Exercise 3: Uniform accelerated motion in one-dimension

Purpose: explore and understand the concept of displacement, velocity, and acceleration by investigating an object undergoing uniform accelerated motion.

Introduction

For an object moving with uniform acceleration in one dimension, we can set up the kinematic equation

$$x = x_0 + v_0 t + \frac{1}{2} a t^2,$$

where, x is the position at time t, x_0 is the initial position, v_0 is the initial velocity, and a is the acceleration. The equation can be rearranged as

$$x - x_0 = v_0 t + \frac{1}{2} a t^2,$$

where, $x - x_0$ is the displacement in the x-direction.

If such an object starts from rest ($v_0 = 0$), then the displacement as a function of time $x(t)$ is

$$x - x_0 = \frac{1}{2} a t^2.$$

The equation shows that the displacement of an object initially at rest under constant acceleration is proportional to time squared. We wish to further explore this mathematical elegancy for uniform accelerated motion of an object.

Laboratory assignment

We can use a horizontal track and an object subject to a constant force to explore an object undergoing constant acceleration. We will use a computer to take many measurements over a short period of time to explore trends between the displacement, velocity, and acceleration.

1. Setup the track so that it is roughly level (perpendicular to the gravitational acceleration). The cart should be close to level so that the constant force from the source is dominant over the contribution from the acceleration due to the gravitational force in the y direction. Not that the acceleration contribution from the gravitational force is also constant, which is why the track does *not* need to be *perfectly* level.
2. Place the cart on the track with the 500 g weight riding securely on the cart.
3. Attach the fan on the cart, but do not turn the fan on yet.
4. Clip the motion sensor to the end of the track that does not have the rubber stopper. Be sure and orient the sonic source/receiver so that it faces the cart. Connect the motion sensor to the laptop and start the "Capstone" software.
5. Select the "table and graph" display option. Add two columns for a total of four columns; these should be in order of time (s), position (m), velocity (m/s), acceleration (m/s^2). The graph should be velocity vs. time.
6. Change the acquisition rate at the bottom of the screen to 50.0 Hz.
7. Set the cart at the end of the track with the middle of the cart at the 20cm mark.
8. Hold the cart in place and start data recording on the computer.

9. Once the data recording has begun, release the cart and watch it accelerate towards the stopper at the end of the track. (Make sure that nothing blocks the motion sensor's sonic readings between the cart and the motion sensor.)
10. Stop the data recording after the cart has reached the stopper.
11. On the graphing screen, highlight all the data which corresponds to the time period when the velocity graph has a linear slope (just after releasing the cart and before stopping the cart.
12. Copy the highlighted data for time, displacement, velocity, and acceleration and paste into Excel.
13. Remake a "zeroed" time column so that the initial time starts from zero.
14. Calculate the average and standard deviation of the acceleration data. You may use the Excel commands "=AVERAGE(##:##)" and "=STDEV(##:##)" for these calculations.
15. Graph the velocity vs. time graph in Excel and fit a linear trend line to find the slope. Compare the slope to the acceleration found in step 14. Do they agree within uncertainty?
16. Graph the displacement, $x - x_0$, as a function of time, t.
17. Approximate the slope of the displacement vs. time graph at 2.0 seconds. Then determine the value of the velocity at 2.0 seconds in the velocity vs. time graph.
18. Compare the two velocities via the % difference, where $\% \text{ diff} = \left(\frac{v_{\text{observed}} - v_{\text{calc}}}{v_{\text{observed}}}\right)(100\%)$.
19. Graph the displacement, $x - x_0$, as a function of $t^2/2$ and fit a linear trend line to find the slope. Compare the slope to the acceleration found in step 14. Do they agree within uncertainty?

Equipment list: track, PAScar, fan, laptop.