Motion Graphs Laboratory I
Graphing Average Velocity

Purpose

1. To experimentally determine and graph the average (or constant) velocities of two cars of varying speed.
2. To calculate the slope (*m*) of each vehicle (the slope will be the velocity).
3. Predict from the *position vs. time* graph you made, the position at which a faster car will overtake a slower car, if the slower car is given a head start.
4. From your *position vs. time* graph and data, draft a *velocity vs. time* graph and analyze the acceleration of each car.

Introduction

The average velocity *(v_{av})* of a moving body is calculated by measuring the change in position or *displacement (Δd)* the moving body travels, and dividing that by a time interval *(t)*, which can be represented as follows:

$$v_{av} = \frac{\Delta d}{t}$$

On a graph, if displacement (or position) is plotted along the y-axis, and time interval on the x-axis, the line *(m)* that results would represent *average velocity*. Recollect the general form of the equation for a line:

$$y = mx + b$$

If we assume that the value for b is 0, we can rearrange the equation and "solve" for *m*:

$$m = \frac{\Delta y}{\Delta x} \quad \text{or:} \quad m = \frac{rise}{run}$$

The power of graphs lies in their ability to give analysts the ability to make predictions from them. In this laboratory, we will use graphs to make certain predictions.

First, you will determine experimentally the average velocity of two cars of varying speeds. After completing a plot of the cars average velocities in a *position vs. time* graph, you will then make a prediction: If the slower car is given a head start of 1.5 m (for example), at what point (or position) will the faster car overtake the slower one?

In a second graph, you will plot this very scenario as follows: For the faster car you will graph $d = vt$, and for the slower, $d = vt + 1.5m$ (where 1.5 m is the y-intercept or *"b"*).

The point at which the two lines cross will designate the theoretical position (or displacement) at which the faster car will overtake the slower.

You will empirically test these predictions from your second graph.

Finally, with the empirical data you collected and plotted on your first graph, you will make a third graph demonstrating the relationship between *velocity* and *time*, for both cars. The lines (*m*) that emerge represent a new vector for each car's motion, *acceleration (a)*. We will plot velocity on the y-axis, time interval on the x-axis, and "solve" for *a*, we get:

$$a = \frac{v}{t} \quad \text{or,} \quad a = \frac{\frac{m}{s}}{s}, \quad \text{or,} \quad a = \frac{m}{s^2}$$

Key Equations

$$v_{av} = \frac{d}{t}$$

Equipment

1. Stop watch
2. Two K'NEX vehicles which travel at varying speeds, or two wind-up or other electric cars. They just need to travel at a relatively constant velocity and at different speeds.
3. Tape measure (measure in meters)
4. Track (can use two tables put together or a space on the floor)
5. Blue tape to mark off where the cars intersect, and to establish a start and stop line.

Procedure

Set up a 4 meter track on the laboratory tabletop or floor. With blue tape, designate a start line *($d = 0$)*, and a finish line *($d = 4m$)*.

Part I: Use Table 8.1 to determine constant velocity of the both cars, and plot on Graph 1.

A. Start the motor of the slower car, and keeping the rear wheels raised, place several inches behind the starting line.

1. When your partner is ready with the stopwatch, lower the back wheel to get the car moving, and as soon as *the back wheel crosses the start line,* start the stopwatch, and stop it when *the back wheel crosses the finish line*. Record the time in seconds in Table 1.

2. Repeat this three more times.

3. Calculate average time of all four trials.

4. Calculate average velocity by dividing displacement (d) of 4.0 meters by average number of seconds.

B. Repeat this procedure with the faster car.

C. On Graph 1, plot the displacement in meters on the y-axis, and the average *time* it took for each car to travel four meters along the x-axis. Draw a line connecting each coordinate to the origin and then calculate the value of the slope for each car: this is your velocity.

Part II: Use Graph II to predict the point at which the faster car will pass the slower if given a 1.5 m head start.

A. On Graph II, plot the velocity for the faster car, exactly as it appeared on Graph I.

B. For the slower car, assume we are giving that car a 1.5 meter head-start (which will be the y-intercept), and draw that line on Graph II.

C. Determine the point at which the faster car will overtake the slower, and write that point down in both time and distance from the starting line

Part III. Test your prediction from Graph II, by experimentally determining when the faster car passes the slower, when given a 1.5 m head start.

