

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

Names \_\_\_\_\_

Date \_\_\_\_\_

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## **NEWTON'S LAWS OF MOTION EXPERIMENT**

### **Introduction**

In this lab, you will study the three Newton Laws of motion by measuring the kinematic quantities and their relations with forces. Specifically, how a force affects the acceleration of an object in different situations.

The acceleration of an object is defined as the rate of change of velocity. If the velocity changes by the amount  $\Delta v$  in a time interval  $\Delta t$  then the average acceleration is:

$$a = \frac{\Delta v}{\Delta t} \quad (1)$$

Newton's 2<sup>nd</sup> law of motion: if a non-zero net force  $F_{NET}$  acts on an object, then the object accelerates proportionally to the net force applied:

$$\vec{a} = \frac{1}{m} \vec{F}_{NET} \quad \text{or} \quad \vec{F}_{NET} = m \vec{a} \quad (2)$$

The proportionality constant  $m$  is the inertia of the object, and its numerical value is called the *mass*.

### **Equipment**

Track, hooks, rubber bumper, two smart carts, metal blocks.

### **PART I – Newton's 1<sup>st</sup> Law**

#### **Prediction**

Imagine that you have a cart at one end of a level track. There is no friction.

1. Suppose the cart is initially at rest at one end of the track. You push it with a constant force until it reaches the middle of the track, and then let it roll freely until it reaches the other end.

Make a sketch of the expected velocity vs time curve.



2. Suppose the cart is initially at rest at one end of the track. Imagine giving it a short tap with your finger to set it into motion. When the cart has reached the center of the track, imagine you give it another short tap in the same direction and let it roll to the end of the track. Make a sketch of the expected velocity vs time curve.



3. Suppose the cart is initially at rest at one end of the track. Imagine giving it a short tap with your finger to set it into motion. When the cart has reached the center of the track, imagine you give it another short tap in the direction opposite of the motion. Make a sketch of the expected velocity vs time curve



4. Draw below three free body diagrams of the cart relative to question 3.  
a. The cart is at rest on the track.

b. The cart is in motion at constant velocity.

c. The cart the instant you tap it in the direction opposite of the motion.

### Procedure

*Step 1.* Open the file: “**x-t\_v-t\_a-t.cap**” contained in the T:\Capstone folder. You will be focusing on the velocity vs time graph: you can enlarge this graph for better viewing.

*Step 2.* Pair one of your two carts.

*Step 3.* With your cart beginning at rest, press record on the computer.

*Step 4.* Tap the cart with one finger to set it in motion. Tap the cart again in the same direction when it reaches the middle of the track. It's the prediction 2.

**Analysis**

5. Sketch the graph of the velocity vs time on the plot to the right.

6. How does this plot compare to your earlier prediction of question 2?



7. Is the velocity constant between the two taps? If not, why?

8. Is the graph you have recorded consistent with Newton's 1<sup>st</sup> law? Explain

**PART 2 - Newton's 2<sup>nd</sup> Law**

Open the file: "**F-a.cap**" contained in the T:\Capstone folder. The file will open a Pasco Capstone experiment, which contains a graph of force vs acceleration (find it using the right click on the axes labels). Pair your cart with your computer.

**Procedure**

*Step 1.* Tare the force sensor: you want the cart to read a zero force value if no forces are applied. Go to 'Hardware Setup' on left panel. Click on circle next to 'Smart Cart Force Sensor'. Then click on 'zero sensor now'. Then click 'ok'.

*Step 2.* Connect the hook to the force sensor.

*Step 3.* Press the record button and, while holding only the hook, roll the cart forwards and backwards for about 10 second, until enough data points are generated to fit the expected behavior.

**Analysis**

9. Use the fit tool to provide a linear fit of the graph. From the fit find the mass of the cart.

10. Print a copy of your graph with axes labeled.

11. Repeat five times the analysis for finding the mass (no need of extra graph printouts). Record your measurements in the first row of the table below. Calculate the average mass and the deviations.

Measurement	1	2	3	4	5
Mass (kg)					
Deviation $d_i$					

Average $\bar{m}$	(kg)
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12. Calculate the standard deviation and the error. You can use the formula below or excel or your calculator or any online resources.

$$\sigma_T = \left( \frac{1}{N-1} \cdot \sum_{i=1}^N d_i^2 \right)^{1/2} = \text{_____} \quad \sigma_{average} = \frac{\sigma_T}{\sqrt{N}} = \text{_____}$$

13. Record the final answer for your calculation of the mass of the cart.

$$m = \bar{m} \pm \sigma_{average} = \text{_____} \pm \text{_____}$$

14. Your linear fit has a non-zero y-intercept, that means if  $a = 0$  then  $F = B$ . But from Newton 2<sup>nd</sup> Law if  $a = 0$  then  $F = 0$ . Why do you think you're getting  $F \neq 0$ ?

### PART 3 - Newton's 3<sup>rd</sup> Law

Open the file: "F-t.cap" contained in the T:\Capstone folder.

The file opens a Pasco Capstone experiment which contains a graph of the two force vs time. The two forces are shown with opposite magnitude for displaying purpose.

#### Procedure

*Step 1.* Pair both of your Pasco carts with your computer. In the <Select Measurement> of the table input your two carts force sensor.

*Step 2.* Attach the rubber bumper to each cart. Click *Record* to check the sensors' calibration. Both sensor should read zero a force = 0 N, if not calibrate the sensors (see previous step).

*Step 3.* Put both carts on the track with the rubber bumpers facing each others.

*Step 4.* Press down with your hand and hold cart 1 in position. Now press cart 2 against cart 1 for a time interval of about  $\Delta t = 5$  sec. Press using a constant force: keep an eye on the graph of force vs time to maintain an almost constant force.

15. What is the average value (over  $\Delta t$ ) of the force acting on cart 1?

16. What is the average value (over  $\Delta t$ ) of the force acting on cart 2?

17. Do the answers to the two questions above agree with Newton 3<sup>rd</sup> law?

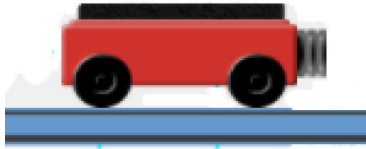
*Step 5.* Slightly increase the force against cart 1.

18. How does the force acting on cart 2 changes?

*Step 6.* Add one (or two) metal block on cart 1 and do not hold it down this time. Press cart 2 against cart 1 and observe the values of the two force as the two carts are moving.

19. How are the two forces related while the two carts are moving?

20. Draw on the two figure below the free body diagram of each cart relative to *Step 6*. Include any external force.



22. Identify and label any action/reaction pairs in the two free body diagrams above.