Appendix E: Sample Lab Report

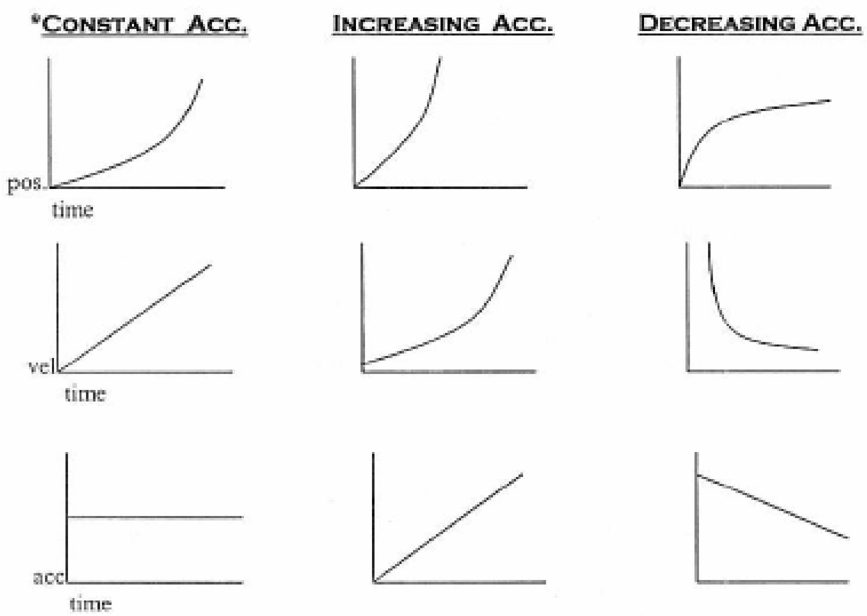
Problem#2:
Motion Down An Incline

Problem Description:

The state safety board is interested in determining how a car rolling down a hill accelerates so that they can better understand the dynamics of car accidents. This lab investigates the acceleration of a car rolling down a hill without any brakes. In lab, this problem was approached using a basic scientific method. First, predictions were made about the motion of the car. Second, the motion of the car was tested and recorded. Finally, the motion was analyzed using video analysis and conclusions were made. The experimental results of the lab where then compared to the theoretical results based upon vector and trigonometric reasoning. The lab required use of a stopwatch, cart, meter stick, end stop, as well as a video camera and the video analysis software, LabView.

Prediction:

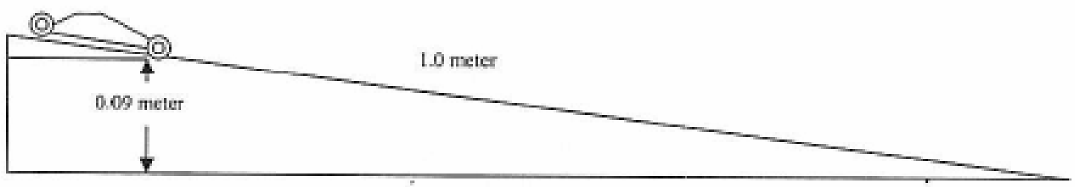
The essential question in this lab is whether the acceleration of the car down an incline is increasing, decreasing, or constant during its motion. This can be best examined by sketching position-versus-time, instantaneous velocity-versus-time, and acceleration-versus-time graphs for each of the possibilities.



From these graphs, it was predicted that **constant acceleration* best describes the motion of a car rolling down an incline. Velocity will increase during the motion, but acceleration will remain constant because it based entirely on the constant force of gravity (partial). Other than air resistance and friction, there should be no other forces acting upon the cart. The results of the lab will be able to approve or disprove this prediction because actual position vs. time and velocity vs. time data will be captured.

PROCEDURE:

The procedure involved three general steps; apparatus set-up, cart motion recording, and cart motion analysis. The set-up involved using a wooden block to prop up the track at a steady incline. A one-meter long section of the track was then measured and marked at 10 cm increments with white tape. Then, the height from the table-top to the top part of the measured section of the track was measured and recorded to be 0.09 (+/- 0.01) meters. The video camera was then positioned so that the entire one-meter section of track was clearly visible on the display screen. It was important that the camera was positioned parallel to the track so that there would be minimal error due to disparate distances from the camera to the two ends of the track. The cart was then placed at the top of the track, at the first tape mark, demarcating the initial position and start point of the motion. A simple illustration of the set-up can be seen below:



When the set-up was complete, it was time to release the car and record its motion using the video recorder program, LabView. The cart was released from position (0.00 m) and it traveled to the final position (1.0 +/- 0.01 m) near the end of the track. The time elapsed for the 1 meter displacement was also measured and recorded using a stopwatch.

The recorded video file was then opened using the Video Tool program. This program served as the major tool for analyzing the motion of the car. The coordinate system was calibrated and rotated so that the measurements were one-dimensional and approximately 1 meter in length. The program included predicting the equation of the position vs. time graph as well as the velocity vs. time graph. To make these predictions, it was important to first determine the general shape that the graph should be. Because position is exponentially related to acceleration, it was appropriate to predict that the general formula for the position vs. time graph should represent a parabolic shape. By changing the values of the variables in the general equation, a prediction was made based upon the known displacement and time of travel. The prediction was: $f(t) = 0 + 0t + 0.25^2$. In this equation f(t) means that the displacement is dependent on time. Second, the equation of the velocity vs. time graph was predicted using a linear formula. Acceleration and velocity are related by a single factor of time (m/s vs. m/s/s), therefore the graph of velocity vs. time with constant acceleration should be a straight, linear plot. Using the known values of displacement and time, the following prediction was made: $f(t) = 0 + 5t$. Following the predictions, the actual motion of the car was measured.

The motion was measured by marking the position of the car with data points at equally spaced time intervals. Approximately 12 data points were captured in the video. These data points were then plotted onto the same graph that displayed the predicted equations. A line was then fit to the actual data points, representing the actual equation for position vs. time and velocity vs. time for the moving cart.

DATA AND RESULTS:

Displacement = **1.0 (+/- 0.01) meter**
Height (starting point) = **0.09 (+/- 0.01) meter**
Time = **2.13 (+/- 0.1) seconds**

Position vs. Time:

Predicted Equation:

$f(t) = 0 + 0t + 0.25\ t^2$ {parabolic function}

*Actual Fit Equation:

$f(t) = 0 + 0t + 0.19\ t^2$ {parabolic function}

*When fitting the graph to the data points, the view was not zoomed in enough to provide the most accurate fit. This is a considerable source of error and could be easily avoided in future labs by simply making the values on the axis smaller.

It can be asserted that the predicted equation was accurate because of the similarity of the value of the 3rd term of the equation, $(0.25)^2$, to that of the actual equation, $(0.19)^2$. The similarity can be best understood by viewing the x-position vs. time graph on the next page.

Velocity vs. Time:

Predicted Equation:

$f(t) = 0 + 5(t)$ {linear function}

Actual Fit Equation:

$f(t) = 0 + 0.45(t)$ {linear function}

The predicted equation was relatively inaccurate compared to the actual fit equation. The predicted equation's slope was much too great and the line did not fit the data adequately. The x-velocity vs. time graph on the next page illustrates how the predicted equation had much too steep of a slope to fit the data points. The graph of this equation can be analyzed to determine if a cart moving down an incline has a constant, increasing, or decreasing acceleration.

ANALYSIS:

As evidenced by the velocity vs. time graph for the car's actual motion down an incline, *the acceleration is indeed constant.* This can be determined because the plot of the data points is linear and relatively straight. It resembles the graph illustrated in the initial prediction for constant acceleration. Using the function representing the velocity versus time graph, the acceleration of the cart as a function of time can be calculated.

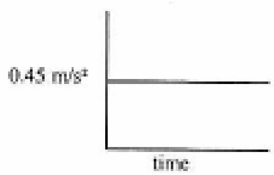
Velocity Function: f(t) = 0.45(t) {m/s}

Using the equation, $x = \frac{1}{2} a (t)^2 + v_0 (t) + x_0$ acceleration can solved for by substituting in values for the displacement (x), time (t), and initial position (x_0) variables.