1. Turn the motors on both cars, and keep the back wheels raised on each.

2. Place the front wheels of both cars right behind the starting line.

3. Release the slower car, and as soon as its front wheels approach the 1.5 m mark, lower the faster car.

4. Take note of the position at which the faster car passes the slower.

5. Measure this position from the starting line, and record in Table 2.

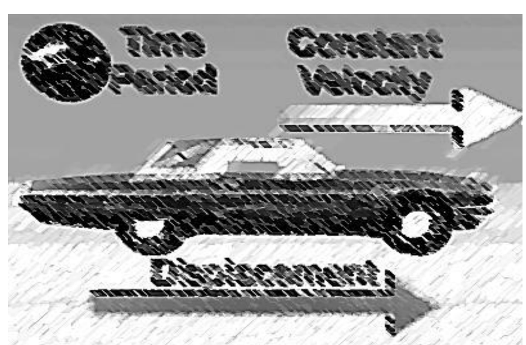
6. Repeat three more times, then calculate the average position.

7. Compare these results with what you predicted from Graph II and calculate percent discrepancy.

Part IV. Plot a third graph of velocity verses time (Graph III).

A. Using Graph III, plot the velocities of the slower and faster cars.

B. Make any observations concerning the slope. Can you determine the value of the slope?



Report Sheet

Table 1: Experimental Determination of Average Velocity

Time to travel 4 meters (in seconds)									
Slower Car					Faster Car				
Trial 1	Trial 2	Trial 3	Trial 4	Avg	Trial 1	Trial 2	Trial 3	Trial 4	Avg
Average velocity: ________________ m/s					Average velocity: ________________ m/s				

Graph 1. Position vs. Time

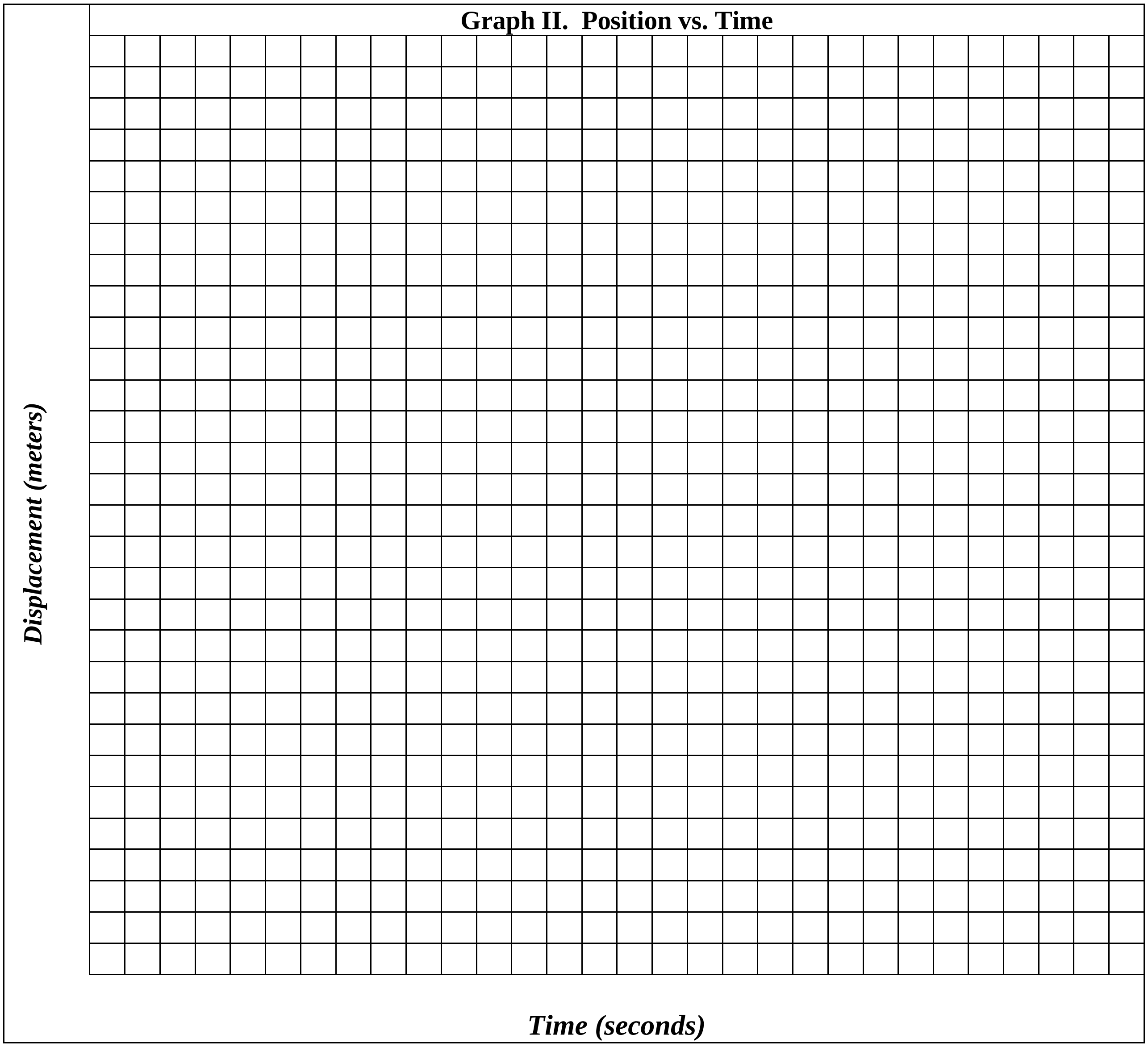
Displacement (meters)

Time (seconds)

Show your work for finding slope (average velocity) for each car in the space below:

Equation of the line for faster car:____________________

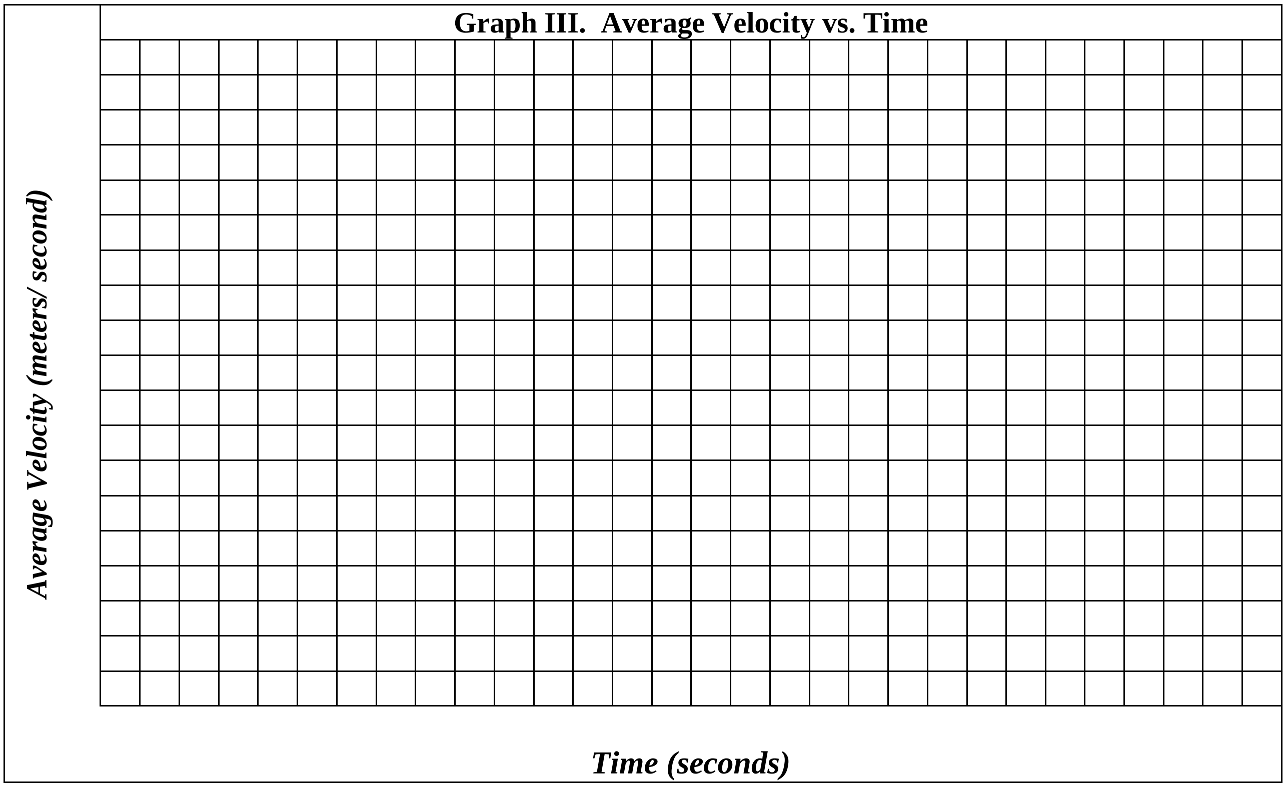
Equation of the line for slower car: _____________________



Prediction from graph of the displacement or position at which the faster car overtakes the slower:___________________ m.

Table 2: Experimental Determination of Position when Faster Car overtakes Slower

Trial 1	Trial 2	Trial 3	Trial 4	Avg
Average position: _________ m % disc = |difference|/ accepted x 100 = ______________%				



Questions

1. What do you notice about the lines (*m*) created in Graph III? What is the value for acceleration?

2. Which line in Graph I is steeper? What does that say about the magnitude of velocity for that car, when compared to the other car?

3. What do you notice about the direction of each line? Why do they have positive slopes?