Wizards of Wright

WOW! on Wheels

Extension Activities for Newton's Laws

These activities are planned as a *WOW! on Wheels* extension after the *WOW! in the Classroom* Newton's Laws demos have been presented by a Wizard. If that isn't possible, the teacher has the option of presenting the *WOW! in the Classroom* lesson without the Wizard, then flowing into these extension activities, or just using these extension activities on its own.

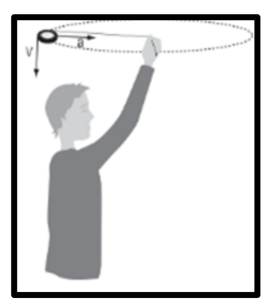
Please feel free to use any or all of the activities. They can be used in any order that fits your schedule. Materials are not included, but are inexpensive and not difficult to find.

Newton's First: Activity 1
Newton's First Law and the Swift Satellite

The Swift Satellite - Swift is a space-based multi-wavelength observatory dedicated to the study of gamma-ray bursts. It was launched by NASA in 2004 and its mission history involves many great findings and detections, including the most powerful observed gamma-ray burst just last year (2019).

Swift orbits the Earth about 600 km (350 miles) above us, and travels at a speed of about 7,600 meters per second (17,000 miles per hour). According to Newton's First Law, if Swift were to reach deep space, far away from the gravitational pull of any planets or stars, it would travel in a straight line and at the same speed, forever. Without the influence of gravity, there would be nothing to cause Swift to change directions or speed. However, the Earth's gravitational pull will keep Swift from moving in a straight line, causing it instead to move in a circular orbit around the Earth.

Use the following demonstration to show Newton's First Law to your class.



Whirl a yo-yo around on the end of its string. Explain that the string's tension (created by the pull of your hand) is the force which allows the yo-yo to move in a constant circular path. If you let go of the string, the yo-yo will fly off in a straight line tangent to the point on the circle where it was let go. Again, this is consistent with Newton's First Law. (Note: For safety purposes, you might consider attaching a string to a Nerf ball, whiffle ball, or bagel.)

Newton's First: Activity 2
Inertia – A Body In Motion

Have your students try to drop a tennis ball on a target as they run past the target. Think it's easy?

Before they begin, have students try to guess what will happen. The true question is: When will they need to release the ball in order to hit the target?

> *As you conduct this experiment, think of the challenges Air Force pilots had before the invention of the guided missiles that are used today. Pilots in World War II had to understand mathematics in order to drop bombs on targets while causing as little harm as possible to surrounding buildings and people. These are the same concepts that you will see with this experiment.*

Materials
- one tennis ball
- clearly-marked target(s), i.e., notebook paper, a chalk mark, or tape

Procedure

1. Place a target about 10-15 meters (32-49 feet) away from a starting line. Mark the starting line with chalk or tape.

2. Hold the tennis ball and do not let your elbow leave your side as you run and drop the ball. Do not throw the ball. You should hold the ball from its sides so that you can release your grip as you let it drop.

Remember to drop the ball and not throw it, otherwise you will change the intent of the experiment.

3. Have three students stand alongside (but slightly back from) the running path to act as observers. One should stand before the target, one at the target, and one just after the target. Their objective is to determine exactly where the runner released the ball and where the ball strikes the ground.

4. Ask the runner to sprint toward the target as fast as she or he can and try to drop the ball so that it lands on the target.

5. Next, have the observers make a diagram in their science notebook of where the ball was released and where it landed. Repeat the experiment until the ball hits the target.

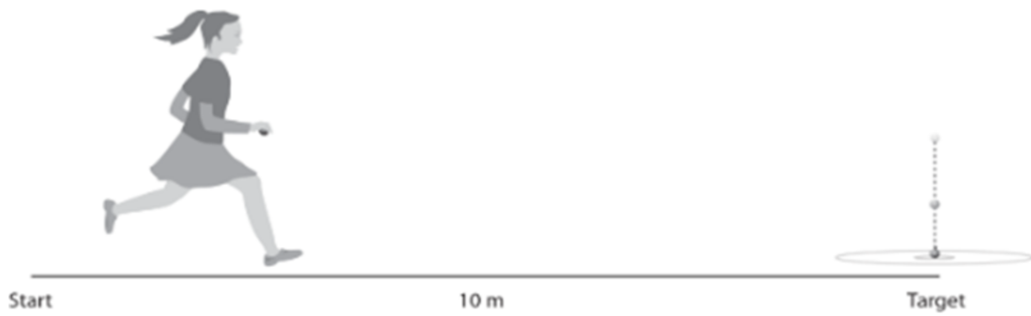
6. Use the information in Step 5 to predict what would happen if a student ran at a slower speed.

7. Repeat Steps 4-5, using a different runner sprinting at a slower speed.

8. Use the information in the previous trials to predict what would happen at a walking speed.

9. For the last trial, ask a student to walk toward the target. Repeat Steps 4-5.

10. Write a summary of your results in your science notebook. Form conclusions based on the speed of each runner, the location of each ball's release, and the exact point where each ball landed.



Notes to Teachers

When running, students will miss the target when the tennis ball is dropped directly over it. The ball needs to be dropped before the target is actually reached. As the ball drops, its horizontal motion remains unchanged because there is no force in that direction. Newton's First Law applies to the horizontal motion. You might have your students start this activity by rolling (or pushing) the ball on the floor, and observing its constant velocity once they let go of it. This is another application of Newton's First Law of Motion: A body in motion will continue in motion in a straight line unless acted upon by an outside force. In this case, the motion is that of the runner, and gravity is the outside force.

Possible Extensions

- If time permits, try the experiment again using a smaller target. Another idea would be to try dropping the ball into a bucket, decreasing the size of the bucket with each step.
- If you have access to a digital camera, enhance the activity by filming each runner (with a wide angle) and the path of each drop. Slow motion of the video will allow your class to analyze the trajectories.

Newton's First: Activity 3
And They're Off!

This experiment will teach you more about why Newton's First Law of Motion is also called the Law of Inertia. The method used in this experiment is very similar to one that Galileo conducted. (Galileo was discussed in the WOW! in the Classroom demo.)

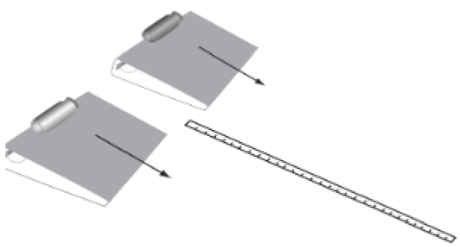
In this experiment you will discover how Newton's First Law works by conducting a race with two jars.

Materials
You will need the following items for this experiment:
- two identical jars with lids (either plastic or glass jars)
- flour or sand to fill one of the jars
- iron filings or small lead pellets to fill one of the jars
- two identical, empty three-ring binders (at least 2.5" in width)
- a measuring tape

Procedure
1. Fill one jar with flour or sand. Pack it tightly.

2. Fill the other jar with iron filings or small lead pellets. Again, fill it tightly.

3. Put lids on both of the jars. Lids should be on tight.



4. Place both three-ring binders next to each other on a wooden or tile floor. Place each jar on its side and release both from the top of the "ramps" at exactly the same time.

5. In the Table below, record how far each jar rolled. Do not measure the binder itself, just the distance from the end of the binder to where each jar actually stopped.

6. Repeat Steps 3-4 for each of the surfaces listed on the Table.

7. Fill in the Table with your results for each race.

Race	Surface	How far did the empty jar travel?	How far did the filled jar travel?
1	Wooden Floor		
2	Carpet		
3	Linoleum		
4	Tile Floor		
5	Other (____________)		

Examine your data to look for trends and record your observations in your science notebook. This will prepare you for the questions that follow. For example, determine if one jar always rolled farther than the other. Look to see which jar rolled farthest on a given surface. Try to figure out why you got the results you did for each jar on each surface.

Think About It

Write the answers to the following questions in your science notebook.

1. Did the results depend on whether the jar was filled with flour/sand versus iron/lead? If so, in what way?
2. Did the results depend on the kind of surface you used? If so, in what way?
3. What can you say about a body's tendency to maintain its status quo – its inertia?

Notes to Teachers

According to Newton's First Law, each jar will roll in a straight line at a constant speed unless a force acts on it. In this experiment, the jars roll in straight lines because there is no force making them turn to the left or to the right. However, because of friction, they do slow down. Friction is the resistance to motion between two surfaces that touch, i.e., resistance of a body in motion to the air, water, or another medium through which it travels – or to the surface *on* which it travels. Oil reduces friction. Bodies moving through a vacuum do not encounter friction. A sled moves more easily on smooth ice (which has less friction) than on rough ground.

Your students will make an important observation as they conduct the race on different surfaces. Smoother surfaces create less friction. It is the force of friction which eventually stops objects from continuing to roll forever in a straight line. Galileo was first to realize this.

If your class is ready to explore moments of inertia, have them race one of the filled jars against an empty jar. Perform the experiment on both a carpeted and a tile surface. Observe what happens in each case. When the race begins, the filled jar moves down the ramp faster than the empty jar. This happens because its weight is evenly distributed throughout its volume thanks to the material inside. The empty jar's weight consists only of the jar itself, so it doesn't roll quite as fast. Scientifically, the empty jar has a greater moment of inertia than the filled jar. The empty jar is essentially a hoop, and the moment of inertia for a hoop of radius R is equal to mR2. The filled jar of radius R is a solid cylinder (or a solid disk), which has a moment of inertia equal to 1/2 mR2. Objects with larger moments of inertia require larger torques to change their rotation rates. So the filled jar (with the lesser moment of inertia) is easier to accelerate and thus reaches the bottom of the incline first. On a tile surface, the filled jar will roll further than the empty jar. But if you allow the jars to roll onto a rough surface such as a carpet, the greater weight of the filled jar causes greater friction between the jar and floor. The filled jar will slow down much faster - allowing the lighter, empty jar to roll farther!

Newton's Second: Activity 1
Paper Clip Racer

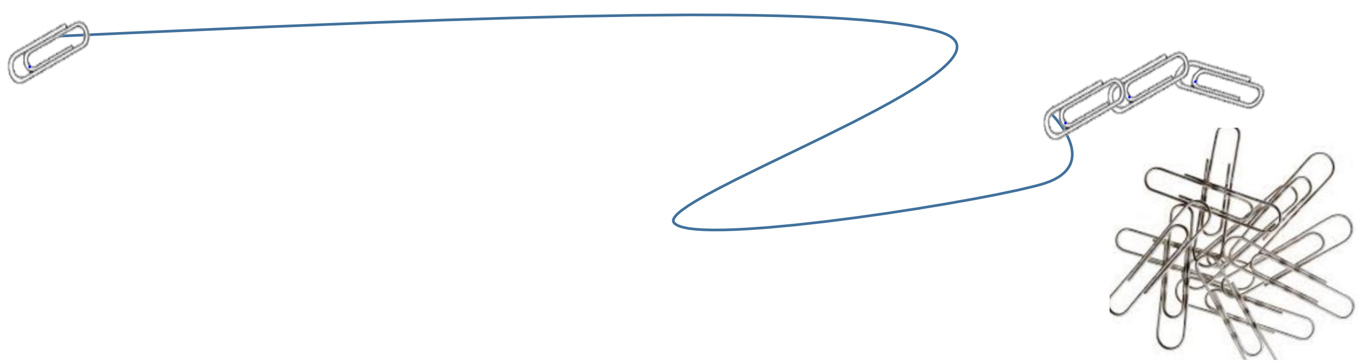
Materials
large paper clips
yarn/string

Students will drag large paper clips across a desk by a weight hanging off the end of the desk on a string. The additional weights will not be seen as mass (m), but rather, increased force (F).

TIP: Adding additional paper clips should be considered an increase in force and not an increase in mass.

1. Tie a paper clip to each end of a long string.
2. Hook two more paper clips to one end.
3. Place the single paper clip end in the center of the table.
4. Hang the three paper clip end off the side of the table.
5. Release the paper clips and record your observations.
6. Add one more paper clip to the hanging end, repeat the experiment, and record your observations.
7. Place as many paper clips of your choosing on one end, repeat the experiment, and record your observations.

What does it show us? Acceleration (A) is based upon force (F) applied to the object and the mass (M) of the object. A change in force or mass will change the object's acceleration. This law can be summed by the formula F=ma (Force = mass X acceleration).

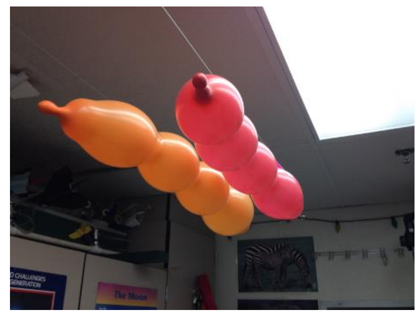


Newton's Second: Activity 2
Balloon Racer

(This is very similar to an activity in our WOW! in the Classroom demo. However, if you want to go bigger and better in your classroom…try this! I found this online at betterlesson.com)

Materials

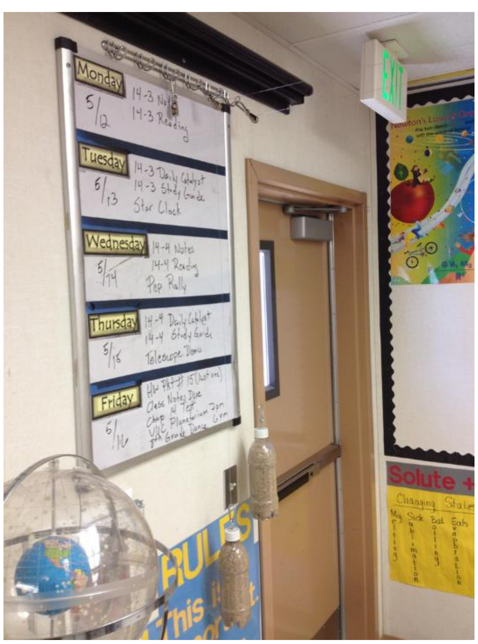
1. 100 lb tension fishing line
2. Cheap metal coat hooks (2) or eyebolts(4)
3. Rope clips (4)
4. Small pulleys (2)
5. Silicon grease
6. Balloon rockets (similar to balloon animals, but wider)
7. Balloon pump (optional)
8. Binder clips (to hold an inflated balloon closed)
9. Pennies (I've also used paper clips - any small weighted object will do)
10. Clear tape



Each group receives four balloons, two for each race.

Rig Set-Up

Run 2 lines of 100 lb tension fishing line across the classroom. Cut two straws in half (lengthwise) and thread both halves on each line.



Using a rope clip, attach one end of the line to the wall. At the opposite wall, attach a small pulley, run the fishing line through the pulley and attach a weight (sand filled water bottles).

“I purchased some cheap metal coat hooks and bolted them to the walls of my classroom. I kept them high enough so students can walk underneath. Another option would be to run the fishing line across the classroom and attach them to the end of desks. The weight will keep the fishing line taunt as the kids work with the lines. Use a rag or paper towel to grease the lines with silicon grease (helps reduce friction). Mark a point on the fishing line approximately 3 meters from the start. I stick little flags in the ceiling to designate the three meters (serves as a starting line).”

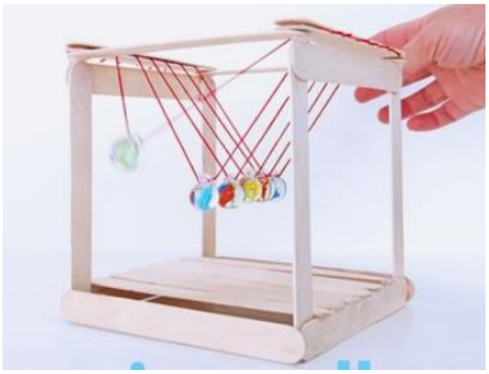
Newton's Second Law will be in effect for this lesson. Newton's Second Law states that acceleration (a) is based upon force (F) applied to the object and the mass (m) of the object. A change in force or mass will change the object's acceleration. This law can be summed by the formula F=ma (Force = mass X acceleration).

1. Inflate two balloons of unequal size (one small and one large).
2. Tape each balloon to the straws.
3. Release at the same time.
4. Record your observations

5. Inflate two balloons of equal size (same size).
6. Tape 5 large paper clips to one balloon.
7. Tape one small paper clip to the other balloon.
8. Release at the same time.
9. Record your observations

Newton's Third: Activity 1
Newton's Cradle

There are lots of sites online that will give you directions for your students to build their own Newton's Cradle. Here's just one.



Materials
Jumbo Craft Sticks
(6) Marbles
String
Scissors
Glue
Tape
Pencil
Hot Glue Gun/Glue

Instructions

1. Glue (4) craft sticks together at the corners to make a square. Repeat with (4) more crafts sticks. Let dry. These will be the sides of the frame.

2. Cut string into (6) equal pieces approximately 8" long

3. Hot glue a marble to the center of one of the pieces of string. Repeat to end up with (6) separate marbles, each glued to the center of a string.

4. Make (6) marks along two craft sticks every ½". Make sure the marks are centered on the sticks.

5. Tape one end of the strings with marbles attached along one of the craft sticks at each mark. Set aside.

6. Using hot glue, assemble the frame. Take the two sides and hot glue a craft stick perpendicular to each corner. The final frame will be a cube.

7. Glue the craft stick with the taped string/marbles to one side of the frame.

8. Glue the second marked craft stick to the opposite side of the frame.

9. Tape the loose end of each string with a marble attached to the marked craft stick. Pull on the strings gently to make sure the marbles align. The marbles must line up both horizontally and when viewed from the top.

Pull one of the end marbles up and let go! Watch what happens!

Newton's Third: Activity 2
Extension to Rocket Racer

If students participated in the WOW! in the Classroom demo, they constructed Rocket Racers with small groups, and tested them. As an extension, use those same rocket racers, or have them make modifications and hold Rocket Racer drag races.

> Lay out a 3 meter-long course. The fastest car is the one that crosses the finish line first. Calculate racer average speed by timing start to finish with a stopwatch.
>
> Have students try multiple balloons for additional thrust. How will students design cars that are balanced with the extra load?
>
> What other variables can be adjusted?
>
> What other devices can be created that demonstrate the action-reaction principle of Newton's Third Law of Motion?

This activity is also available as a full WOW! demo.

Newton's Third: Activity 3
Hero's Engine

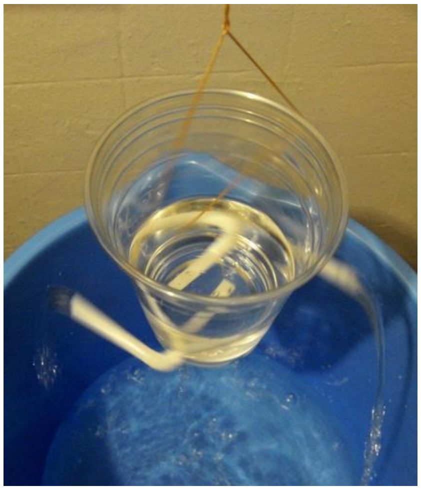
Imagine dropping a tennis ball to the ground. What happens in response to the action of the ball striking the ground? It bounces back up towards you. This is due to the reactionary force of the floor acting against the ball, which pushes it upwards into the air.

To explore this idea more fully, you can easily construct your very own device called an aeolipile (sometimes referred to as Hero's Engine or a Hero engine). Created by an engineer named Hero of Alexandria about 2000 years ago, this invention was able to show one way in which an action can lead to an equal and opposite reaction: an example of Newton's third law.

Materials
Plastic cup
2 plastic bendable straws
String
Craft knife
Water and sink
Modeling clay

Procedure

1. Poke two small holes near the top rim of the plastic cup on opposite sides from one another.
2. Thread string through the holes and tie a knot so that the cup can be suspended from the string.
3. Make two slightly larger holes near the bottom of the cup as seen in the picture below (make sure these holes are just large enough for the straws to fit through)
4. Cut each straw about 1.5 inches below its bendable portion.
5. Slide the straws into the holes. Make sure that they both point in a clockwise direction.
6. Use your modeling clay to seal the space between the cup and the straw so that no water leaks out when you fill the cup.
7. Hold the finished Hero Engine away from your body. Pour water into the cup and observe.



Results

Gravity draws the water downward and out through each straw. This causes the engine to spin in a clockwise direction.

Why?

The water being forced by gravity to leave the cup in a clockwise direction pushes back on the cup in a counterclockwise direction, causing the cup to turn. This is the same principle that enables rockets to work—gas that's forced out of the nozzle pushes back on the rocket, propelling it forward!

Activity: Testing Variables

This activity is similar to the activity Balloon Race in the WOW! in the Classroom Newton's 2nd demo, but there's a bit more.

Materials

Balloons of various shapes and sizes
Construction paper
String
Straws|
Tape
Scissors
Kitchen clips
Normal paperclips, crafting sticks or other items that can be used as weights on the balloons
Anchor points – could be chairs, tables or even people holding the string
Stop watch
Fabric tape measure or you can use string and measure the string
Kitchen Scale
Science notebook or other way of recording data

Directions

Since this activity is inquiry based, be prepared for lots of playing and exploring. The goal is to really explore and understand how variables impact Newton's third law.

First, set up the anchor points about 10 feet apart. When selecting your anchor points, choose ones that can be easily moved.

Thread your string through a straw, then secure the string to the two anchor points. Leave lots of slack so you can change the distance as required.

Attach your balloon to the straw using tape. For each challenge simply release the balloon to start it racing.

BALLOON PHYSICS CHALLENGES – NEWTON'S **SECOND** LAW OF MOTION

CHALLENGE #1

How does volume impact distance?

Change the distance between the anchor points until the balloon no longer reaches the end. What is the farthest the balloon will travel? Mark that point or record the distance.

Using a fabric tape measure or a string, measure the circumference of the inflated balloon. Now race it and record the distance it traveled. For the next race change the circumference making it smaller or larger. How does it affect the distance traveled? Record the results.

CHALLENGE #2

How does volume impact speed?

Set your distance to the minimum the balloon travels. Now vary the circumference and use a stop watch to measure how fast the balloon travels the distance. Does varying the circumference, and therefore volume and pressure in the balloon, affect the speed? Record the results.

CHALLENGE #3

How does mass impact distance traveled?

In this challenge we are exploring how mass affects Newton's Third Law. From earlier tests we know how far our balloons will travel. Keeping the circumference consistent, change the mass by adding paperclips, tape, paper, etc. to the balloon. Then race the balloon and measure the distance. How does it compare with greater mass? Record the results.

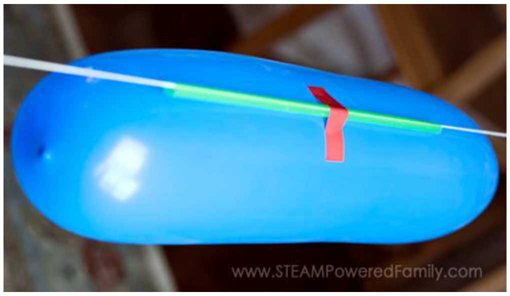
CHALLENGE #4

How does mass impact speed?

Repeat the experiment but measure the speed of the balloon. Does mass affect the speed the balloon travels? Record the results.

CHALLENGE #5

Does shape of the balloon impact speed or distance?



If you have different shaped balloons test how the shape of the balloon affects the results. Does a long skinny one work better than the traditional oval balloons? Try to keep the number of breaths used to blow up the balloons consistent to ensure the volume of air in the balloons does not change. Measure distance and speed to see how the results differ.

NEWTON'S **FIRST** LAW OF MOTION

In a way, we explored the First law in this exercise too. The balloons required a force to be exerted on them before they would move long the string. As long as that clamp was left in place, the balloon was stationary.

CHALLENGE #6

How can we apply force?

A fun way to explore this law is to challenge the students to find ways to apply force to start the balloon moving beyond the obvious one we have been using (releasing the pressure/air). Perhaps they can change the angle of the string so gravity applies its force. Or maybe they can blow on it. Then have them explore how they can apply force to change the speed and direction of the balloon.

activities and graphics credited to: https://swift.sonoma.edu/education/newton/newton_1/html/newton1.html; https://betterlesson.com/lesson/634370/newton-s-2nd-law-paper-clip-racers-newton-s-law-expo-7-of-9?from=breadcrumb_lesson; https://betterlesson.com/lesson/634369/newton-s-2nd-law-balloon-racers-newton-s-law-expo-6-of-9?from=breadcrumb_lesson; https://babbledabbledo.com/how-to-make-a-simple-newtons-cradle/; https://www.nasa.gov/pdf/153417main_Rockets_Rocket_Races.pdf; https://www.education.com/science-fair/article/newton-law-motion-action-reaction/#:~:text=Imagine%20dropping%20a%20tennis%20ball,it%20upwards%20into%20the%20air; https://www.steampoweredfamily.com/activities/physics-activities/