SCIENCE FAX!
P.O. Box 219 • Batavia, IL 60510
(800) 452-1261 • Fax (866) 452-1436
www.flinnsci.com • E-mail: flinn@flinnsci.com

FLINN SCIENTIFIC, INC
"Your Safer Source for Science Supplies"
Catalog No. AP7408
Publication No. 7408

Newton's Laws

Activity Stations Laboratory Kit

Introduction

Whether you're lifting a heavy box, playing hockey, or flying to the moon, Newton's laws of motion explain a great deal of motion and physical interactions in the world. Explore each of the three laws as you rotate through a series of activity stations.

Concepts

- Newton's laws of motion
- Inertia
- Acceleration
- Force

Experiment Overview

The purpose of this "activity-stations" lab is to investigate and explore Newton's three laws of motion. Three distinct activity stations are set up around the lab. Each activity focuses on one of the laws and is a self-contained unit, complete with background information and discussion questions. The activities may be completed in any order.

Activity A. Newton's First Law: Air Pucks

Activity B. Newton's Second Law: Hanging Weight

Activity C. Newton's Third Law: Balloon Rockets

Safety Precautions

Be aware of your surroundings as you walk through the classroom. Please follow all normal laboratory safety guidelines.

Activity A. Newton's First Law: Air Pucks

Until the end of the Middle Ages, the common European understanding of objects and motion was based on the ideas of the Greek philosopher Aristotle (384–322 BC). Aristotle believed that all objects had their natural place of rest in the universe, and would progress toward those states. Rocks fell to Earth because their natural place was land; smoke rose to the sky because its natural place was the sky. Once an object reached its natural state, it would remain at rest. When slid along the ground, rocks would eventually stop moving because their natural state on Earth was rest.

Isaac Newton (1642–1727), basing his work on ideas already in place by Galileo Galilei (1564–1642) and René Descartes (1596–1650), developed his *First Law of Motion,* also called the law of inertia. Rather than believing an object's natural state was at rest, Newton proposed that an object in motion with a constant velocity tends to stay in motion maintaining that velocity unless acted upon by an external force. If an object is at rest, the object tends to stay at rest unless acted upon by an external force. *Inertia* may be defined as the tendency of an object to resist change in motion. Inertia is directly related to mass—the greater the mass of an object, the greater its inertia. The reason a rock comes to rest when slid across the ground is not that its natural state is rest, but rather another force is acting upon it—in this case, friction from the ground and the air. In the absence of all forces—e.g., a rock thrown in the vacuum of space—the rock would remain in constant motion.

Pre-Lab Questions *(Answer on a separate sheet of paper.)*

A1. A truck driver places a crate on his perfectly slick flatbed, but forgets to secure it to the truck. As he drives off, the crate slides and falls off the back. Explain why this occurred in terms of Newton's first law.

A2. Why are balloons used with the pucks for this activity? What advantage do the balloons provide?

Materials

Air pucks, 2

Balloons, 2

Clothespins (to temporarily seal the balloon), 2

Pennies or washers

Safety Precautions

Latex balloons may be an allergen. Wear safety glasses. Please follow all normal laboratory safety guidelines. Aggressive or excessive pushing of the pucks is not permitted.

Procedure

1. Inflate one balloon and twist (but do not tie) the neck shut to prevent air from escaping. Alternatively, use a clothespin to seal the neck of the balloon.
2. Without allowing the neck to untwist, carefully stretch the mouth of the balloon over the stem of the air puck assembly. *Note:* The balloon may tear if overstretched.
3. To levitate the puck, untwist the neck of the balloon.
4. Gently push the puck to accelerate it over any smooth surface. Record observations of the movement of the puck on the worksheet. *Note:* If using a surface such as a lab table, do not allow the puck to fall off.
5. Repeat steps 1–4 if necessary to make detailed observations.
6. Repeat steps 1–3.
7. Allow the puck to hover motionless until the balloon deflates. Record observations on the worksheet.
8. Repeat steps 1–3 with two balloons and two air pucks.
9. Gently push one puck toward a levitating stationary puck so the two pucks collide.
10. Record observations of the collision on the worksheet. Describe the observations in terms of Newton's first law of motion.
11. Increase the mass of the stationary puck using pennies or washers, and repeat steps 8–10.

Name: ______________________________

Newton's First Law Worksheet

Data Table and Observations

	Newton's First Law of Motion
Velocity of one puck (step 4)	
Non-accelerated puck (step 7)	
One puck colliding with a stationary puck (step 9)	
Stationary weighted puck collision (step 11)	

Post-Lab Questions

A1. In your own words, define the following terms.

a. Force

b. Inertia

c. Acceleration.