$1.0\ m = \frac{1}{2} a (2.1s)^2 + 0 + 0$
$1.0\ m = \frac{1}{2} a (4.4s^2)$
$\underline{1.0\ m = 2.2s^2\ a}$
$a = 0.45\ m/s^2$

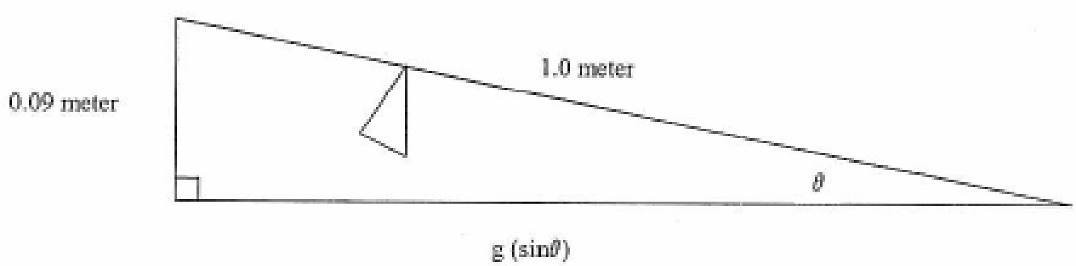
Acceleration Function: f(t) = 0.45 {m/s/s}

This can be graphed as follows:



The average acceleration of the cart is equal to its instantaneous acceleration in this particular case. The acceleration does not change throughout the motion of the car down the incline as shown by the graph above.

The average acceleration of the car using the stopwatch and meter stick measurements is calculated below. This is accomplished by utilizing vector quantities and trigonometric functions.



g = gravity constant = $9.8\ m/s^2$

Using this information and the illustration, the angle θ was determined using the lengths of the opposite and hypotenuse sides in the sine function.

sin (θ) = opposite/hypotenuse
sin (θ) = 0.09 m / 1.0 m
sin (θ) = 0.09
(θ) = $\sin^{-1}$ (0.09)
(θ) = 5.2°

Using the angle measurement for θ and the magnitude of the acceleration for gravity, the acceleration can be determined using another sine function on the interior vectors of the illustration.

sin (θ) = opposite/hypotenuse
sin (5.2°) = x-acceleration / gravity acceleration
sin (5.2°) = x-acc. / 9.8 m/s^2
0.09 = x-acc. / 9.8 m/s^2
x-acc. = 0.09 x 9.8 m/s^2
x-acc. = 0.88 m/s^2

This theoretical acceleration value, **0.88m/s^2**, is greater than the value derived from the video analysis, **0.45m/s^2**. This can be explained by several factors which were omitted in this basic calculation. The first of which is friction, which opposes the acceleration vector of the car down the incline. The second is air resistance, which would also oppose the car's acceleration. These tangible forces were at work during the car's motion and were accounted for in the video analysis. However, in the hypothetical sense in which the theoretical acceleration was calculated, these factors were not taken into account. If these forces were considered, the theoretical value of acceleration would likely be lower, and much closer to the value derived from the video analysis.

There were also several other sources of error in this lab. There were many measurements taken throughout the lab and any of them were subject to human error. The stopwatch may not have been started at the instant the car was released or it may not have been stopped at the exact instant when the car reached the end-point. Also, because the track was marked with white tape, there could be discrepancies up to one centimeter in the measurements based on the position of the tape and how it was perceived during the trial. In addition, the relatively blurry display screen may have contributed to errors in video recording, calibration, and/or data point collection. Not having the green dot on the same exact position of the car during data point collection may also lead to inconsistencies in the results.

Conclusion:

After the various analyses, it can be concluded that a car has constant acceleration as it moves down an inclined ramp. The x-component of the acceleration was the focus of this study. Using vector diagrams, it was asserted that the x-acceleration of the car is indeed a small component of the downward force of gravity. Using video analysis and theoretical calculations, the x-acceleration was determined to be constant. This is supported by the fact that the velocity vs. time graph for the car's motion is a linear, upward sloping line indicating that velocity increased constantly. Therefore, as the definition of acceleration (the change in velocity over time) states, an object that has a constant velocity increase over time is accelerating at a constant rate. This conclusion agrees with the initial predictions set forth. Although there are several sources of error, the result of the investigation proved to be accurate and reliable. The investigation proved to be a useful application of the kinematics principles that have been discussed in both lecture and lab.