Name_____ Period_____ Date_____

| **CONCEPTUAL PHYSICS** | **Experiment** |

4.7 Linear Motion: Motion Graphs

Go! Go! Go!

Thanx to Dean Baird

Purpose
In this experiment, you will plot a graph that represents the motion of an object.

Required Equipment and Supplies
constant velocity toy car
butcher paper (or continuous—unperforated—paper towel, or equivalent)
access to tape
stopwatch
meterstick
graph paper

Discussion
Sometimes two quantities are related to each other, and the relationship is easy to see. Sometimes the relationship is harder to see. In either case, a graph of the two quantities often reveals the nature of the relationship. In this experiment, we will plot a graph that represents the motion of a real object.

Procedure
We are going to observe the motion of the toy car. By keeping track of its position relative to time, we will be able to make a graph representing its motion. To do this, we will let the car run along a length of butcher paper. At one-second intervals, we will mark the position of the car. This will result in several ordered pairs of data—positions at corresponding times. We can then plot these ordered pairs to make a graph representing the motion of the car.
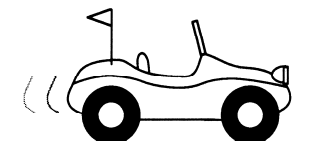
Step 1: Fasten the butcher paper to the top of your table. It should be as flat as possible—no hills or ripples.

Step 2: If the speed of the toy car is adjustable, set it to the slow setting.

Step 3: Aim the car so that it will run the length of your table. Turn it on and give it a few trial runs to check the alignment.

Step 4: Practice using the stopwatch. For this experiment, the stopwatch operator needs to call out something like, "Go!" at each one-second interval. Try it to get a sense of the one-second rhythm.

Step 5: Practice the task.
   a. Aim the car to drive across the length of the butcher paper and let it go.
   b. **After** it starts, the stopwatch operator will start the stopwatch and say, "Go!"
   c. Another person in the group should practice marking the location of the front or back of the car on the butcher paper every time the watch operator says, "Go!" For the practice run, simply touch the eraser of the pencil to the butcher paper at the appropriate points.
   d. The watch operator continues to call out, "Go!" once each second and the marker continues to practice marking the location of the car until the car reaches the end of the butcher paper or table. Take care to keep the car from running off the table!

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Step 6: Perform the task.
    a. Aim the car to drive across the length of the butcher paper and let it go.
    b. **After** it starts, the stopwatch operator will start the stopwatch and say, "Go!"
    c. Another person in the group will mark the location of the front or back of the car on the butcher paper every time the watch operator says, "Go!" **No marks are to be made on the paper until the car is moving.**
    d. The watch operator continues to call out, "Go!" once each second and the marker continues to mark the location of the car until the car reaches the end of the butcher paper or table. Take care to keep the car from running off the table!

Step 7: Label the marked points. The first mark is labeled "0," the second is labeled "1," the third is "2," and so on. These labels represent the time at which the mark was made.

Step 8: Measure the distances—in centimeters—of each point from the point labeled "0." (The "0" point is 0 cm from itself.) Record the distances on the data table. Don't worry if you don't have as many data points as there are spaces available on the data table.

Data Table

Time t (s)	0	1	2	3	4									
Position x (cm)	0													

Step 9: Make a plot of position vs. time on the graph paper. Title the graph "Position vs. Time." Make the horizontal axis time and the vertical axis position. Label the horizontal axis with the quantity's symbol and the units of measure: "t (s)". Label the vertical axis in a similar manner. Make a scale on both axes starting at 0 and extending far enough so that all your data will fit within the graph. Don't necessarily make each square equal to 1 second or 1 centimeter. Make the scale so the data will fill the maximum area of the graph.

We could just as easily make a graph of time vs. position. But we prefer position vs. time for a few reasons. In this experiment, time is what we call an "independent variable." That is, no matter how fast or slow our car was, we always marked its position at equal time intervals. *We* were in charge of the time intervals; the *car* was "in charge" of the change in position it made in each interval. But the change in position of the car in each interval depended on the time interval we chose. So we call position the "dependent variable." We generally arrange a graph so that the horizontal axis represents the independent variable and the vertical axis represents the dependent variable. Also, the slope of a position vs. time graph tells us more than the slope of a time vs. position, as we will see later.
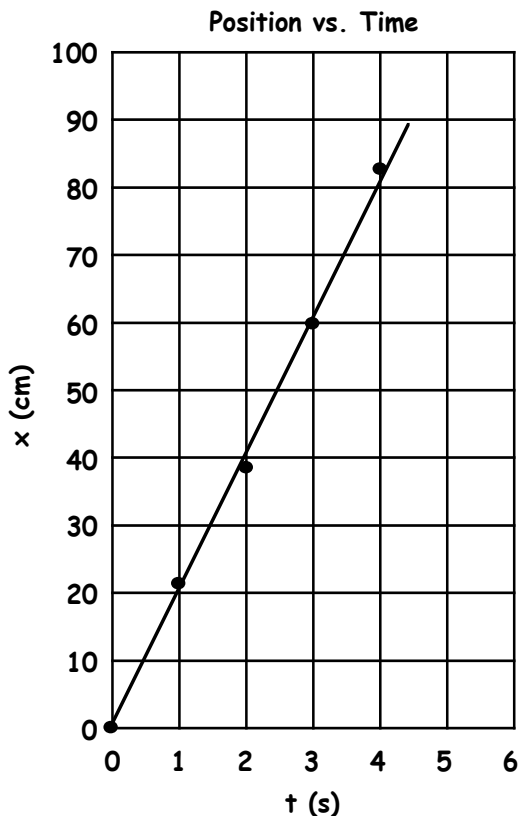
Figure 1

Step 10: Draw a line of best fit. In this case, the line of best fit should be a single, straight line. Use a ruler or straight edge; place it across your data points so that your line will pass as close as possible to all your data points. The line may pass above some points and below others. Don't simply draw a line connecting the first point to the last point. An example is shown in Figure 1.

Step 11: Determine the slope of the line. Slope is often referred to as "rise over run." To determine the slope of your line, proceed as follows.

a. Pick two convenient points on your line. They should be pretty far from each other. Convenient points are those that intersect grid lines on the graph paper.

b. Extend a horizontal line to the right of the lower convenient point, and extend a vertical line downward from the upper convenient point until you have a triangle as shown in Figure 2. It will be a right triangle, since the horizontal and vertical lines meet at a right angle.

c. Find the length of the horizontal line on your graph. This is the "run." Don't use a ruler; the length must be expressed in units of the quantity on the horizontal axis. In this case, seconds of time.

Run: _____ s

d. Measure the length of the vertical line. This is the "rise." Don't use a ruler; the length must be expressed in units of the quantity on the vertical axis. In this case, centimeters of distance.

Rise: _____ cm

e. Calculate the slope by dividing the rise by the run. **Show your calculation** in the space below.
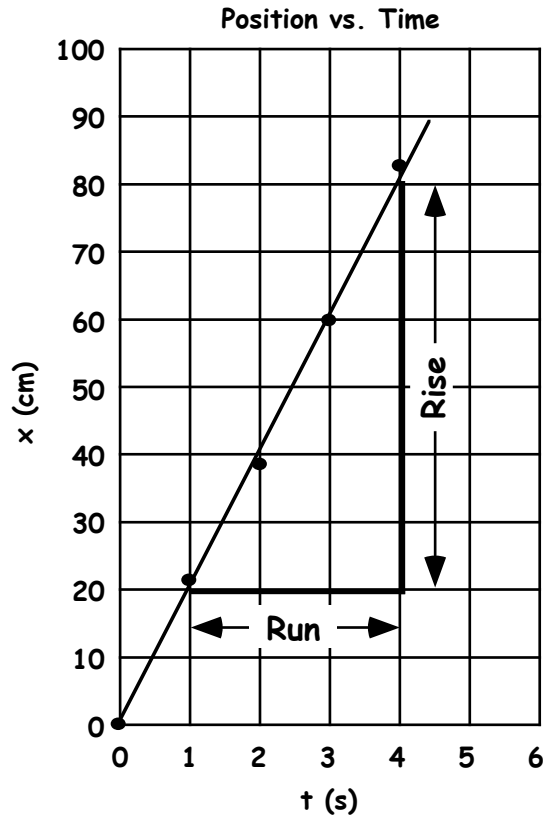
Slope: _____ cm/s

Figure 2

Summing Up

1. Suppose a faster car were used in this experiment. What would have been different about

   a. the distance between the marks on the butcher paper?

   _____

   b. the number of seconds the car would have spent on the butcher paper before reaching the edge?

   _____

   c. the resulting distance vs. time graph? (How would the slope have been different?)

   _____

2. Add a line to your graph that represents a faster car. Label it appropriately.

3. Suppose a slower car were used in this experiment. What would have been different about

a. the distance between the marks on the butcher paper?

_____

b. the number of seconds the car would have spent on the butcher paper before reaching the edge?

_____

c. the resulting distance vs. time graph? (How would the slope have been different?)

_____

4. Add a line to your graph that represents a slower car. Label it appropriately.

5. Suppose the car's battery ran out during the run so that the car slowly came to a stop.

a. What would happen to the space between marks as the car slowed down?

_____

b. Add a line to your graph that represents a car slowing down. Label it appropriately.

6. What motions do these graphs represent? In other words, what was the car doing to generate these motion graphs?

Line A.

_____

_____

_____

_____

Line B.

_____

_____

_____

_____

Position vs. Time

x (cm) vs t (s) graph showing LINE A and LINE B