A2. How can you tell whether or not all the forces acting on the non-accelerated puck in step 7 are balanced?

A3. Imagine an air puck with a limitless air supply—i.e., a level air table of infinite length.

a. Once the puck was pushed, would it continue to travel forever?

b. Why or why not?

A4. List three more examples of Newton's first law in action in everyday life.

Activity B. Newton's Second Law: Hanging Weight

Newton's Second Law of Motion states that force applied by an object is equal to the mass of the object multiplied by the object's acceleration (see Equation 1). For a given force, the mass of an object is inversely proportional to its acceleration, while for an object of specific mass, the force needed to accelerate the object is directly proportional to its acceleration. In other words, if the same force were applied to two objects of different masses, the object with less mass would experience a greater acceleration than the more massive object.

$$F = ma \qquad \textit{Equation 1}$$

Multiple forces acting in complex systems can be summed to find the resulting acceleration. Acceleration along a given axis, however, can only be the result of all the forces in the same axis—forces in the y-direction will not affect the acceleration in the x-direction, and vice-versa. Imagine a game of tug-of-war, with two teams pulling on a rope with great force. The whole system will often experience very little acceleration because the two forces are acting in opposition along the same axis, and thus cancel each other out.

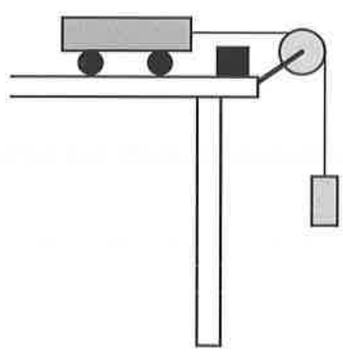
In this lab, the acceleration of a hanging weight system will be measured by recording the time it takes the weight to traverse a measured distance. The acceleration can be calculated using Equation 2.

$$a = 2d/t^2 \qquad \textit{Equation 2}$$

By modifying the weight of the hanging mass and analyzing the forces on the system, you will be able verify the relationship between force, mass, and acceleration.

Pre-Lab Questions *(Answer on a separate sheet of paper.)*

B1. Sketch and label the following free body diagram, filling in all force vector arrows.



B2. Only the mass of the hanging weight will be varied during this activity. Does the mass of the cart make a difference? Why or why not?

Materials

Assembled cart with hook	Plastic bag
Balance, 0.1-g precision	Stopwatch
Mass, 5-g	String, 130 cm
Mass, 10-g	Table pulley
Meter stick or ruler	

Safety Precautions

Projectiles may be inadvertently launched during this activity. Wear safety glasses. Please follow all normal laboratory safety guidelines.

Procedure

1. Mass the cart and record this value on the Newton's Second Law worksheet.
2. Measure the distance between the two tape marks on the table surface (placed by the instructor), and record the distance in meters on the worksheet.
3. Obtain the 130-cm length of string, with loop knots on both ends.
4. Obtain the plastic bag and 5-g mass. Place the mass in the bag and weigh the combination. Record this value on the worksheet.
5. Attach the bag to one end of the string using a looping knot (see Figure 1).

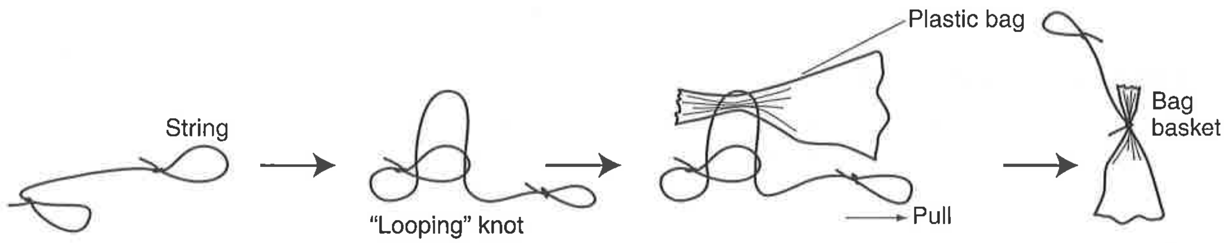


Figure 1.

