Title: "Introduction to Newton's second law"

Synopsis: Students will use Newton's second law (F=m*a), along with previous knowledge of kinematic equations, to explore the acceleration of a constant-mass system consisting of a cart of known mass, a hanging mass, and several 50g weights. This activity is intended to be done with a partner.

Purpose: For students to understand how changing the force applied on a constant mass system affects the acceleration *of the system*, reaffirming Newton's second law. (It is important that students understand that we are analyzing the acceleration of an entire mass-cart system, and not just the acceleration of the cart)

Next Generation Science Standards:

Students who demonstrate understanding can:

HS-PS2-1.	Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. [Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.] [*Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.*]
HS-PS2-2.	Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system. [Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.] [*Assessment Boundary: Assessment is limited to systems of two macroscopic bodies moving in one dimension.*]
HS-PS2-4.	Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects. [Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.] [*Assessment Boundary: Assessment is limited to systems with two objects.*]

Objectives:

-Investigate Newton's second law of motion
-Compare calculations based on Newtonian physics to actual motion
-Determine the validity of an experiment

Introduction: Newton's second law states that acceleration is produced when force acts upon a mass. As force increases, acceleration increases linearly. (Force=mass *acceleration) Some examples to explain include it's harder to lift a book than a feather, if you push harder on a cart it will speed up faster, etc.

Knowledge needed beforehand:

-basic kinematic equations
-knowledge of acceleration due to gravity (9.8 m/s)
-basic knowledge of Newton's second law

Materials(per pair):

-1 Cart
-1 length of sting
-1 hanging mass
-4 50g weights
-1 cart track (if not available, tabletop may be used; however make sure students have cart going in straight line)
-stopwatch
-Student worksheet (provided)
**Note- this is intended to be done in pairs. It is up to the teacher's discretion how partners are chosen*

Career Connection:

Mechanical Engineer

-apply the principles of engineering and physics
-work on analysis, design and manufacturing
-produce and use machines and tools
-help processes become more efficient

Civil Engineer

-apply the principles of engineering and physics
- work on design and manufacturing of infrastructure
- produce bridges, roads, etc.

Setting Up the Lab:

-Have an area at least a meter high, place tracks upon it.
-Put the rest of the materials around the room where students can easily access

Procedure:

1. Gather all materials
2. Tie one end of the string to hanging mass, other end to cart
3. Place all 4 weights on top of the cart
4. Place cart one meter away from edge of table (must be at least one meter high)
5. Have one partner (partner A) release the hanging mass over the edge of the table as the other partner (B) starts the stopwatch.
6. When the cart reaches the end of the table, partner B will stop the timer. (Important: do **not** let the cart drop; make sure partner A catches it.
7. Record the time it took for the cart to move 1m.
8. Repeat steps 3-6 until three trials have occurred
9. Take one weight from the top of the cart and put it on the hanging mass. Repeat steps 3-7.
10. Repeat 3-8 until there are three trials for all four weights on the hanging mass.

Questions to Engage the Students/Analysis:

1) How close were your predicted values for force to your measured values?
2) What are some things that could explain the difference between expected and actual force?
3) Why is it important that we keep the mass of the system constant?
4) Is this experiment valid? Why or why not?

Note: If the students are unable to complete the student worksheet in the time allotted it may be taken home for homework

NEWTON'S SECOND LAW

Materials(per pair):
-1 Cart
-1 length of sting
-1 50g mass hanger
-4 50g weights
-1 cart track (if available)
-stopwatch

Procedure:

1. Tie one end of the string to hanging mass, other end to cart
2. Place all 4 weights on top of the cart
3. Place cart one meter away from edge of table (must be at least one meter high)
4. Have one partner (partner A) release the hanging mass over the edge of the table as the other partner (B) starts the stopwatch.
5. When the cart reaches the end of the table, partner B will stop the timer. (Important: do **not** let the cart drop; make sure partner A catches it.
6. Record the time it took for the cart to move 1m in the below table.
7. Repeat steps 3-6 until three trials have occurred
8. Take one weight from the top of the cart and put it on the hanging mass. Repeat steps 3-7.
9. Repeat 3-8 until there are three trials for all four weights on the hanging mass.

Weight on hanging mass	Trial 1 time	Trial 2 time	Trial 3 time	Average time
50g(initial weight of hanger)				
100g				
150g				
200g				
250g				

POST EXPERIMENT ANALYSIS:

1) How would you figure out the acceleration of the system if we know the time it took to travel one meter? (hint: use kinematic equations) Use this method to fill out the “measured acceleration” column in the table below.
2) Using Newton’s law and the measured acceleration, calculate the force that was acting upon the cart at each stage. Fill in the “measured force” column in the table.
3) Using Newton’s law and the known weight on the hanging mass, calculate the expected force on the cart for each trial, and record on the below table.

Weight on hanging mass	Measured Acceleration	Measured Force	Expected Force
50g(initial weight of hanger)			
100g			
150g			
200g			
250g			

THOUGHT QUESTIONS

1) How close were your predicted values for force to your measured values?

2) What are some things that could explain the difference between expected and actual force?

3) Why is it important that we keep the mass of the system constant?

4) Is this experiment valid? Why or why not?