Uniformly Accelerated Motion

OBJECTIVES

- ❑ Investigate how the displacement of a ball down the inclined plane of a table is related to the elapsed time.
- ❑ Determine the acceleration of the ball from an analysis of the displacement versus time data.
- ❑ Determine an experimental value for g (the acceleration due to gravity) by interpretation of the ball's acceleration as a component of g. Compare with the accepted value of g.

EQUIPMENT LIST

- A laboratory table and two-meter long measuring stick
- Heavy metal ball (2.54cm or more in diameter) and a laboratory timer or stopwatch
- Blocks to raise one end of the table to form an inclined plane

THEORY

When an object undergoes one-dimensional uniformly accelerated motion its **velocity** increases linearly with time. If it is assumed that the initial velocity of the object is zero at time $t = 0$, then its velocity v at any later time t is given by

$$v = at \qquad \text{(Eq. 1)}$$

where a is the **acceleration,** which is constant in magnitude and direction.

Consider a time interval between $t = 0$ and any later time t. The average velocity $\overline{v}$ during the time interval is

$$\overline{v} = \frac{0 + v}{2} = \frac{v}{2} \qquad \text{(Eq. 2)}$$

The displacement x of the object during the time interval t is given by

$$x = \overline{v}t = \frac{vt}{2} \qquad \text{(Eq. 3)}$$

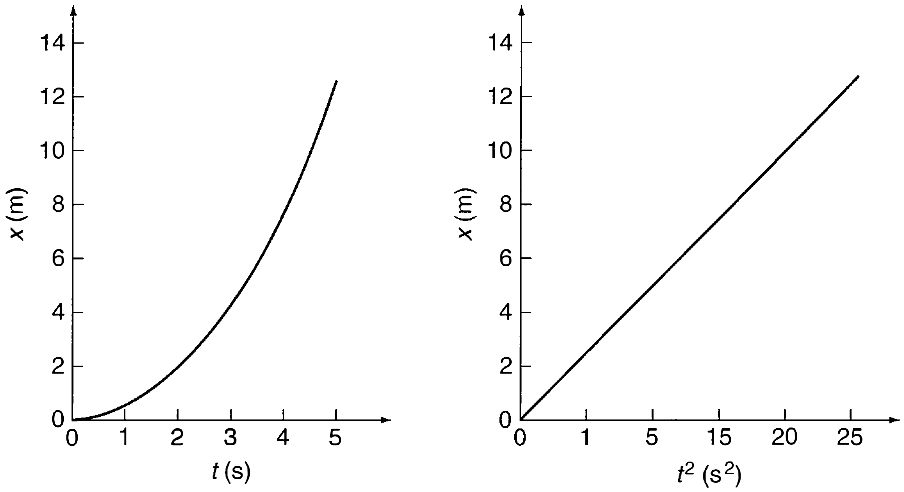


Figure 4-1 Graphs of displacement versus time and displacement versus the square of the time for uniformly accelerated motion. The displacement is linear with time squared.

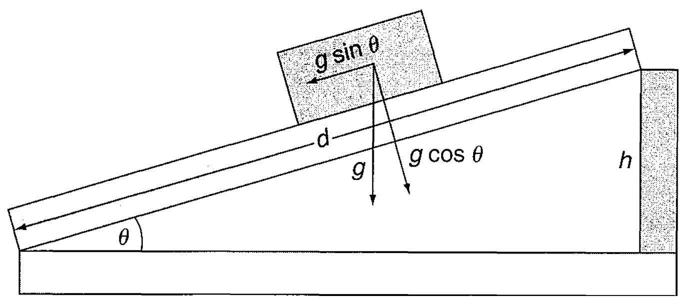


Figure 4-2 Components of g, the acceleration due to gravity on inclined plane.

Substituting Equation 1 for v in Equation 3 gives

$$x = \frac{at^2}{2} \qquad \text{(Eq. 4)}$$

Equation 4 states that if an object is released from rest, its displacement is directly proportional to the square of the elapsed time. **Figure 4-1** shows graphs of both x versus t and x versus t2 for uniformly accelerated motion.

An object shown in **Figure 4-2** is placed on a table that is raised at one end to form an inclined plane with an angle of inclination of θ. The acceleration due to gravity points directly downward, but can be resolved into components that are perpendicular and parallel to the plane. The object moves down the inclined plane with acceleration a, the component of the acceleration due to gravity g acting down the plane. In equation form this is:

$$a = g \sin\theta \qquad \text{(Eq. 5)}$$

EXPERIMENTAL PROCEDURE

1. Precisely measure the height of a stack of two wooden blocks to the nearest hundredth of a centimenter (θ.1 mm). The blocks will be piled with their largest sides touching, such that the height measured will be in the vicinity of 8 cm. Lift the end of the table nearest the wall and place a stack of two blocks securely under each foot of the table at that one end. If the table is too heavy, please ask the instructor or a classmate for help.

2. Precisely measure the distance d between table legs against the bottom of the table, that is, from the pair up on blocks to those resting on the floor
3. Release the ball from rest at a precise zero mark at the top of the incline and simultaneously start a timer. Stop the timer when the ball has traveled 0.400 m down the track. Repeat four more times for a total of 5 trials. The ball should roll straight and parallel to the joint lines in the wood. Record all times in the Data Table. Take turns with partner in using the stopwatch to see if times are similar for a roll of the same distance.
4. Repeat Step 3 for roll distances of 0.600, 0.800, 1.000, 1.200, 1.400, 1.600, and 1.800 m.

