

SAMPLE LABORATORY REPORT

Laboratory 1

Problem # & Title: 4: Motion down an incline with initial velocity

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Lab Instructor's Initials: _____

Grading Checklist	Points
LABORATORY JOURNAL:	
PREDICTIONS (individual predictions completed in journal before each lab session)	
LAB PROCEDURE (measurement plan recorded in journal, tables and graphs made in journal as data is collected, observations written in journal)	
PROBLEM REPORT:*	
ORGANIZATION (clear and readable; correct grammar and spelling; section headings provided; physics stated correctly)	
DATA AND DATA TABLES (clear and readable; units and assigned uncertainties clearly stated)	
RESULTS (results clearly indicated; correct, logical, and well-organized calculations with uncertainties indicated; scales, labels and uncertainties on graphs; physics stated correctly)	
CONCLUSIONS (comparison to prediction & theory discussed with physics stated correctly ; possible sources of uncertainties identified; attention called to experimental problems)	
TOTAL (incorrect or missing statement of physics will result in a maximum of 60% of the total points achieved; incorrect grammar or spelling will result in a maximum of 70% of the total points achieved)	
BONUS POINTS FOR TEAMWORK (as specified by course policy)	

* An "R" in the points column means to rewrite that section only and return it to your lab instructor within two days of the return of the report to you.

Motion down an incline with initial velocity

Peter McIntyre, Hui Chin, and Teruki Kamon

Abstract—The motion of a frictionless car on a one-dimensional track was studied. The car was supported on a cushion of air to minimize friction drag. The track was inclined so that the acceleration of gravity produced a small component parallel to the track. The car was propelled from one end of the track with an initial velocity, and its motion was recorded using a video camera. The car's motion in the succession of images was analyzed to test the agreement of the car's motion with the hypothesis of constant acceleration. An estimate of g , the acceleration of gravity, was found to be consistent with previously published values.

Index Terms—kinematics, acceleration.

I. INTRODUCTION

GRAVITY produces a force between all material objects, and this force produces an acceleration of any object on Earth, oriented towards the center of the Earth. A key feature of gravity is that the gravity force \vec{F} is proportional to mass m . Since the motion produced by such a force is also proportional to mass ($\vec{F} = m\vec{a}$), the gravity acceleration of any object should depend only upon the altitude of the object and not upon the mass of the object. The acceleration at sea level has been measured to great precision by many authors¹. Its approximate value² is $g = 9.79647 \text{ m/s}^2$.

The purpose of the present study was to analyze the motion of a nearly frictionless car as it traveled on an inclined plane. The car was given an initial velocity in order to test the hypothesis that its motion would exhibit a constant acceleration.

II. EXPERIMENTAL ARRANGEMENT

A. Apparatus

The apparatus consisted of a 2 m long air track³ and an L-shaped car, as shown in Figure 1. Compressed air was emitted from a matrix of holes along the body of the track, so that the car could ride on a cushion of air that largely eliminated friction drag.

The motion of the car was recorded using a digital video

camera⁴ with 30 Hz frame rate. The sequence of frames was transferred to a PC, where it could be analyzed. An application in LabView⁵ was used to cursor-select points on each image. The time of the frame and the x - and y - screen coordinates of the selected points were transferred to a spreadsheet⁶.

B. Procedure - Configuration for motion on an incline with initial velocity.

The air track was inclined at an angle to the horizontal by inserting spacer plates under the support foot at one end of the track as shown in FIGURE 1. For the data reported here, a spacer of thickness $d = 1.5 \text{ cm}$ was used. The support feet are space apart by a distance (l) of 1.7 m along the track. The angle of incline is therefore

$$\theta = \tan^{-1}(d/l) = 2.5^\circ$$

Make your hand drawing of the experimental setup here.
Bonus points for professional drawing.

Figure 1. Configuration of air track, car, and incline

III. RESULTS AND ANALYSIS

A. Calibration and Error Estimate

At the beginning of the analysis of the video sequence, a pair of points on a meter stick were digitized, and their known separation (60 cm) was used to obtain the calibration of the length scale of the screen coordinates of the video images.

There are two sources of error in the measurement of position of a target: random error in the cursor selection of the pixel in the display of an image that corresponds to the target location, and systematic error due to distortion of the video

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image in the camera optics. The random error was estimated by making repeated measurements of the location of a target in successive images of a stationary object: $\sigma_x = 0.2$ cm. The systematic error from distortion was determined by measuring a succession of equally spaced points along the image of a meter stick spanning the entire field of view; the length scale varies by $\pm 1\%$ from edge to center of the field of view.

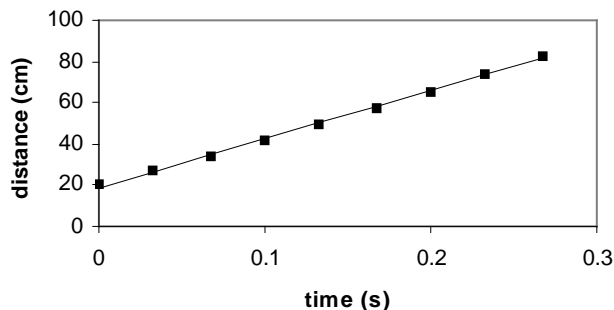


Figure 2. Distance vs. time for motion along the inclined track.

B. Measured Motion

The car was launched by hand from one end of the track with an initial velocity. The position of a target on the car was cursor-selected in each image of the video sequence. The time and the digitized y -coordinate of the target were recorded. The distance vs. time are plotted in Figure 2.

The straight line in the figure is a least-squares regression to obtain the *linear* slope of the motion, ignoring acceleration. The data are well fit by a linear relationship, with an initial position of 18.8 ± 0.2 cm and a velocity of 235 ± 2 cm/s.

There is only slight variation of the accelerated motion from the linear fit for uniform motion (the expected acceleration $a = g \sin \theta \sim 0.4$ m/s² would produce a change in velocity of only 10 cm/s during the time of observation). From this it became clear that the car had been launched with too great an initial velocity, so that the effect of acceleration was obscured.

A second set of data was taken, in which the initial velocity was reduced by about a factor of 10. Every third frame of the video sequence was analyzed. The position vs. time data are presented in Figure 3. Now the effect of acceleration is immediately evident.

In order to extract a measure of acceleration, each successive pair of position measurements was used to determine a velocity, and the velocity vs. time was plotted. The results are presented in Figure 4. The solid line is the regression-fit straight line, with slope $a = -22.1 \pm 0.4$ cm/s². From the measured slope of the air track the acceleration of gravity can be estimated:

$$g = a / \sin(2.5^\circ) = (980 \pm 4) \text{ cm/s}^2$$

This measurement agrees with a published number of $g = 9.79647$ m/s².

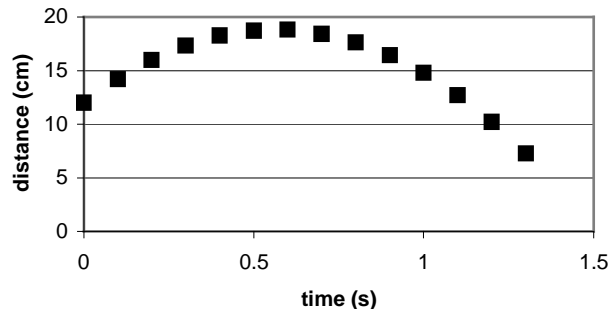


Figure 3. Position vs. time using slower launch velocity.

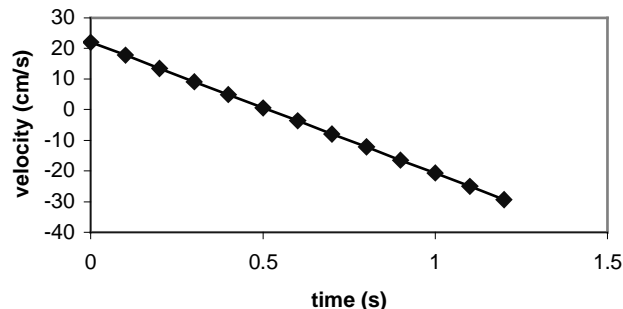


Figure 4. Velocity vs. time for the data of Figure 3.

IV. CONCLUSION

We conclude that the motion of a car on an inclined plane can be described as a combination of its motion under the initial velocity imparted to it, and the quadratic trajectory produced by a constant acceleration. The measured acceleration was used to obtain an estimate of the acceleration of gravity, which is in agreement with previously published values.

ACKNOWLEDGMENT

We gratefully acknowledge the help of Mr. Eric van Mayes, who instructed us in the physics of accelerated motion and in the use of the equipment.

REFERENCES

- ¹ <http://cires.colorado.edu/~bilham/FG5references.html>
- ² <http://www.ngs.noaa.gov/GRD/GRAVITY/MiniGravTest/data.htm>
- ³ Daedalon Corp., intermediate air track.
- ⁴ Sony model DWF-VL500.
- ⁵ National Instruments Co., LabView v.6.1.
- ⁶ Microsoft EXCEL 2002.