab

Purpose:

A planned collision: A hot-wheels car is placed on top of a ramp 100 to 200 cm long, and allowed to roll down. You need to figure out where the constant motion car needs to start so that the cars collide at the bottom of the ramp. Both cars must be moving when they collide. You define the steepness of the ramp.

Materials:

- A spark timer or videos of each car to analyze their motion
- A constant motion car
- A hot- wheels car
- A meter stick or wind-up tape marked in meters
- Masking tape or duck tape
- Graph paper
- Ramp, 100 to 200 cm long, as available (a wood board or shelf works well.

Directions:

Since this is an application lab, you get to decide how you set up and conduct this lab. Here are the requirements:

a) Set up the ramp with any incline you wish. Use a spark timer or video analysis to make measurements, and then graph the v-t and a-t motion of the cars.

b) Calculate how far from the bottom of the ramp you need to start the battery car so it collides with the hot-wheels car at the bottom of the ramp.

c) Test your calculation.

Your lab notes: