

Course and Section \_\_\_\_\_

Names \_\_\_\_\_

Date \_\_\_\_\_

## **ONE DIMENSIONAL MOTION EXPERIMENT**

### **Introduction**

In this lab you will study the different forms of motion and the relations between an object's position, velocity, and acceleration.

In this lab, you will use the Pasco wireless cart to study motion in 1-D. The cart contains all the sensors needed to collect data on position, velocity and acceleration. The carts collection data is controlled by a software called Pasco Capstone, which can be used to plot and analyze the data.

**Equipment:** Cart + Magnetic Bumpers, Aluminum track + Magnetic ends.

### **PART 1 – Horizontal motion**

#### **Procedure** average velocity

*Step 1.* Open the file: "**x-t\_v-t\_a-t.cap**" contained in the T:\Capstone folder.

This file opens Pasco Capstone and loads a preset experiment. This experiment will display the position, velocity and acceleration vs time graphs. Once open, select hardware setup to join your experiment to the cart you have on your table. If you need more help, ask the TA .

*Step 2.* Pair your cart by clicking the hardware tab on the top left.

*Step 3.* Place your cart on the track.

*Step 4.* Start taking data. Click on the *Record* button at the bottom left of the screen and drag the cart back and forth on the track a few times.

*Step 5.* To stop taking data, click *Stop*. You can clear your measurement to start over by clicking on the *Delete Last Run tab* at the bottom of the screen.

#### **Analysis**

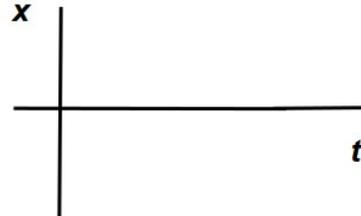
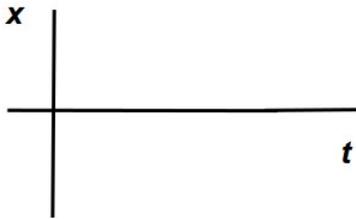
Find the average velocity of the cart moving forward and the average velocity of the cart moving back. To do so highlight the portion of the velocity plot using the pencil  with 3 dots symbol corresponding to the positive velocity. Then click on the  symbol and select mean to display the average value of the velocity. Repeat for the negative velocity.

2. What are the two average velocities?

$$v_+ = \underline{\hspace{2cm}}$$

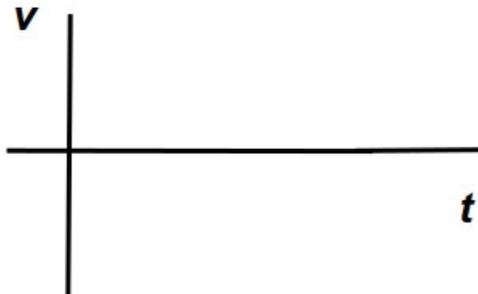
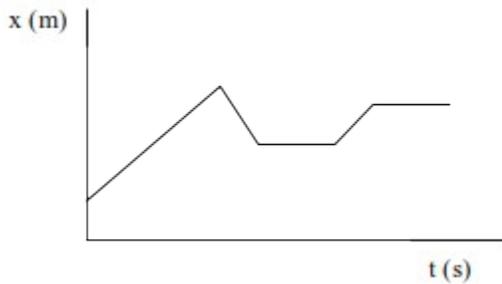
$$v_- = \underline{\hspace{2cm}}$$

3. Draw below the two position vs time graphs obtained with Pasco Capstone for positive and negative velocity.



**Procedure** constant velocity

4. You are given the position vs time graph below. Sketch on the right the velocity vs time graph that you would expect from the graph given.



Try to reproduce this graph by moving the cart: you may have to try this a few times.

5. Using the data you have collected, how does the velocity vs time graph you have sketched compare to the data?

**Analysis**

The first part of the  $x(t)$  plot represents motion at constant positive velocity, followed by a motion at constant negative velocity. The goal is to find the two velocities. Highlight the points corresponding to the motion at constant positive velocity and click on the  symbol to select the linear fit. Repeat for the constant negative velocity negative

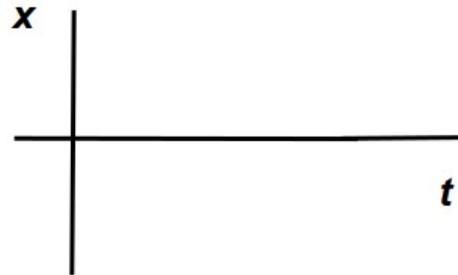
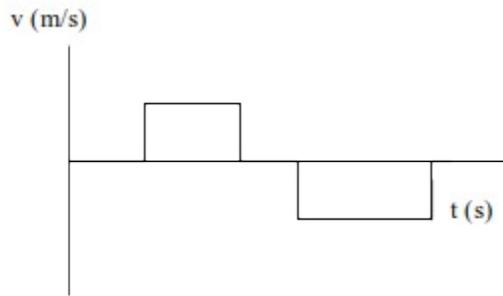
6. What are the two constant average velocities?

$$v_+ = \underline{\hspace{2cm}}$$

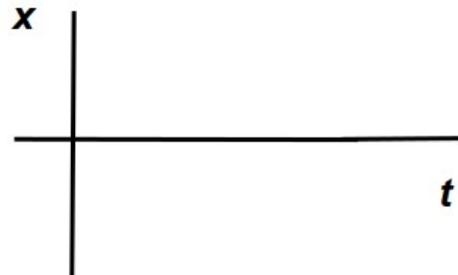
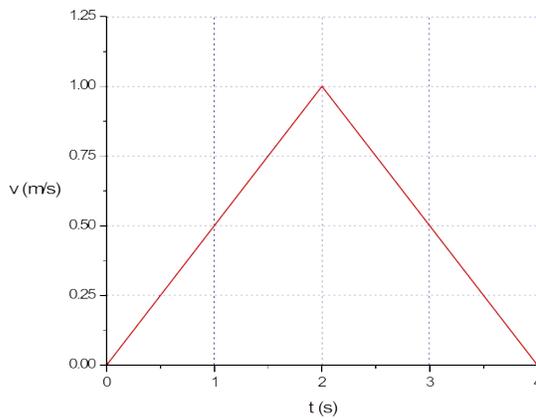
$$v_- = \underline{\hspace{2cm}}$$

Print and attach a copy of your Pasco Capstone graph.

7. You are given below the velocity vs time graph below. Sketch on the right the corresponding position vs time graph

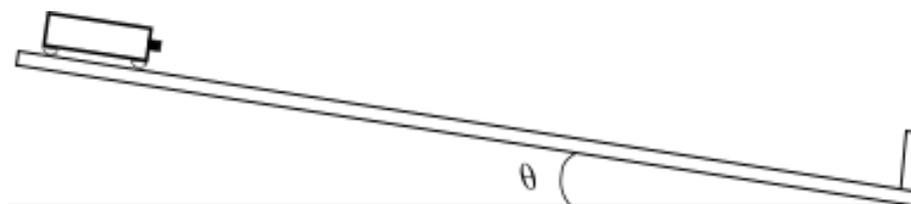


8. You are given below the velocity vs time graph below. Sketch on the right the corresponding position vs time graph



## PART 2 – Incline plane

Use the aluminum track with the magnetic stopper attached at one end. Lift the other end to set up an incline plane, use a book for example (about 4 to 8 cm height). Attach the magnetic bumper on the cart such that it would bounce back after the collision with the magnetic stopper. The goal is to determine  $g$ , the acceleration due to gravity.



### Predictions

Before taking measurements, release the cart from rest at the top and observe its motion as it falls down and bounce back up a few times.

10. Is this motion an example of a free fall motion? Explain.
11. Sketch a graph of the position vs time for the motion of the cart.
12. Sketch a graph of the velocity vs time for the motion of the cart.
13. Sketch a graph of the acceleration vs time for the motion of the cart.

