

Newton's Second Law—Constant Force

Mechanics: Newton's Second Law, acceleration, net force	
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Qty	Equipment and Materials	Part Number
1	PASPORT Xplorer GLX	PS-2002
1	PASPORT Motion Sensor	PS-2103
1	1.2 m PASCO Track	
1	GOcar	ME-6951
1	Super Pulley with Clamp	ME-9448A
1	Hooked Mass Set	SE-8759
1	Balance	SE-8723
1 m	Braided Physics String	SE-8050

Purpose

The purpose of this activity is to determine what happens to an object's acceleration when the net force applied to the object stays constant but the mass of the system is changed.

Background

Often, several forces act on an object simultaneously. In such cases, it is the net force, or the vector sum of all the forces acting, that is important.

Newton's First Law of motion states that if no net force acts on an object, the velocity of the object remains unchanged. The Second deals with what happens when a net force does act on an object.

Newton's second law states that the acceleration is directly proportional to the net force acting on the object and in the same direction as the net force. Newton's Second Law also states that the acceleration is inversely proportional to the mass. If the mass of an object increases and the net force is kept constant, the acceleration decreases.



Newton (1642–1727)

Safety Precautions

- Follow all directions for using the equipment.

Preview

Use a Motion Sensor to measure the motion of a cart that is accelerated by a net force. Use the Xplorer GLX to record the motion and display and analyze the velocity of the cart.

$$a \propto F_{net}$$

$$a \propto \frac{1}{m}$$

$$a = \frac{F_{net}}{m}$$

Prediction

- What will happen to an object when you apply a net force to it?
- What will happen to the motion of an object as its mass changes but you keep the magnitude of the net force on it constant?

Procedure

GLX Setup

1. Connect the Motion Sensor to one of the sensor ports on the top end of the GLX. Put the range selection switch on the top end of the Motion Sensor to the 'near' (cart) setting.
2. Turn on the GLX (☺).
- The Graph screen opens with a graph of Position (m) versus Time (s).

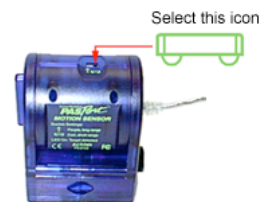


Fig. 1: Motion Sensor setting

Equipment Setup

1. Measure and record the mass of the cart.
2. Place the track on a horizontal surface and level the track. (Place the cart on the track. If the cart rolls one way or the other, adjust the track to raise or lower one end.)
3. Attach the Motion Sensor to one end of the track. Place the cart about 15 cm from the sensor. Aim the sensor at the cart.
4. Attach the Super Pulley with Clamp at the other end of the track. Place a block in front of the pulley to protect it from being hit by the cart.
5. Get a piece of string that is about 20 cm longer than the distance from the floor to the top of the pulley. Tie the string to the end of the cart and place the string over the pulley. Tie a loop in the other end of the string.

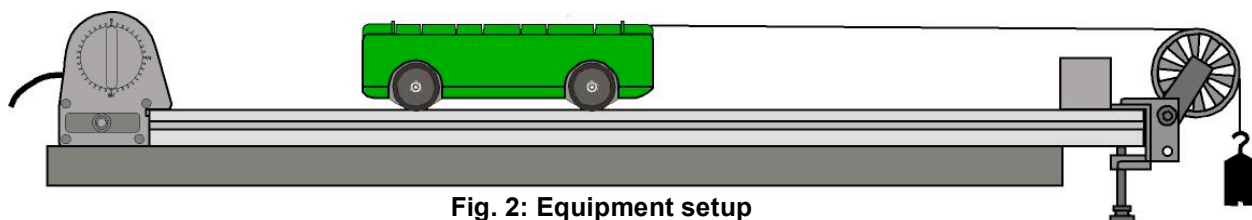


Fig. 2: Equipment setup



6. Measure and record the mass of a 20-g hooked mass and hang the mass from the loop at the end of the string.
7. Adjust the string if needed so that when the cart is at the pulley, the hooked mass on the end of the string almost reaches—but does not touch—the floor.

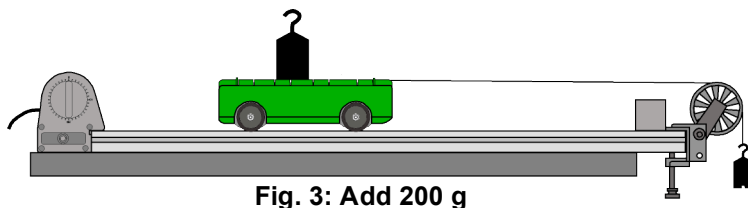
Record Data

Part 1: No Extra Mass Added

1. Pull the cart back so the mass is just below the pulley (but make sure that the cart is at least 15 cm away from the sensor).
2. Press Start (▶) to start recording data. Release the cart so it moves toward the pulley.
3. Press (▶) to stop recording data *just before* the cart reaches the end of the track.

Part 2: First Extra Mass Added

1. For Run #2, add 200 g (0.2 kg) to the top of the cart. Record the total mass of the cart plus extra mass.
2. Press Start  to start recording data. Release the cart so it moves toward the pulley.
3. Press  to stop recording data *just before* the cart reaches the end of the track.

**Fig. 3: Add 200 g****Part 3: Second Extra Mass**










1. For Run #3, add another 200 g (0.2 kg) to the top of the cart (for an additional mass of 400 g or 0.4 kg). Record the total mass of the cart plus extra mass.
2. Record the motion of the cart as before.

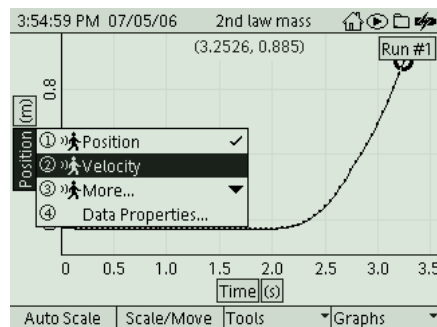
Part 4: Third Extra Mass Added


1. Finally, for Run #4, put a total of 600 g (0.6 kg) on top of the cart. Record the total mass of the cart plus the extra mass.
2. Record the motion of the cart as before.

Analysis

Use the Graph screen to examine the velocity of the cart for each data run. Find the slope of the velocity to determine the acceleration for each run.

1. To change the Graph screen to show a specific run of data, press  to activate the vertical axis menu. Press the up-arrow key () to move to 'Run #_' in the upper right corner. Press  to open the menu, select the data run in the menu, and press  to activate your choice.
 2. To change the Graph screen from Position (m) versus Time (s) to Velocity (m/s) versus Time (s), press  to activate the vertical axis menu. Press  again to open the menu. Select 'Other' and then select 'Velocity'. Press  to activate your choice.
 3. To determine the slope of the velocity, press **F3** () to open the 'Tools' menu. Use the up-down arrow keys to select 'Linear Fit' and press  to activate your choice.
- The 'Linear Fit' shows the slope of the entire plot of velocity. You may need to select a region of interest (ROI) in your plot of data.

**Fig. 4: Select 'Velocity'**

4. To select a region of interest in your data, move the active cursor to the end of the region of interest. (Note: There is another, smaller cursor at the beginning of the data.) Open the 'Tools' menu and select 'Swap Cursor'. Press  to activate your choice.
 - The active cursor is now at the beginning of the data and the smaller cursor is at the end of the region of interest.
5. Use the right-left arrow keys to move the active cursor to the beginning of the region of interest. The slope of the 'Linear Fit' of your data appears below the horizontal axis.
6. Record *Slope* as the acceleration for Run #1.
7. Repeat the analysis process to find the acceleration for each run of data.

Record your results and answer the questions in the Lab Report section.

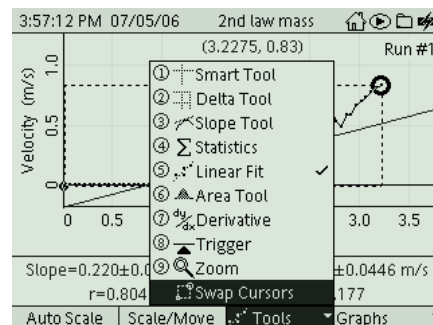


Fig. 5: Select 'Swap Cursor'

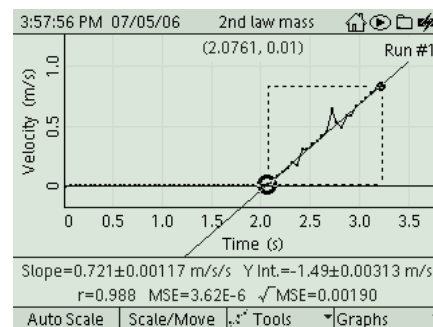


Fig. 6: Move the active cursor

Lab Report – Activity 7A: Newton's Second Law—Constant Force**Name** _____ **Date** _____**Prediction**

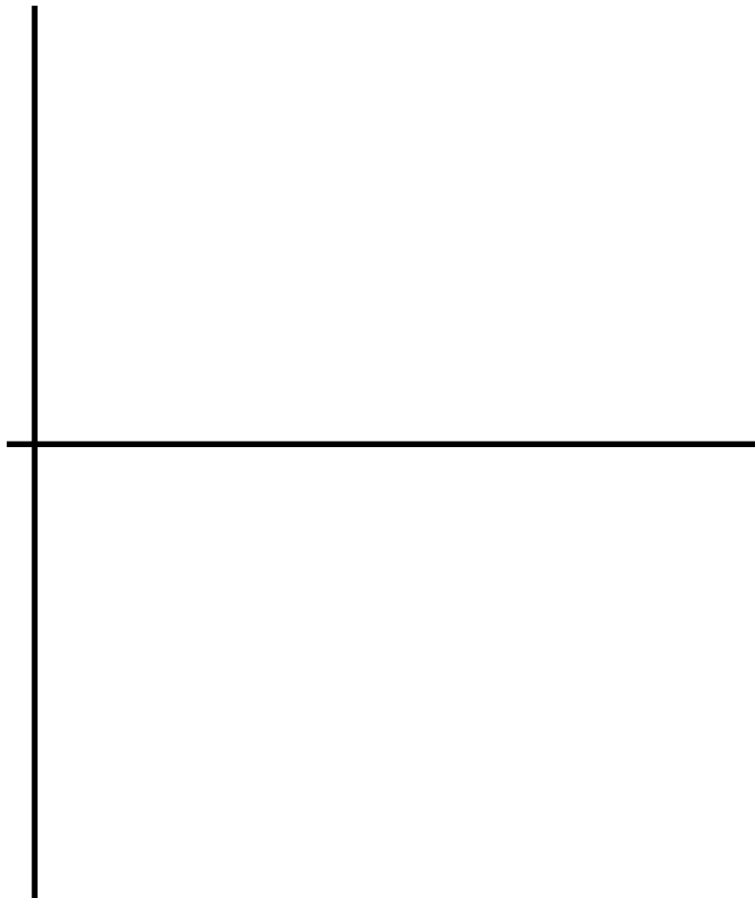
1. What will happen to an object when you apply a net force to it?
2. What will happen to the motion of an object as its mass changes but you keep the magnitude of the net force on it constant?

Data

Sketch a graph of position versus time for one run of data. Include labels and units for your y-axes and x-axes.



Sketch a graph of velocity versus time for one run of data. Include labels and units for your y-axes and x-axes.



Calculations

Calculate the theoretical acceleration when the mass is constant and the net force is changed and record the calculations in the Data Table 3.

- The theoretical acceleration is the ratio of the net force divided by the total mass.

$$a = \frac{m_{\text{hanging}} g}{m_{\text{cart}} + m_{\text{hanging}}}$$

- For runs #2, #3, and #4, the total mass of the system (mass of cart plus hanging mass) increases and the net force (hanging mass x 9.8) remains constant.
- Assuming no friction, the net force is the weight of the hanging mass (mass x 9.8 N/kg).

Find the percent difference between the theoretical and experimental acceleration and record it in

the data table. $\%diff = \left| \frac{\text{theoretical} - \text{experimental}}{\text{theoretical}} \right| \times 100$

Data Table 1

Item	Mass (kg)
Run #1: Total mass of the hanging mass (m_{hanging}):	
Run #1: Total mass of cart (m_{cart}):	
Run #2: Total mass of cart plus 0.200 kg:	
Run #3: Total mass of cart plus 0.400 kg:	
Run #4: Total mass of cart plus 0.600 kg	

Net force (hanging mass x 9.8 N/kg): _____

Data Table 2: Experimental Acceleration

Run	Acceleration (m/s^2)
#1	
#2	
#3	
#4	

Data Table 3

Run	Mass, cart (kg)	Total mass (kg)	Acc., theory (m/s^2)	Acc., exp. (m/s^2)	% difference
#1					
#2					
#3					
#4					

Questions

- For runs #2, #3, and #4, what did you observe about the slope of the Linear Fit as the net force remained constant but the total mass increased?
- What happens to an object's acceleration if the net force applied to the object is kept constant but the object's mass increases?