6. Attach the other end of the string to the hook on the cart.
7. Set the cart at the beginning tape mark, and line the string up over the top of the pulley (see Figure 1). *Note:* Have one partner hold the cart in place until both partners are ready to take data.
8. When ready, have one partner release the car while the other partner uses a stopwatch to measure the time it takes to reach the end tape mark. *Note:* Ensure that someone is ready to catch the cart before it is pulled off the table.
9. Record the time in seconds on the worksheet.
10. Repeat steps 4–9 once more and average the results.
11. Increase the hanging mass by increments of 5 g, and repeat steps 4–10 twice for each new mass combination. Record all data in the data table. Note: Replace the 5-g mass with a 10-g mass for the second set of trials and then use the 5-g and 10-g masses together for a total of 15 g for the third set.

Name: ______________________________

Newton's Second Law Worksheet

Data Table

Distance _________ m   Mass of cart _________ g

Hanging Mass (g)	Trial 1 (s)	Trial 2 (s)	Average Time (s)	Acceleration (m/s²)

Post-Lab Analysis and Questions

B1. Using Equation 2 and the average time recorded for each hanging mass, calculate the acceleration of the cart for each hanging mass used and record in the data table.

B2. Plot a graph of the hanging mass vs. acceleration.

B3. A heavy box and a light box are accelerated to the same speed and then released. Ignoring friction, which mass will require more force to bring it to a stop?

B4. *(Advanced)* Using the free body diagram from the *Pre-Lab Question,* solve for the acceleration of the cart. Assume the pulley is weightless, and the system is without friction. Prove that the acceleration of the system is given by Equation 3.

$$a = m_{hanging}\, g / (m_{hanging} + m_{cart}) \qquad \textit{Equation 3}$$

Hint: Start by totaling the forces on the hanging weight, then totaling the forces on the cart.

B5a. *(Advanced)* Based on Equation 3, what constant must be compared to the acceleration to show a directly proportional relationship? Calculate the appropriate relationship, and plot this data.

B5b. Calculate the slope of the "best-fit" line. Select two points—(x_1, y_1) and (x_2, y_2)—that are closest to the actual line. The slope (m) is calculated using Equation 4. *Show all of your work!* What are the units of the slope? What is represented by the slope ?

$$m = \frac{(y_2 - y_1)}{(x_2 - x_1)} \qquad \textit{Equation 4}$$

B6. *(Advanced)* A heavy box and a light box are accelerated over the same distance using the same force. Ignoring friction, which mass will require more force to bring it to a stop?

Activity C. Newton's Third Law: Balloon Rockets

Newton's Third Law of Motion states that for every action force there is an equal and opposite reaction force. Rockets clearly show Newton's third law in action. When a rocket burns fuel, hot gases are forced out the bottom of the rocket at high speed. The fast-moving gas particles are pushed by the rocket chamber in one direction and the gas particles, in turn, push on the rocket in the opposite direction. A common misconception about rocket thrust is that when the fast-moving gas particles exit a rocket engine, the gas particles push against the air outside the rocket and this causes the rocket to shoot upward. However, if this were the case, then rockets would never work in outer space because there are no air molecules in space for the fast-moving gases to push against. Instead, the fast-moving particles are forced out the rocket engine by the body of the engine.

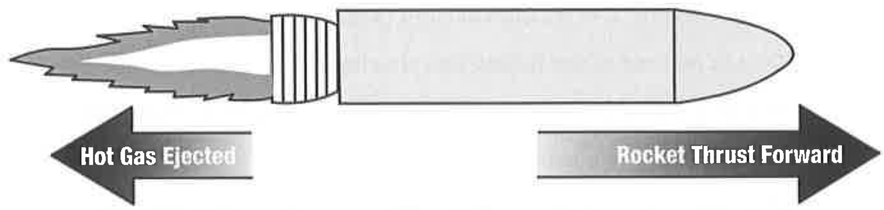


Figure 2.

When the fuel burns, a great amount of heat is created and the pressure inside the rocket combustion chamber increases. At the same time, the walls of the combustion chamber push back on the fast-moving gas particles. Rockets are composed of strong, solid materials with a small opening at the bottom. This opening is the only region on the engine where the pressure can be released. Since gas particles move from high to low pressure, the gas shoots out the bottom of the rocket. The rocket accelerates in the opposite direction of the ejected gases (see Figure 2).

An enormous amount of fast-moving gas particles need to be generated in order to lift a rocket into orbit. A small thrust channel increases the speed of the hot gases as they exit from the larger combustion chamber. Gases always accelerate toward lower pressure, so the high-pressure gas moves faster and faster as it rushes out of the nozzle. The constricted flow path increases the speed of the gas particles. This increase in particle speed in a chamber as the diameter decreases is an example of *Bernoulli's principle* (see Figure 3). The small-diameter chamber increases the speed of the exiting particles and therefore increases the net force that blasts off the rocket.

