Constant velocity and constant acceleration

Physics 110 Laboratory

Introduction

In this experiment we will investigate two rather simple forms of motion (kinematics): motion with uniform (non-changing) velocity, and motion with a changing speed, but uniform acceleration. The primary aims of this experiment are: i) to develop an understanding of graphical presentations of position and velocity changes as a function of time, ii) to investigate the connection between acceleration and speed, and iii) to learn how to calculate values of velocity and acceleration from position and time measurements.

Also, in this experiment we will investigate the motion of a simple object under the influence of a constant force. According to Newtons second law, the effect of a constant force is to create an accelerating motion in one dimension. This is of course the simplest form of application of Newtons second law. To check the validity of this law we will obtain two separate values for the acceleration of a system. The first acceleration will be determined by applying the dynamical relationship that we derive using Newtons second law, $F = ma$. For the second value we will collect position measurements as a function of time and use these to obtain the value of acceleration. Finally, we will estimate the uncertainty in our experimental results and compare these two values of acceleration within their respective limits of uncertainty.

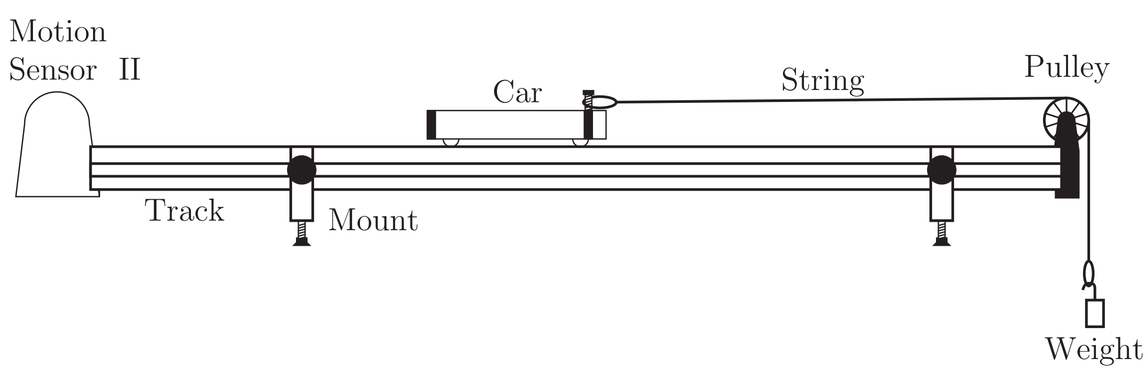
Apparatus

1D Motion

The setup that we will use in this experiment consists of a 2-meter long track (rail), a fan-cart, and a sonar motion detector. The fan-cart's wheels fit in the grooves of the track, so it is constrained to move on a straight line. The motion detector emits pulses of sonar, at regular intervals of time, along the direction of the track. Once an obstacle reflects the sonar pulses, the instrument detects the reflected pulses and determines the position of the obstacle. The data is fed to the computer, where it is collected, displayed, and analyzed by a software package called Capstone.

1D Force

The setup that we will use in this experiment is almost identical to the one we used above. It consists of a 2 meter long track (rail), a cart, and a sonar motion detector. We tie a light string to the cart, pass it over a pulley that is connected to the end of the rail opposite to the sonar, and hang a mass m_h from the other end of it. As before, we will use the Data Studio software to collect position versus time data for the moving cart.



1D Motion Procedure

Measuring Constant Velocity

1. Using a bubble level, adjust the feet until the track is level. The free cart should not move at all when left alone.
2. Connect the Motion Sensor II instrument to the Science Workshop 750 Interface. Put the yellow plug in Channel 1 and black plug in Channel 2.
3. Weight your cart.
4. Place the cart on the track with nothing attached to it.
5. Set up the software
   - Double-click Pasco Capstone
   - Click on Hardware Setup on the left, then Add Sensor
   - Choose digital and then Motion Sensor II
   - Close the hardware setup
   - Double-click "graph" on the right hand side to open a blank graph
   - Choose position measurement. On the horizontal axis choose time, and the vertical axis choose position
6. Gently push the cart to get it rolling, and click the Start/Stop acquisition button. The program should record position data. Push stop after a couple seconds.
7. Hover your mouse over the graph, and choose "select range for analysis". Drag the box around the data points you collected. Click on the fit button and choose linear fit.
8. Repeat steps 6 and 7 for two other cart speeds. For one of these two runs push the cart *at* the motion sensor instead of away from it. You should now have three graphs two for the cart moving away from the motion sensor and one at the motion sensor.
9. For each lab partner print a copy of this graph. Write your name and the date of the experiment at the top of the page. Also on this page make a separate table for each of the three runs. In each table record the position and time coordinates for two data points on each straight line. From this data calculate the corresponding velocity values, by hand, and compare these with the slopes of the straight lines. Explain why the slope of the motion towards the motion sensor is negative.

Measuring Constant Acceleration

10. Now turn on the fan on the cart and collect data as the cart speeds away from the sonar. Be careful to keep your fingers away from the fans!
11. Select the points as before, but this time choose a quadratic fit. Print the graph and write a few sentences describing these resulting motions.
12. Repeat steps 10 and 11 for the fan cart speeding toward the sonar. Again fit the data and print out this page and write on it a short summary of the motion, answering the following questions:

(a) In the position versus time graph: how does motion with constant speed appear?

(b) How do two such graphs, on the same plot, indicate the faster moving object?

(c) Which object is moving "forward" and which one "backward"?

(d) How does "slowing down" appear? How does "speeding up" appear? How does a "stop" appear?

(e) What is the significance of a parabolic position versus time graph? How can you tell the accelerating object is moving forward or backward?

(f) What was the maximum speed that your cart could reach with its fan turned on?

1D Force Procedure

13. Set up a pulley on the end of the track opposite the position sensor. Affix the string on one end to the car. Putting the string over the pulley, make a loop and hang a 10 g weight from it.
14. Set up a stop-block to make sure the cart does not run into the pulley.
15. Release the cart and measure position versus time.
16. By using a quadratic fit to the data, determine the acceleration.
17. Record the value in the table below, then repeat the measurement 4 more times.
18. Repeat for 20 g, 30 g, 40 g, and 50 g hanging mass.

Mass of the cart (kg): ______________

Trial	a_{kin} $\left(\frac{\text{m}}{\text{s}^2}\right)$ for $m = 10\,\text{g}$	a_{kin} $\left(\frac{\text{m}}{\text{s}^2}\right)$ for $m = 20\,\text{g}$	a_{kin} $\left(\frac{\text{m}}{\text{s}^2}\right)$ for $m = 30\,\text{g}$	a_{kin} $\left(\frac{\text{m}}{\text{s}^2}\right)$ for $m = 40\,\text{g}$	a_{kin} $\left(\frac{\text{m}}{\text{s}^2}\right)$ for $m = 50\,\text{g}$
1					
2					
3					
4					
5					
Average					
Std. Dev.					

Analysis

19. Calculate the average acceleration of the five trials for each mass, and the standard deviation.
20. Determine the expected acceleration a_{dyn} by using Newton's second law.

21. In the following table, write the measured and expected values for acceleration

m (g)	$a_{\text{kin}} \pm \Delta a_{\text{kin}}$ (m/s^2)	$a_{\text{dyn}} \pm \Delta a_{\text{dyn}}$ (m/s^2)
10		
20		
30		
40		
50		

22. Do the results agree within experimental uncertainties?