Displacement, Velocity, and Acceleration in One Dimension

Introduction

Consider an object moving in one dimension. Assume that the object is located at position $\mathbf{x} = \mathbf{0}$ and moving with velocity $\mathbf{v}_0$ at time $t = 0$.[1] Further, assume that the object is undergoing constant acceleration, $\mathbf{a}$. Then the following kinematical equations apply:

$$\mathbf{v} = \mathbf{v}_0 + \mathbf{a}t \, , \tag{1}$$

where $\mathbf{v}$ is the instantaneous velocity of the object at time t, and

$$\mathbf{x} = \mathbf{v}_0 t + \frac{1}{2}\mathbf{a}t^2 \, , \tag{2}$$

where $\mathbf{x}$ is the displacement of the object from the origin of the coordinate system at time t. In addition, the average velocity $\bar{v}$ of the object during a time interval Δt is given by

$$\bar{\mathbf{v}} = \frac{\Delta \mathbf{x}}{\Delta t} \, , \tag{3}$$

where $\Delta \mathbf{x}$ is its displacement during that time interval.

Procedure

One person will be responsible for initiating the motion of the hotwheels car. As many as 15 individuals, with timers, are positioned at different locations along the track (One individual should be located near the end of the track.). A convenient unit for measuring position is blocks of floor tiles. First, one person propels the car along the track. As the car passes the position on the track whose coordinate is zero, that person indicates that all individuals should start their timers. As the car passes each individual, that individual stops the timer. Record the data in Table 1.

1. Using Excel, plot a graph of displacement vs. time.

2. Assume the car has undergone constant acceleration. Perform a polynomial regression of degree two, requiring the intercept to be zero. Report parameters

[1] Vectors are denoted in bold font.

Figure 1: The equipment used in the experiment comprises timers, a hotwheels car, and 17 hotwheels tracks.

estimated for the polynomial and the value of R^2. Based on the value of R^2 do the data support the hypothesis that the car has undergone constant acceleration?

3. Compare the regression equation of part two to Eq. 2 and estimate the acceleration of the car and its initial speed. Is the acceleration positive or negative? What is the significance of the sign? Whenever the sign of the acceleration is negative, does this always imply deceleration?

4. Substitute the values of the initial velocity and acceleration estimated by regression into Eq. 1 to obtain an explicit expression for the instantaneous velocity as a function of time.

5. Using the equation derived in part 4, calculate the instantaneous velocity of the car at the end of the run, i.e. at the time recorded when the car has reached the end of the track.

6. Calculate the average velocity of the car for the entire trip using Eq. 3.

7. Does the instantaneous velocity at the end of the trip equal the average velocity for the trip? Should these two quantities be equal if the car is undergoing constant acceleration? Explain.

	t (s)	$\mathbf{x}$ (blocks)
1		
2		
3		
4		
5		
6		

Table 1: Time and Displacement Data