SAN DIEGO MESA COLLEGE
PHYSICS 195 LAB REPORT

Name__________________________
Date __________**Time**___________
Partners _______________________
____
____
____

TITLE: Straight-line Kinematics

Objective: To determine the acceleration of a glider by several different methods and to learn techniques of data recording and graphical analysis.

Theory: Here are equations that describe the motion of an object moving in a straight line and with a constant acceleration.

$$\mathbf{x = x_o + v_o t + 1/2\ at^2} \qquad \mathbf{v = v_o + at} \qquad \mathbf{v_{avg} = 1/2\ (v_i + v_f)}$$

In general:

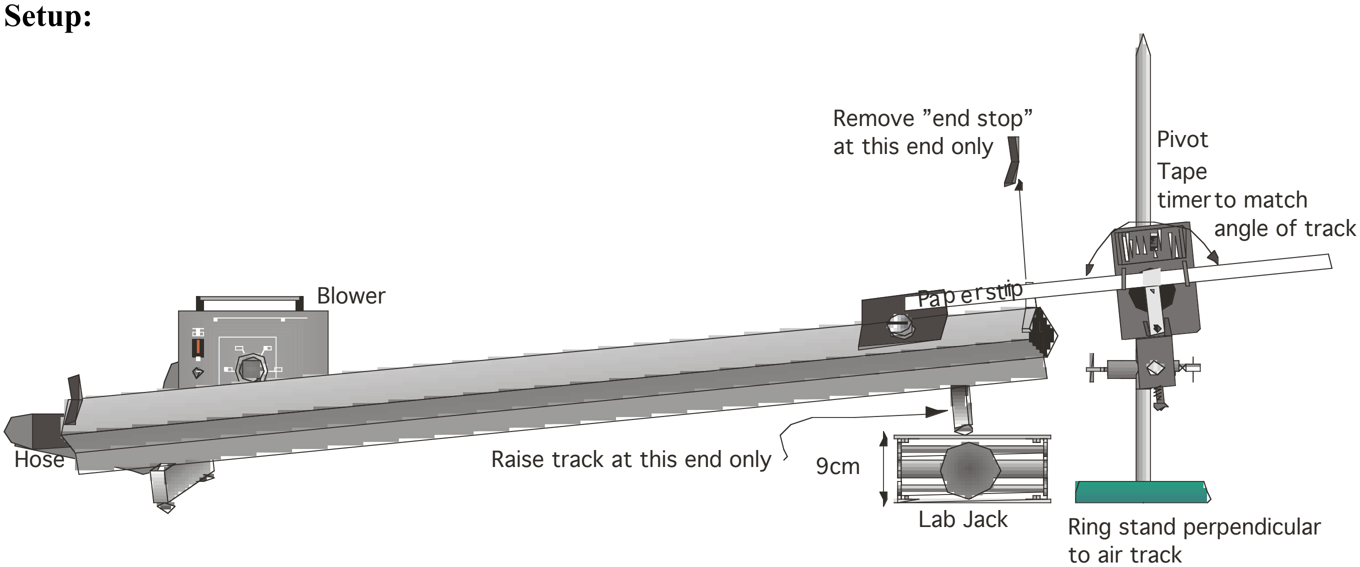
$$\mathbf{v_{avg} = \Delta x / \Delta t} \qquad \mathbf{v = dx / dt}$$

$$\mathbf{a_{avg} = \Delta v / \Delta t} \qquad \mathbf{a = dv / dt}$$

Equipment:

- Air track
- Lab jack / wooden blocks
- Meter stick
- 12" ruler
- Accessory box for air track:
- Glider
- Four 50-gram glider masses
- Ring stand
- Blower and hose
- 1/2 inch white-paper tape
- Masking tape
- Tape timer
- Bumpers

Setup:



Procedure: Level the airtrack with the tilt screws so that the glider shows no direction preference in its motion.
Tilt the track by 8 – 10 centimeters by inserting the lab jack under the single leg support.
Measure the height **h** of the lab jack and record on the diagram below.
The distance D between the two points of support is 1.00 m. Measure it to be sure.

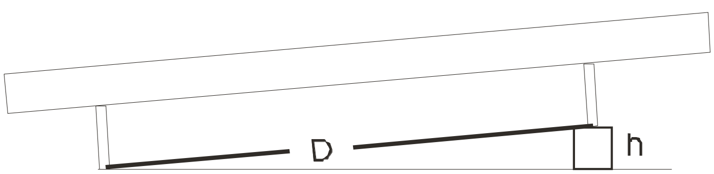
THEORETICAL PREDICTION:

If the track is horizontal the glider will not accelerate.
If the track is vertical the glider will fall freely with an acceleration (**g**) of 981 cm/s^2.
If the track is inclined the acceleration (**a**) of the glider will be proportional to the inclination:

h = _________

DIAGRAM:

D = _________



$a_1 = g \sin\theta$ $\sin\theta = h/D$ Thus $a_1 = g\, h/D$

show your work

Theoretical acceleration: a_1 =________ cm/s^2

EXPERIMENTAL TECHNIQUES:

Take a strip of white timer-paper and thread it through the first slot of the Pasco Tape Timer box, guide it *between* the rectangular metal bar and round ink paper, and then lastly through the second slot, and then tape it to the top edge of the glider as shown in the diagram. The tape timer box will make an ink dot on the white-paper strip at regular time intervals. In this experiment, the timer will be set to 10 Hz, so that the timer makes 10 dots on the paper each second. Thus the time between successive dots on your paper strip is 0.1 seconds.
Place two 50-gram glider masses on each side of the glider.
Hold the glider in position at the top of the track. Turn the air blower on and allow the air to circulate for several seconds. Turn on the tape timer box, and release the glider. Catch the glider before it crashes into the end of the track. Now shut off the tape timer source. Remove the recording tape and check for missing or double dotted points and obvious misplaced points. Redo if necessary.
Your instructor will choose one of the first clear points as zero time and zero position. (*Note*: the *actual* coordinate $x_o = 0$ is the position where you let go of the glider.)

Record subsequent **POSITIONS** of the glider at each dot to the nearest 0.5mm on the data sheet for 12-15 positions. The recording tape should be taped to a two-meter stick to make measurement easier. Record the corresponding time for each position in your data table (i.e., 0.1s, 0.2s, …)

Data:

Dot period = 1/10s: the time interval between dots is 0.10s

					corrected values	
	x(cm)	**t(s)**	**Δx (cm)**	$\bar{v}$ **(cm/s)**	**x_c (cm)**	**t_c(s)**
1	0	0				
2						
3						
4						
5*						
6						
7						
8						
9						
10						
11*						
12						
13						
14						
15						

Analysis:

A. Record the positions of each dot with respect to the dot marked as the origin. Then, calculate the displacement, $\Delta x = x_f - x_o$, for successive positions of the glider, and record this in your data table.

B. You will need to calculate the average velocity for your glider for each time interval. The **average** velocity of the glider can be calculated by finding the displacement (Δx) during the time interval and dividing by the time it took the glider to cover that interval. Note that the displacement and average velocity are offset on the data sheet to emphasize that they are values for time intervals. Calculate the average velocity, $\bar{v}$**,** of the glider for each 0.1-second interval and record this in your data table.

$$\bar{v} = \frac{\Delta x}{\Delta t}.$$

Calcs:

C. Determine the acceleration $a = \frac{\Delta v}{\Delta t}$ of the glider from the data table. Note that to find the acceleration you must know the instantaneous velocity at two different times. However, your data only indicates the *average velocity* of the glider for each time interval. Remember that for constant acceleration, the glider has the value of the average velocity *at the middle* of that particular time interval (0.05s, 0.15s, 0.25 s,…etc). Thus pick two average velocities, one from the top and one from the bottom of your data table (treating each average velocity as an instantaneous velocity at its appropriate time) to find the change in the velocity, and divide by the corresponding time interval.

SHOW YOUR WORK:

$a_{data\ table} = v_f - v_i / t_f - t_i$

a_2 = ______________

D. Graph 1. Plot position (x) as a function of time (t) on regular graph paper.
Please refer to the download titled 'How to Draw a Graph'.

Draw tangent lines to two points on the curve located in the upper and lower portions of the curve, respectively. Choose points #5* and #11* from your data table. On the graph paper, calculate the slopes of the tangent lines and record the corresponding times. The slope of a tangent line on a position-time plot is the instantaneous velocity at the time corresponding to the tangent point. Show all slope work clearly on the graph! (*Use proper units!*)

Determine the acceleration of the glider from the slopes of the two tangent lines (i.e., the instantaneous velocities) from Graph 1.

$a = v_f - v_i / t_f - t_i$

copy from Graph 1: **SHOW WORK**

v_{11} =

v_5 =

t_{11} =

t_5 =

a_3 = ___________________

E. Graph 2. Plot instantaneous velocity as a function of time.
Recall that your data only indicates the *average velocity* of the glider for each time interval and that for constant acceleration, the instantaneous velocity of the glider at the middle of each time interval is equal to the average velocity of the glider during that time interval
Plot the instantaneous velocities of the glider as a function of time. Remember that your first velocity occurs at 0.05s, and the next is at 0.15s, 0.25s, …etc.

NOTE: Leave 1/3 of the left side of the graph paper free in order to find the intercept on the time axis.

Draw a best-fit straight line to your data and extend the line all the way down to the t-axis.
Note the point on your graph where your line crosses the v-axis at t = 0. This point represents the velocity of the glider at the dot that the instructor circled for you. Call it $\mathbf{v_o}$.

$\mathbf{v_o}$ = ________________________

Determine the acceleration of the glider from your graph of velocity as a function of time.
Show work on the graph and record the acceleration here:

a_4 = _______________

Now write the equation for the position of the glider as a function of time for the offset coordinates **x** and **t**, using the velocity $\mathbf{v_o}$ obtained from Graph 2. ** The 'offset' coordinates have $x_o = 0$ where the instructor circled your first point. ** This means that at t = 0, the initial position of the glider is $x_o = 0$, but $v_o \neq 0$ (the glider was moving with speed v_o where the first data point was circled!)

This equation has the form: $x = 0 + \mathbf{v_o}\, t + 1/2\, a_4\, t^2$. Write your equation of motion for x(t).

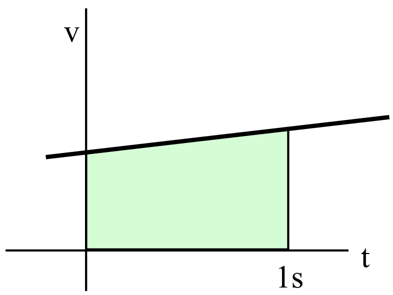
x(t) = ____ (include units!!!)
This equation should yield a position in agreement with your data. At **t** = 1 s, the position predicted by your equation is: (SHOW WORK)

x(1s) = ______________________

$$\% Difference = \frac{\left|X_{meas} - X_{pred}\right|}{X_{meas}} * 100$$

_______________%

F. Recall that $v = \dfrac{dx}{dt}$ *and so* $\Delta x = \int v\,dt$. Thus the area under the line on your graph of velocity versus time represents the displacement of your glider. Use your graph to calculate the area bounded by your line and the time axis from t = 0s to t = 1 s.



Area = _______________

Now calculate this same displacement using your data table for the position of the glider at times 0 and 1 second.

$\Delta x = x_{1second} - x_{0\ seconds}$ = ________________

Compare this value of the glider's displacement with the area under the velocity vs. time graph:

$$\%\,Difference = \frac{\left|\Delta X_{data\ table} - \Delta X_{area}\right|}{\Delta X_{data\ table}} * 100$$

% Difference = _______________

G. Graph 3. Plotting position as a function of time on 2 X 2 cycle log-log paper. Please refer to the download titled 'How to graph on log log'.

A correct plot of the data on log-log paper demands that the actual position of the glider at the actual release time be known, rather than arbitrarily choosing a starting point. (*Remember, the instructor chose an arbitrary starting point for your data.)

To find the necessary correction terms for position and time, first extrapolate your line on the velocity vs. time graph to the **t** axis. The time interval between the **t**-intercept and the origin will be the time elapsed between when the glider actually started moving and what your instructor chose as "zero time". This corrected time, t_c, must be added to each time interval to find the corrected time. Do this now in your data table! (t_c is a positive number.)

t_c = _____________

The distance traveled, x_c, during this time interval must be calculated and added to each position measurement.

To find this corrected position you can use the equation of motion $x_c = x_o + v_o t + 0.5\, a_4 t_c^2$, where $x_o = 0$ and $v_o = 0$, for the time interval from when you let go of the glider up to the circled dot. Use your value of t_c from your graph of *v* vs. *t* and use your value of a_4 for the acceleration to calculate x_c.

$x_c = 1/2(\qquad)(\qquad)^2 =$ ____________centimeters

Add this value of x_c to each position measurement in your data table.

Now use the corrected position and corrected time data to plot the log-log graph.
Note: Since we are using 2-cycle log paper, only those values of x_c between 1cm and 100cm will fit on your graph paper. Thus you will not be able to plot any data points for x_c that are less than 1cm or greater than 100 cm.

H. Analysis of log-log graph. You have seen that the graph of position as a function of time (Graph 1) indicates an exponential relationship between the two variables, rather than a linear function. This relationship can be written as:

$$x_c = k t_c^n$$

where x_c and t_c are corrected position and time values, **k** is some constant of proportionality and **n** is some exponent. Since taking the log of both sides of the equation results in the equation of a straight line:

$\log x_c = n \log t_c + \log k$ <u>has the same form as</u> $y = mx + b$

Plotting the same data (the 'corrected' data) on log-log paper yields the values of the constants, The slope of the graph is the exponent **n**, and the t = 1s intercept of the graph is the value of the proportionality constant **k**.

NOTE that both of these quantities are determined with a procedure different from that used with Cartesian paper. The slope has no units (nor do exponents) and the intercept does not take the units of its axis (you cannot take the log of, nor the antilog of a unit). Calculate the slope of your line.

n = _______________

To find the intercept k, recall that your line has the form $\log x_c = n \log t_c + \log k$.
Recall for a line $y = mx + b$, the intercept **b** is found from setting $x = 0$. So to find the intercept **k** on your graph, you must set the term '$n \log t_c$' = 0. Since $\log t_c$ is zero when t_c is 1, then your intercept is found where your line crosses the $t = 1$ axis.
Mark this x_c value on your graph as the intercept **k**.

k = ________________

Now write the equation for the motion of the glider with numerical values, and proper units for the proportionality constant, in the form: $x_c = kt^n$

x_c = ______________________________

How is the value of **k** related to the acceleration of the glider?

Use your value of **k** to determine the acceleration of the glider by this last, and fifth, method.

a_5 = _______________

Conclusion and Summary of Results:

You have determined the acceleration of the glider by five methods. Summarize your results of this experiment. Include a table of values and their sources. Write a conclusion, including a brief discussion of the physics involved in this experiment, possible sources of error and their effect on your results. How could you reduce these errors?