### **Procedure**

*Step 1.* Open the file: "**x-t\_v-t\_a-t.cap**" contained in the T\Capstone folder.

This file opens Pasco Capstone and displays the position, velocity and acceleration vs time graphs.

*Step 2.* Place the cart at the top of the track.

*Step 3.* Press record and release the cart from rest.

*Step 4.* Record the motion of the cart until it comes to rest again.

### **Analysis**

14. What differences and similarities do you observe between the measured *position* and your predicted graph (PART 2 above)? Explain the differences.
15. Look at the obtained velocity graph and compare it with your predicted graph on question 12.
16. Look at the obtained acceleration graph and compare it with your predicted graph on question 13.

The equations which describe the position, velocity and acceleration of the cart are:

$$x(t) = \frac{1}{2}g \sin(\theta)t^2 + v_0 t + x_0$$

$$v(t) = g \sin(\theta)t + v_0$$

$$a(t) = g \sin(\theta)$$

Where  $\theta$  is the angle between the track and desk and  $v_0$  is the initial velocity.

**17.** You can determine  $\theta$  by measuring the height and the base (or the hypotenuse) of the incline plane and using trigonometry. What is your value of  $\theta$  ?

The numerical value of  $g$  can be obtained from each one of the plots  $x(t)$ ,  $v(t)$  and  $a(t)$  and their corresponding parameters. Select a time interval which only includes the cart's motion in between bounces.

$x(t)$ : fit to a quadratic equation and use the parameters  $A$ ,  $B$ , and  $C$ .

$$A = \underline{\hspace{2cm}}$$

$v(t)$ : fit to a linear equation and use the parameters  $m$  and  $B$ .

$$m = \underline{\hspace{2cm}}$$

$a(t)$ : find the average acceleration by clicking on the symbol  $\Sigma$  and select mean.

**18.** Collect your results for  $g$  in the following table.

Plot	$g$ ( $m/s^2$ )
$x(t)$ vs $t$	
$v(t)$ vs $t$	
$a(t)$ vs $t$	

**19.** Which graph of question 18 gives the best estimate for  $g$  ?

**20.** Suppose the cart was three times as massive  $M = 3m$  (ignore shapes, material and friction), how will your results be different?

Print and turn in the plots from Pasco Capstone of position, velocity and acceleration.

### **PART 3 – Error Analysis**

To have a better estimate for  $g$ , you have to repeat the measurement several times. In this way, a more precise estimate of the 'real' value of  $g$  can be obtained.

21. Take five measurements of the velocity of the cart on the track, and calculate  $g$  for each of them using Pasco Capstone. *Note: Make sure to use the data collected in between bounces.*

Measurement number	1	2	3	4	5
Measurement value, $g_i$ (m/s <sup>2</sup> )					
Deviation, $d_i$ (m/s <sup>2</sup> )					

22 Calculate the average value of  $g$  for  $N = 5$

$$\bar{g} = \frac{1}{N} \cdot \sum_{i=1}^N g_i = \underline{\hspace{2cm}}$$

23 Calculate the deviation from the mean and enter to the above table.

$$d_i = g_i - \bar{g}$$

24. Calculate the standard deviation,

$$\sigma_T = \left( \frac{1}{N-1} \cdot \sum_{i=1}^N d_i^2 \right)^{1/2} = \underline{\hspace{2cm}}$$

25. The error for the average  $\sigma_{\text{average}}$  is related to the standard deviation  $\sigma_T$  by

$$\sigma_{\text{average}} = \frac{\sigma_T}{\sqrt{N}} = \underline{\hspace{2cm}}$$

26. Record the final answer for the series of five measurements above.

$$g = \bar{g} \pm \sigma_{\text{average}} = \underline{\hspace{2cm}} \pm \underline{\hspace{2cm}}$$

27. Which are the possible sources of error?

Human errors:

Instruments errors:

Others source of errors: