NEWTON'S SECOND LAW (Fall 2023 version 9/15/23)

EQUIPMENT

1 connecting string	*Three 1/2 kg masses for cart*
1 dynamics car	*1 table edge pulley*
1 dynamic cart track	*1 set of masses*
Newton's 2nd Law Program	*1 triple beam balance*
Lab Pro interface	*1 50g mass hanger*
• *Power supply*	*1 25g mass*
• *USB cord*	
Motion detector	

INTRODUCTION

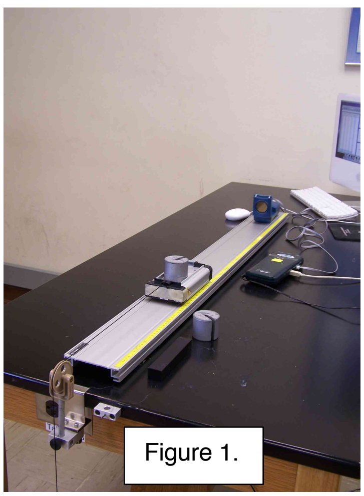


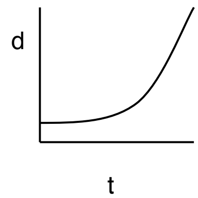
Figure 1.

The purpose of this experiment is to examine the motion of an object under the influence of a uniform, or constant, force and to observe the effects of inertia on the motion.

Galileo discovered that objects change their state of motion when acted on by an external force, the velocity of the object changes at a constant rate. Galileo's studies did not adequately explain the relationship between the inertial mass of an object and the force causing the motion. A century after Galileo's discoveries, Isaac Newton was able to explain the relationship between force, mass and acceleration. Newton stated that the acceleration, or rate of change of velocity, is directly proportional to the unbalanced force acting on the object and inversely proportional to the mass of the object. This relationship (known as **Newton's Second Law**) can be expressed as:

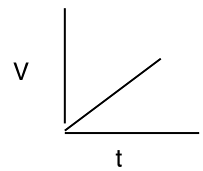
$$acceleration = \frac{Force}{Mass} \quad \text{or} \quad a = \frac{F}{a}$$

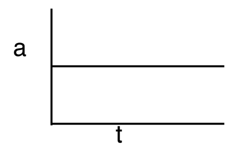
In this experiment you will observe the acceleration of a small cart pulled by a constant force. The force to move the cart is provided by the weight of a suspended mass attached to the cart by a string as shown in Figure 1.



We remember that a curved line on a distance vs. time graph means that an object is accelerating.

The acceleration of the cart can be determined from the acceleration versus time graph, or by calculating the slope of the velocity versus time graph. The slope of the graph of velocity versus time is the acceleration of the cart. If the acceleration is constant, the slope is constant and a straight line can be drawn through the points.





Any object undergoing motion caused by a uniform force has constant acceleration. The object's velocity is changing, but the rate of change (or acceleration) is constant. We can compare the slope of the velocity graph to the mean (or average) value of the acceleration graph, knowing that they should be equal.

The experiment will be repeated several times, first by varying the mass of the cart and then by varying the force pulling the cart. From the graph obtained for each run, you will investigate the change in the acceleration of the cart when the mass of the cart and the force pulling the cart are varied.

PROCEDURE:
A. Acceleration

1. The mass of the dynamics cart is ½ kg.
2. Set the motion detector at one end of the track and the pulley at the other.
3. Place the cart no closer than 20 cm to the motion detector, and position the string to run over the pulley. One partner should prevent the cart from moving while the other attaches a 50g mass hanger to the end of the string .
4. Open the NEWTON'S 2nd LAW program from the "Experiments" folder.

5. Press COLLECT and release the cart. Do not allow the cart to hit the “track stop”.
6. Click the velocity vs. time graph, highlight the portion of the graph with a straight diagonal line, and find the equation of the line by clicking the **“Linear Fit”** button. You are interested in the slope of the line.

   Remember: y = mx + b, and m = slope.
7. Click on the acceleration vs. time graph, highlight the portion of the graph that makes a straight line (this should be the same section that was diagonal for the velocity graph) and find the mean value of acceleration by clicking the STATS button.

   The **mean** (i.e., the average) for the acceleration graph should be equal to the slope for the velocity graph!
8. Copy this value of acceleration into the table below.
9. Duplicate the graph of velocity vs. time on the last page of the procedure (page 28

   Your plot(s) should be fully labeled. This means to label both x & y axes including units. You should also include the **linear fit line with the value of the slope** (which is the acceleration of the cart).

B. Variation of Mass

10. Add ½ kg to the top of the cart. You have now increased mass of cart by a factor of 2. (What do think should happen to you acceleration?) Repeat steps 5-9 in part A.
11. Add another ½ kg (now 1 kg total added to cart). What do think should happen to you acceleration?
12. Again repeat steps 5-8 in part A.

C. Variation of Force

13. Remove all additional masses until the **cart has a mass of 1/2 kg** (cart only). *The cart should have the same mass as in step one.*
14. The suspended mass should still be 100g. Repeat steps 5-8 in part A.

Refer to this table for each trial!

Trial	Mass 1 (Cart + Mass)	Mass 2 (Hanging Mass)	Acceleration from slope of Velocity vs.time (m/s/s)
1	Cart only	0.050 kg	
2	Cart +1/2 kg	0.050 kg	
3	Cart + 1 kg	0.050 kg	
4	Cart only	0.100 kg	
See lab question # 4	Cart	0.150 kg	**See lab question# 4**

DATA SHEET

Name: ________________________ Section:____

QUESTIONS

1. From your velocity versus time graphs, can you conclude that the acceleration of the cart was constant during each run? State your reason(s).

2. When the mass of the cart was increased and the suspended mass held constant, what happened to the magnitude of the acceleration? Why?

3. When the suspended mass was increased, and the mass of the cart held constant, what happened to the magnitude of the acceleration? Why?

4. In the last row of the data table you are asked to fill in the (approximate) acceleration of the cart (with no added masses) if you had added 150g total hanging mass. Be sure and refer to and comment on the accelerations you measured in trials one (1) through four (4).

5. Relate the results of your experiment to Newton's second law. In other words explain why your results were (or were not) consistent with Newton's 2^{nd} Law (i.e., acceleration = Force/mass).

6. If a cart has a weight of 10 N and is pulled by a constant 20 N force, what is the resulting acceleration? HINT: You must distinguish between mass and weight. Use g = 10 m/s/s

Velocity vs. Time Sketches

(Be sure and include linear fit lines & the slopes of the lines)

Trial 1 (

Trial 2-

Trial 3

Trial 4

Trial 5