

Lab - Newton's 2nd Law

Purpose: To investigate Newton's Second Law using a dynamics cart in order to find the relationship between force, mass, and acceleration.

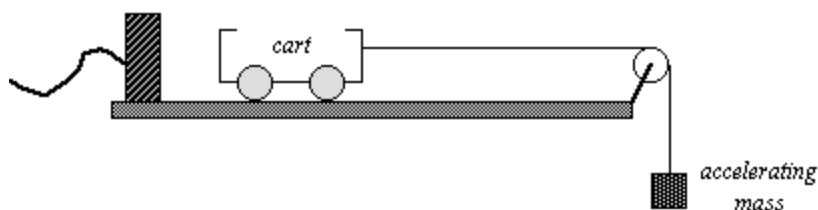
Materials: dynamics cart super pulley
mass pieces set Mac Interface
weight hanger string

Discussion: One of the most powerful of all of the Laws of Physics in solving real world applications is Newton's Second Law. The Law states that an unbalanced force applied to an object will cause it to accelerate in the direction of that force. As long as that force is applied the object will accelerate!

$$\Sigma \mathbf{F} = m \cdot \mathbf{a}$$

This seems to go against common sense. When driving a car the constant force of the engine keeps the car going at constant speed (without acceleration!). But this is because friction and air resistance are opposing the force of the engine and the forces are balanced--no net force. However, if the driver pushes on the gas pedal the force of the engine becomes greater than the drag forces and the car accelerates.

In this lab, you will measure the acceleration of a dynamics cart when different accelerating forces are applied then you will keep the accelerating force constant and change the mass of the cart (by adding mass pieces). Your goal is to accurately collect data, analyze the data by drawing graphs, then to draw some conclusions about the relationship between (i) force and acceleration and (ii) acceleration and mass.



Procedure: The effects of changing **the applied force** on acceleration

*Before beginning, make sure to level the track with the leveling device on the end of the track.

- Record the mass of the cart and hanger in your data section. Set up the apparatus above.
- Mark off a distance of 40-50 cm from the sensor. Do NOT start the cart any nearer than this or the sensor may not function properly.
- INTERFACE SETUP: Turn on the PASCO interface. Load "Data Studio". Create an experiment. Select a "motion sensor" and set up a graph of velocity vs. time as the "display".

- Attach the weight hanger to the string and get ready to let it fall to the ground. When you are ready to take data press the RECORD button. Right before the cart hits the end of the track press the STOP button.
- Have the software draw a “best-fit” line and find its slope (a_2) in order to determine the experimental acceleration. Record this in the data table.
- Repeat the above process four times adding 10 grams to the hanger each time. BE CAREFUL TO PREVENT THE CART FROM SLAMMING INTO THE PULLEY.

The effects of a **constant applied force to an object of varying mass**

- Set up the experiment just as in part A. This time use 50g (an empty hanger) to accelerate the cart every time.
- Place 100g in the cart and allow the mass to fall. Carefully find the time it takes for the accelerating mass to hit the ground and use the graph of vel. vs. time to determine the acceleration. Record this in Data Table 2.
- Repeat the above steps four times with 200g, 300g, 400g, and 500g added to the cart. Record your results.

Data:

Table #1 – Accel. Vs. Applied Force

Trial	Mass Cart (kg)	Weight Cart (N)	Mass Applied (kg)	Force Applied (N)	Exper. Accel (m/s/s)	Theor. Accel (m/s/s)	% error
1							
2							
3							
4							
5							

Table #2 – Accel vs. Mass

Trial	Mass Cart (kg)	Weight Cart (N)	Mass Applied (kg)	Force Applied (N)	Exper. Accel (m/s/s)	Theor. Accel (m/s/s)	% error
1							
2							
3							
4							
5							

Analysis:

- Determine the “weight of the cart” and the “weight applied” using the equation: $W = m \cdot g$ where m is the mass applied/mass of cart and $g = 9.81 \text{ m/s}^2$. Record.
- Determine the theoretical acceleration using $a = F/M$. Where F is the applied force and M is the mass of the cart + the mass of the hanger. Compare to the experimental values.
- Determine your average % error between the experimental and theoretical accelerations.

Graphs:

- Make a graphs of:
 - acceleration vs. applied force** for constant mass (from Table 1)
 - acceleration vs. mass** for a constant force (from Table 2)
 - acceleration vs. F/M** ($M = \text{total mass of cart and hanger}$) (from Table 2)

When graphing,

- (1) be sure to graph the dependent variable on the y axis
- (2) scale the graphs so your data is spread out evenly over the whole graph
- (3) draw best fit lines/curves and determine the equations representing each one
- (4) determine the slope of graphs (i) and (iii)

- Questions:**
1. How does the shape of the graph (i) look? What does this imply about the relationship between force and acceleration when the mass is constant?

 2. What is the slope of graph (i)? How does it compare to the total mass of the system (mass of the cart + mass of hanger)? Should they be the same? Explain.

 3. How does the shape of the graph (ii) look? What does this imply about the relationship between acceleration and mass when the force is constant?

 4. What is the shape of graph (iii)? What is the slope? Explain why the slope should be close to a value of "one".

 5. The graph of force versus acceleration should pass through the origin (Why?). If it does not that means that there was some other force being applied that was not accounted for. What could this force be?

Error Analysis Determine your percent error. How did your experimental values compare to the theoretical values? Discuss any sources of error in this lab and describe ways that you could improve the accuracy.

Conclusion: What did you do? What did you find? What generalizations can you make?