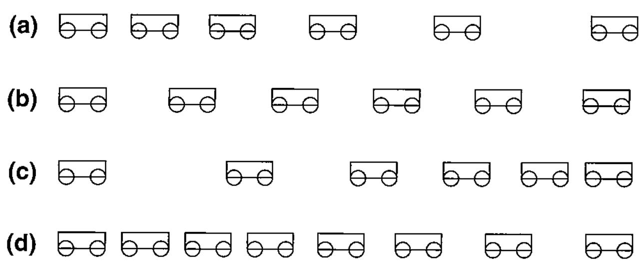
CALCULATIONS

1. Today and in every experiment this semester, keep only *one significant digit* in all standard error values, and in the associated mean, drop decimal places farther to the right than the *decimal position* of that one most significant digit of the standard error..., rounding answers appropriately.
2. Calculate the mean time t, the standard deviation, and the standard error for the five trials of the time at each distance.
3. Calculate the square of each of the mean times for the eight distances.
4. Enter t-squared and x data into an Excel spreadsheet and create a linear scatter plot graph with x as the vertical axis and t-squared as the horizontal axis. Select options to display equation and r-squared on graph.
5. The appearance of the Y=mX+b equation and r-squared value on the graph indicates that Excel has performed a linear least squares fit to the data with x as the Y data and $(\bar{t})^2$ as the X data. Your instructor may choose to have you confirm with a manual calculation, perhaps including a hand-drawn graph showing the best fit line produced by the linear least squares fit. From the slope, m obtained, calculate the acceleration a of the cart where $a = 2$(slope) according to Equation 4. Intercept b=0 if not for error sources.
6. Calculate the value of $\sin\theta = h/d$ using the values of $\bar{h}$ and $\bar{d}$.
7. Use Equation 5 to calculate an experimental value for the acceleration due to gravity (g_{exp}) from the measured values of a and $\sin\theta$.
8. Calculate the percentage error in your value of g_{exp} compared to the accepted value of 9.803 m/sec^2.

Name _______________ Section _______________ Date _______________

LABORATORY 4 *Uniformly Accelerated Motion*

PRE-LABORATORY ASSIGNMENT



The carts pictured above are all moving in a straight line to the right. The pictures were taken 1.00 s apart. Choose which of the descriptions below matches which pictures.

1. These pictures show a cart that is moving at constant velocity.
   (a) (b) (c) (d)

2. These pictures show a cart that has a positive acceleration.
   (a) (b) (c) (d)

3. These pictures show a cart that travels at a constant velocity and then has a positive acceleration.
   (a) (b) (c) (d)

4. These pictures show a cart that has a negative acceleration.
   (a) (b) (c) (d)

5. A cart on a linear air track has a uniform acceleration of 0.172 m/s^2. Use Equation 1 to find the velocity of the cart 4.00 seconds after it is released from rest. Show your work.

6. How far does the cart in Question 5 travel in 4.00 seconds? Calculate the distance x two ways, first using Equation 3 and then using Equation 4. Show your work.

7. An air track like the one shown in Figure 4-2 has a block with a height $h = 12.0\,\text{cm}$ under one support. The other support is 3.50 m away. What is the angle of inclination θ? According to Equation 5, the component of acceleration parallel to the track is $a = g \sin\theta$ where $g = 9.80\,\text{m/s}^2$. For this value of θ what is a? Show your work.

Name | Section | Date

Lab Partners

LABORATORY 4 *Uniformly Accelerated Motion*

LABORATORY REPORT

Data Table

	Trial 1	*Trial 2*	*Trial 3*	*Trial 4*	*Trial 5*
h (m)		---------	---------	---------	---------
d (m)		---------	---------	---------	---------

x (m)	t_1 (s)	t_2 (s)	t_3 (s)	t_4 (s)	t_5 (s)

Calculations Tables

$\sin\theta = \overline{h}/\overline{d} =$		

x (m)								
$\bar{t}$ (s)								
σ_{n-1} (s)								
α_t (s)								
$\bar{t}^2$ (s^2)								

Slope =	$a =$ m/s^2	$g_{exp} =$ m/s^2	%Err =	$r =$

SAMPLE CALCULATIONS

1. $a = 2(\text{slope})$
2. $g_{exp} = a/(\sin\theta) =$
3. $\%\ \text{error} = \dfrac{g_{exp} - g}{g} \times 100\% =$

QUESTIONS

1. The decimal place of the standard error coincides with the least significant digit of the mean and determines the number of significant figures in the value of t. Because these are used to calculate the experimental value of g, they determine the number of significant figures in your value of g. How many significant figures are in your values of t, and how many are in your experimental value of g?

2. Would friction tend to cause your experimental value for g to be greater or less than 9.803 m/sec^2? In which direction is your error for the value for g? Could friction be the cause of your observed error? State your reasoning.

3. What was the instantaneous velocity of the cart at $x = 1.800$ meters assuming your value of the acceleration a is correct? Show your work.

4. State how well the objectives of this laboratory were met. State your evidence for your opinion.