Instantaneous vs. Average Velocity

In this experiment, you will measure instantaneous and average velocities.

APPARATUS:

- Photogate timer and accessory photogate.
- Air track system with one glider.

INTRODUCTION:

An *average velocity* can be a useful value. If you know you will average 50 miles per hour on a 200 mile trip, it's easy to determine how long the trip will take. On the other hand, the highway patrolman following you doesn't care about your average speed over 200 miles. He wants to know how fast you're driving at the instant his radar strikes your car, so he can determine whether or not to give you a ticket. He wants to know your *instantaneous velocity.* In this experiment you'll investigate the relationship between instantaneous and average velocities, and see how a series of average velocities can be used to deduce an instantaneous velocity.

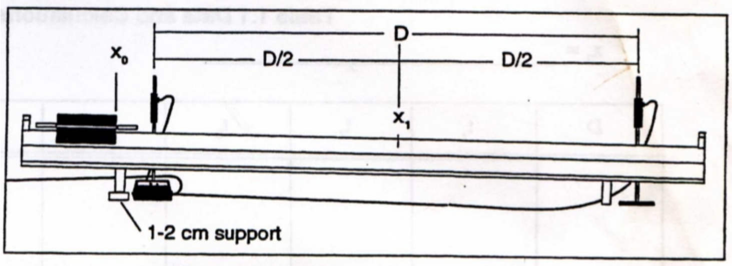

Figure 1: Setting up the equipment.

PROCEDURE:

1. Set up the air track as shown in Figure 1, elevating one end of the track with a $1 - 2$ cm support.
2. Choose a point x_1 near the center of the track. Measure the position of x_1 on the air track metric scale, and record this value in Table 1. If you are using an air track without a scale, use a meter stick to measure the distance of x_1 from the edge of the upper end of the track.
3. Choose a starting point x_0 for the glider, near the upper end of the track. With a pencil, carefully mark this spot on the air track so you can always start the glider from the same point.
4. Place the photogate timer and accessory photogate at points equidistant from x_1, as shown in the figure. Record the distance between the photogates as D in Table 1.
5. Set the slide switch on the photogate timer to PULSE.
6. Press the RESET button.
7. Hold the glider steady at x_0, then release it. Record time t_1, the time displayed after the glider has passed through both photogates.

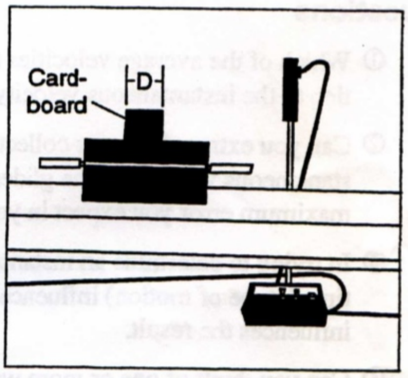

Figure 2: Measuring velocity in gate mode.

8. Repeat steps 6 and 7 at least four more times, recording the times as t_2 through t_5.
9. Now repeat steps 4 through 9, decreasing D by approximately 10 centimeters.
10. Continue decreasing D in 10 cm increments. At each value of D, repeat steps 4 through 8.
11. You can continue using smaller and smaller distances for D by changing your timing technique. Tape a piece of cardboard on top of the glider, as shown in Figure 2. Raise the photogate so it is the cardboard, not the body of the glider, that interrupts the photogate. Use just one photogate and place it at x_1. Set the time to GATE. Now D is the length of the cardboard. Measure D by passing the glider through the photogate and noting the difference in glider position between where the LED first comes on, and where it goes off again. Then start the glider from x_0 as before, and make several measurements of the time it takes for the glider to pass through the photogate. As before, record your times at t_1 through t_5. Continue decreasing the value of D, by using successively smaller pieces of cardboard.

DATA AND CALCULATIONS:

1. For each value of D, calculate the average of t_1 through t_5. Record this value as t_{avg}.
2. Calculate $v_{avg} = D/t_{avg}$. This is the average velocity of the glider in going between the two photogates.
3. Plot a graph of v_{avg} versus D with D on the $x-$axis.

Table 1: Data and Calculations

$x_1 =$ ________________

D	t_1	t_2	t_3	t_4	t_5	t_{avg}	v_{avg}

QUESTIONS:

1. Which of the average velocities that you measured do you think gives the closest approximation to the instantaneous velocity of the glider as it passed through point x_1?
2. Can you extrapolate your collected data to determine an even closer approximation to the instantaneous velocity of the glider through point x_1? From your collected data, estimate the maximum error you expect in your estimated value.
3. In trying to determine an instantaneous velocity, what factors (timer accuracy, object being timed, type of motion) influence the accuracy of the measurement? Discuss how each factor influences the result.
4. Can you think of one or more ways to measure instantaneous velocity directly, or is an instantaneous velocity always a value that must be inferred from average velocity measurements?

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DUE NEXT WEEK...

1. The Data Table with the raw data.
2. A graph of the data in Step 3 of Data and Calculations.
3. Answers to the 4 Questions above.

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