Physics 201 Lab 2: Measuring Speed

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Fall 2011

Theoretical Discussion

The average speed of an object is the ratio of the distance it travels to the time it takes to travel that distance. Using mathematical symbols to say this; if the distance traveled is Δd and the time it takes to travel this distance is Δt, then the speed s of the object is

$$s_{\text{avg}} = \frac{\Delta d}{\Delta t} \tag{1}$$

If the speed of the object is changing during the course of the measurement, then the value of the speed you get from applying the equation above depends on the time interval Δt that you use. If the object's speed stays the same all the way through the measurement, then it doesn't matter which time interval you use. Whether or not the object's speed is constant, the *average speed* is defined as the speed calculated using the total displacement Δd and the total time interval Δt in the equation above. On the other hand, the *instantaneous speed*—along the x-axis for example—at some time t_0 is the ratio of the distance traveled to the time interval, in the limit as the time interval goes to zero. Mathematically, this is written as

$$s_{\text{inst}}(t_0) = \lim_{t \to t_0} \frac{x(t) - x(t_0)}{t - t_0} \equiv \frac{dx(t)}{dt}\Big|_{t=t_0}$$

In other words, the instantaneous speed is the derivative of the position with respect to time. Graphically, one can determine this derivative at any point along a plot of x vs. t by finding the slope of the curve at that time coordinate. The slope in question is the slope of the straight line drawn *tangent* to the curve.

Procedure

In this lab we will send a Hot Wheels car speeding down a straight track. Members of your group will be stationed at various points along the track equipped with stopwatches. Each member will record the time it takes for the car to go from the start line to his or her location. A diagram of the experimental procedure is shown in figure 1. Let's say you have 4 group members. One person serves as the launcher. The distance from the start line to the location of member 1 is d_1, the distance from the start line to the location of member 2 is d_2, and so on. The time it takes for the car to go from the start line to the location of member 1 is t_1, the time it takes for the car to go from the start line to the location of member 2 is t_2, etc. The time intervals are given by the equations

$$\begin{aligned} \Delta t_1 &= t_1 - 0 \\ \Delta t_2 &= t_2 - t_1 \\ \Delta t_3 &= t_3 - t_2 \end{aligned}$$

If you have more than one timer at a particular location, which will usually be the case, you should take the average time at that location. This will help to minimize the effect of individual variations in reaction times. The distances traveled in each of the time intervals are

$$\begin{aligned} \Delta d_1 &= d_1 - 0 \\ \Delta d_2 &= d_2 - d_1 \\ \Delta d_3 &= d_3 - d_2 \end{aligned}$$

You will run the race once and then you will tabulate your measurements, making a table whose four columns contain the distance coordinates d, the time coordinates t, the distance intervals Δd and the time intervals Δt. You will each individually plot, *by hand*, the distance vs. time (d vs. t) coordinates. You will use the equation

$$s = \frac{\Delta d}{\Delta t}$$

to calculate the average speed in each time interval, as well as the average speed for the race. The average speed for the race is just the total distance traveled divided by the total time ($s_{\text{avg}} = \frac{d_3}{t_3}$). You will then tabulate your final results in the form of a table whose columns are the distance coordinates d, the time coordinates t, the distance intervals Δd and the time intervals Δt; and the speed s in each time interval. You will also report the average speed for the race. Finally, you will calculate the instantaneous speed at the temporal midpoint of each time interval and calculate the fractional discrepancies between these instantaneous speeds and the average speed in the corresponding time interval.

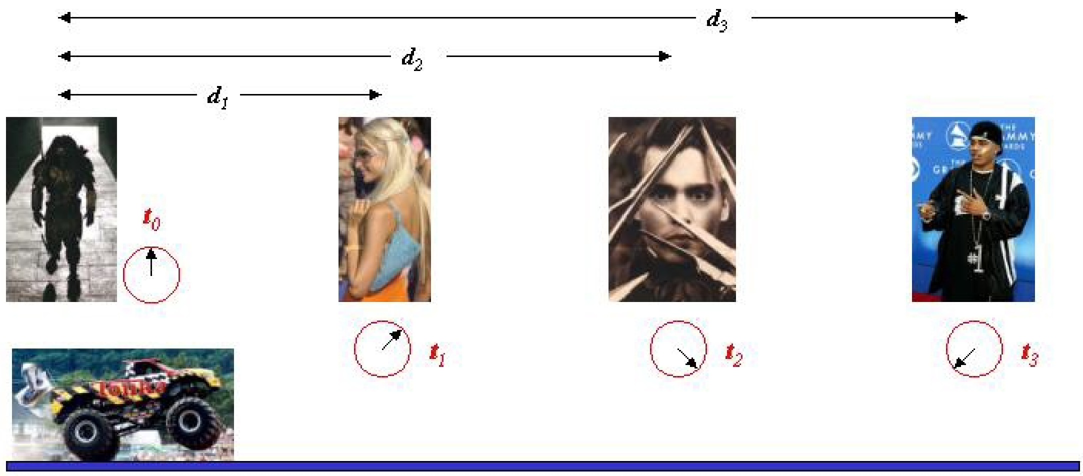

FIG. 1: Experimental procedure for measuring speed

In summary

1. Measure the distances d_1, d_2, and d_3, from the start line to each timer's location.
2. Measure the elapsed times it takes for your car to travel from the start line to the location of each group member t_1, t_2, t_3. If there is more than one group member at a location, record both the individual times and the average of the times at that location. It is the average time that you will use in subsequent calculations.
3. Calculate the distance intervals Δd_1, Δd_2, Δd_3, and the time intervals Δt_1, Δt_2, and Δt_3.
4. Tabulate your data.
5. Plot d vs. t, by hand, on a piece of graph paper with the distances on the vertical axis (ordinate axis) and the times on the horizontal axis (abscissa axis).
6. Use the defining equation for average speed (equation 1) and the measured distance and time intervals (Δd and Δt) to calculate the average speed in each time interval and the the average speed for the total race.

7. Determine the instantaneous speeds at the midpoint of each time interval by drawing a tangent to the curve of distance vs. time on your plot and finding the slope of the tangent line.

8. Calculate the fractional deviation (see lab 1 for details) between the instantaneous and average speeds in each time interval.