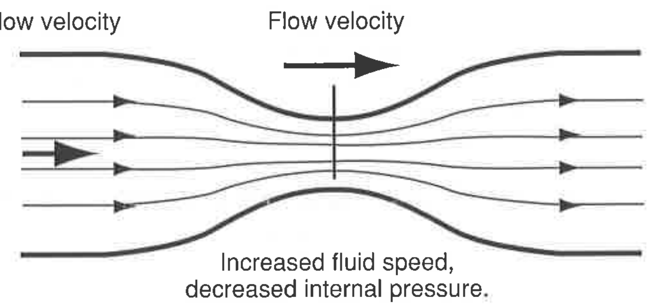


Figure 3.

Pre-Lab Questions *(Answer on a separate sheet of paper.)*

C1. Define Newton's third law of motion in terms of how a rocket "works."

C2. What are some variables or conditions that may affect the distance a balloon rocket will travel? Suggest some possible modifications in the rocket or launch design that may improve the rocket performance. (*One hint:* The fishing line must be as taut as possible, without breaking, for the best performance.)

C3. List two other examples of Newton's third law in action, and describe the forces at work in each case.

Materials

Balloons, thin and long, 2–3	Scissors
Clothespin (to temporarily seal the balloon)	Straw
Fishing line, classroom-length (for rocket guidance)	Support stands, 2 (optional)
Ruler	Tape, masking

Safety Precautions

Latex balloons may be an allergen. Use caution when launching the balloons. Be sure no one is in the path of the balloon rocket on the string before launching the balloon. The fishing line may be difficult to see. Be aware of your surroundings as you walk through the classroom. Do not over-inflate the balloons and cause them to pop. Wear safety glasses. Wash hands thoroughly with soap and water before leaving the laboratory. Follow all normal laboratory safety guidelines.

Procedure

1. Obtain a straw. Use scissors to cut it to three inches long.
2. Detach one end of the fishing line attached to the wall, and slide the straw piece onto the string.
3. Reattach the string, and slide the straw piece toward the fixed end of the fishing line.
4. Obtain a long, thin balloon. Carefully blow up the balloon to stretch it out, and then allow it to deflate.
5. Place two 5-cm pieces of masking tape on the straw piece. Place the midpoint of the tape on the straw so that the tape ends extend equally from each side of the straw (see Figure 4).
6. Inflate the balloon to about ¾-full. Pinch the end of the balloon closed with fingers and twist it several times to seal the balloon. Use a clothespin to clamp the opening closed.

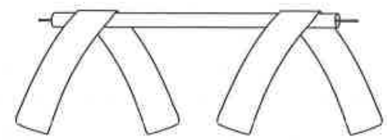


Figure 4.

7. Tape the inflated balloon to the straw piece, making sure the balloon is balanced, the straw piece is lined up along the string and is not crooked, and the balloon is aimed down the string towards to opposite wall. Continue to pinch the opening closed with the clothespin so no air can escape.
8. Hold the balloon near the wall and line up the balloon to "shoot" straight down the fishing line.
9. When the balloon is in position, release the balloon opening. Do not give the balloon any extra push.
10. Launch results: How far did the balloon travel? Did it make it all the way to the opposite wall? If not, what modifications need to be made to achieve the goal of rocketing to the opposite wall? In a data table, record the results of the launch, the distance the rocket traveled, and any sources of problems and corrective action that is required.
11. If the rocket did not travel all the way across the room, make necessary modifications and repeat steps 3–10. It is best to remove the original balloon and tape from the straw piece, and then use new tape.
12. Repeat step 11 until the balloon rocket reaches its goal of traveling across the classroom on the fishing line, or as time permits.

Name: ______________________________

Newton's Third Law Worksheet

Observations and Results

Launch No.	Results of Launch	Possible Solutions If Problems Were Encountered
1		
2		
3		
4		
5		

Post-Lab Questions

C1. Why does the balloon move when it is blown up and the pressure inside the balloon is released?

C2. Why is the air pushed out of the balloon?

C3. List some suggestions that might improve the performance of the balloon rocket.

Open the app "Autodesk Digital STEAM Applied Mechanics" and go through each of the 5 topics listed on the left selecting "Learn More" and take notes on the provided topic. The play each game 3 times and discuss how the game demonstrates the information from "Learn More"

Energy & Work: Best Score ________
Notes and Discussion:

Forces: Best Score ________
Notes and Discussion:

Loading: Best Score ________
Notes and Discussion:

Power: Best Score ________
Notes and Discussion:

Mechanism: Best Score ______
Notes and Discussion: