

Newton's First Law: Inertia and Unbalanced Forces

Duration:
1-2 class periods

Essential Questions:

- What are the properties of inertia?
- How do common experiences with unbalanced forces help us to understand Newton's First Law?

Objectives: Students will...

- see that an object at rest remains at rest unless an unbalanced force acts on it
- see that an object in motion will remain in motion unless acted upon by an unbalanced force
- see that an object in motion will change that motion if acted upon by an unbalanced force

Science Concept:

Newton's First Law of motion states that a body at rest will remain at rest unless acted upon by an unbalanced force. It also states that a body in motion will maintain that motion, in the same direction and with the same speed, unless acted upon by an unbalanced force.

About this Poster

The Swift Gamma-Ray Burst Explorer is a NASA mission which is observing the highest energy explosions in the Universe: gamma-ray bursts (GRBs). Launched in November, 2004, Swift is detecting and observing hundreds of these explosions, vastly increasing scientists' knowledge of these enigmatic events. Education and public outreach (E/PO) is one of the goals of the mission. The NASA E/PO Group at Sonoma State University develops classroom activities inspired by the science and technology of the Swift mission, which are aligned with the national standards. The front of the poster illustrates Newton's First Law. Descriptions of the drawings can be found on the next page. This poster and activity are part of a set of four educational wallsheets aimed at grades 6-9; they can be displayed as a set or separately in the classroom.

The activity provides a simple illustration of Newton's First Law. The activity is complete and ready to use in your classroom; the only extra materials you need are listed on p. 6. The activity is designed and laid out so that you can easily make copies of the student worksheet and the other handouts.

The NASA E/PO Group at Sonoma State University:

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The Swift Education and Public Outreach website is
<http://swift.sonoma.edu>

This poster and other Swift educational materials can be found at: <http://swift.sonoma.edu/education/>

National Science Education Standards and Mathematics Standards for the set of four Newton's Law wallsheets can be found at:
<http://swift.sonoma.edu/education/newton/standards.html>

Description of the Front of the Poster:

Figure skater: To begin moving, a figure skater must apply a force using her skates. Once in motion, she'll continue to glide along the ice in a straight line for a long time unless she applies another force.

Hands pulling on rope: When each end of a rope is pulled, the rope will move in the direction of whoever is pulling harder – whoever is applying more force. In this case, the magnitude or strength of A (on the right) is greater than that of B (on the left), so the rope accelerates to the right.

Snowboarder: A snowboarder experiences a force due to gravity which pulls her down. She will move in a straight line unless she applies a force to the board, changing direction.

Train: A train is a very massive object, and therefore has a lot of inertia. Once in motion, it is very difficult to stop, requiring a very large force to slow it.

Jogger: A jogger experiences many forces while running: gravity, the push of her feet, the friction of her shoes on the ground, and air resistance. Her legs, together with the friction of her shoes, overcomes her inertia to propel her forward.

Car hitting the wall: A car rolling down a hill is being moved by the force of gravity. When the car hits the wall, the greater inertia of the wall stops it. But anything not attached to the car will still move forward, so the man running after the car will lose his coffee, his lunch, and his briefcase.

Background Information for Teachers:



Sir Isaac Newton (1642-1727) established the scientific laws that govern 99% or more of our everyday experiences – from how the Moon orbits the Earth and the planets orbit the Sun to how a hockey puck slides over ice, a person rides a bicycle, or a rocket launches a satellite into space. Newton's Laws are considered by many to be the most important laws of all physical science. They are also a great way to introduce students to the concepts, applications, vocabulary, and methods of science.

Sir Isaac Newton Newton's Laws are related to the concept of motion: Why does an object move the way it does? How does the object accelerate or decelerate? To understand these things, we need to understand the relationship between force and motion.

Forces can cause motion. But what exactly is a force? We can think of a force as a push or a pull. A force has a direction as well as a magnitude; such quantities are called vectors. In a diagram, a force can be represented by an arrow indicating its two qualities: The direction of the arrow shows the direction of the force (push or pull). The length of the arrow is proportional to the magnitude (or strength) of the force.

Historical Perspective

Built upon foundations laid primarily by Aristotle and Galileo, Sir Isaac Newton's First Law of Motion explains the connection between force and motion.

Aristotle theorized that a force is required to keep an object in motion. He believed that the greater the force was on a body, the greater the speed of that body. His theory was widely accepted, since it basically agreed with life's everyday experiences. Aristotle's theory remained largely undisputed for almost 2000 years, when Galileo came to a different conclusion.

Galileo understood that our everyday experiences had friction in them. He imagined a world without friction, and came to the conclusion that it was just as natural for a body to be in horizontal motion at a constant speed

as it was for it to be at rest. It was only in our imperfect, friction-filled world that we needed to continue to push an object to get it to move.

Isaac Newton built upon Galileo's ideas. He agreed that an object would continue to move even if no force acted on it. He also understood that more than one force can act on an object at the same time. The combination of these forces is important. For example, imagine two teams playing tug-of-war; each pulls on a rope in opposite directions. If one team is stronger, then their force is greater and they pull the other team toward them. In this situation, when two forces are not equal, we say they are unbalanced. However, if the two teams have equal strength, the force they apply to the rope is equal – balanced– and neither team moves.

In his work known as the "*Principia*," published in 1687, Newton wrote about his ideas on forces and motion (and readily acknowledged his debt to Galileo). He created three laws, today called Newton's Laws of Motion. His First Law of Motion stated: *A body continues at rest or in motion in a straight line with a constant speed until acted on by an unbalanced force.* The tendency of a body to resist change is called inertia. Newton's First Law is often referred to as the Law of Inertia.

Newton's Laws apply to macroscopic systems – things you can feel and see. There are environments for which Newton's Laws (or Classical Mechanics) only provide an approximate answer, and more general physical laws must be used. For example, black holes and objects moving at nearly the speed of light are more accurately explained by General Relativity, while subatomic particles are explained by Quantum Mechanics.

Pre-Activity Reading:

Newton's First Law and the Swift Satellite

On November 20, 2004, the Swift satellite was sealed in the nosecone of a Delta 2 rocket, ready for launch from Cape Canaveral, Florida. Immediately prior to launch, Swift was "an object at rest" and so was the rocket. There was no unbalanced force on Swift or the rocket, so both of them remained at rest. When the solid rocket boosters ignited at 12:16:00 p.m. EST, an unbalanced force was applied to the rocket. For the first few seconds of the launch, the rocket exhaust went straight down, pushing the rocket straight up, in a line. You can see the Swift launch in a video at:

http://www.nasa.gov/mission_pages/swift/multimedia/index.html

Pre-Activity Discussion:

Ask the following questions to introduce Newton's First Law to your class:

- When were the Swift satellite and rocket at rest?
- When were the Swift satellite and rocket in motion in a straight line?
- What happens when you are riding in a car with a seat belt on, and the car starts or stops suddenly?
- What would happen if you were not wearing your seat belt?
- What is providing the unbalanced force for the Swift launch? For the car?
- Can you think of some more examples when your body is in motion and it is acted on by an unbalanced force?

Answers to Non-Swift Pre-Activity Discussion Questions:

When you are riding in a car with a seat belt on, and the car starts suddenly, you feel the back of the seat push against your back as the car begins to move. This is because your inertia tries to hold you – in the original position – but the car is starting to move forward. Since you are held in the seat by the seatbelt, when the car stops suddenly, you move forward, and feel the seatbelt push against you, holding you in place. If you were not wearing your seat belt, you would continue your forward motion as the car stops, and would smash into the windshield or dashboard of the car. The car is providing the unbalanced force as it accelerates or decelerates.

Other examples include: flying in an airplane as it takes off and lands (wearing a seatbelt!), riding in a train or bus (where seatbelts are not as common because accelerations and decelerations are usually more gradual), or skateboarding (where if the wheels of the board hit a rock, the board can stop, but you keep going).

Procedure for In-class activity: Inertia and Unbalanced Forces:

The basic procedure for most students is described in the student's handout.

In addition, you may wish to write vocabulary on the board (such as *inertia*, *force*, *acceleration*) and prompt the students to explain their observations using the vocabulary.

For advanced students, you can add the post and/or extension activities to add additional opportunities for reflection.

The answers below pertain to the student questions.

Answers to In-Class Activity Questions:

Question 2: When the car and figure are sitting on the desk, there is no unbalanced force acting on them, so they do not move (an object at rest tends to stay at rest). There are forces acting on them: gravity, for one, is pulling them down toward the center of the Earth. But this force is exactly balanced by the surface of the desk, which is pushing them up. This may be a difficult concept for the students to understand. One way to explain it to them is to ask them what would happen if the desk were to be replaced by a very thin sheet of rubber. The car would sink a bit, stretching the rubber sheet, tightening it. The force of gravity is stronger than the force of the rubber sheet trying to contract and support the car. When the sheet stretches enough, the tension in it is strong enough to balance gravity, and once again motion stops.

Question 4: When you put the car on the ramp, gravity will act on it, pulling it down. The car and figure are both pulled by gravity, and both move down the ramp together. When the car reaches the floor, once again gravity is balanced by the floor itself, so the forces on the car are balanced, yet it keeps moving (an object in motion tends to stay in motion). It may eventually hit a chair or a wall, but until it does it should move relatively smoothly. It will slow down due to friction as well.

Question 6: When the car hits the book, the car stops and the book does not move (or moves very little). The book has more inertia than the car, and is also being held in place by friction. The book does not move, while the motion of the car is stopped. Another way to think of it is that the book applied a large force to the car, stopping it (an object in motion tends to remain in motion unless acted on by an unbalanced force). However, this force is applied only to the car, and not to the figure. Since an object in motion tends to remain in motion, the figure will fly off the car. Ouch!

Do not try this at home!

Question 8: This is why we use seat belts, to counteract that tendency to remain in motion. The seat belt applies a force to a person that keeps them from flying out of the car. Even better are air bags, which apply a smaller force to a person over a larger area than a seat belt, so the person is protected in more areas than just the lap and shoulder.



Question 9: When the car hits the wadded piece of paper, the paper is knocked away. This is because the car has more inertia than the paper, so the paper is easier to move. The force from the car is not enough to move the book, but it is easily enough to move the paper.

Post-Activity Demonstration (*Advanced students*):

A chunk of dry ice allowed to sit on the floor for a few minutes will get a flat surface underneath it as the warm floor turns the dry ice into a gas. The chunk of dry ice will float on that gas, like an air hockey puck (see Extension Activity below). A small flick of the finger will cause the chunk to move in a straight line across the floor at a constant speed. It is actually quite odd to see this, since we are used to friction (a force!) slowing things down.

Warning: Dry ice is extremely cold, and can cause severe frostbite. If you perform this demo, follow safety procedures for dry ice (for example, http://www.abc.net.au/science/surfingscientist/pdf/lesson_plan08.pdf and http://www.school-for-champions.com/science/dry_ice.htm). Wear thick gloves, and don't allow the students to touch the dry ice directly.

Post-Activity (optional):

Watch the demonstration of a chunk of “dry ice” moving across the floor. How does this illustrate Newton’s First Law?

Extension Activity (*Advanced students*):

When Swift launched on board the rocket, it was bolted to the rocket. A little over an hour after launch, at 1:36 pm, the bolts holding it in place were cut. Then, 30 seconds later, the rocket fired “reverse thrusters” which backed it away from the Swift spacecraft. You can see the video of this, from a camera on-board the rocket, at:

http://www.nasa.gov/mission_pages/swift/timeline/index.html

How does the motion of the Swift spacecraft in this video illustrate Newton’s First Law?

For a more “down-to-Earth” example, go play air hockey. An air-hockey table is a good example of an almost frictionless surface. Ask the students the following: Why does the puck stop when the air stops? What makes it frictionless? Would the puck go on forever if it could? (If the walls of the table didn’t stop it.) How is this an example of Newton’s First Law?

Post and Extension Activity Answers:

When Swift was bolted inside the rocket’s nosecone, it continued to remain in motion in the same direction and with the same speed as the rocket. When the bolts were retracted, no force was applied to either the rocket or Swift, so both continued to travel together in the same direction and at the same speed. When the rocket fired its reverse thrusters, an unbalanced force was applied to the rocket, but not to Swift. The rocket then moved away from Swift, increasing their separation, letting Swift orbit freely around the Earth.

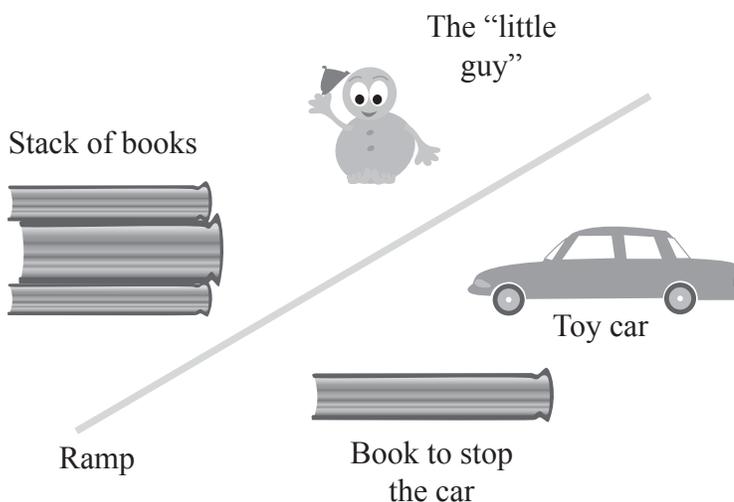
The puck stops when the air stops because the friction on the puck becomes very large. The air cushion provides an almost frictionless surface, on which the puck will continue to move until it hits an obstruction like the edge of the table. Of course, the air cushion is not perfectly frictionless, and if the table were very large, eventually the puck would stop due to the small amount of friction that is present. This illustrates Newton’s First Law in showing that an object in motion will continue that motion in a straight line when there are no unbalanced forces acting on it. A chunk of dry ice floats on a cushion of gas in a similar manner.

Assessment:

Points	Sudden Impact
4	A) Student is able to correctly predict the motion of objects moving with and B) without friction, along a straight line. C) Student knows that inertia is the tendency of an object to resist a change in its motion. D) Student can correctly identify unbalanced forces and can predict the results of such forces.
3	A) Student is able to predict the motion of objects moving with friction along a straight line. B) Student can identify friction as an unbalanced force. C) Student knows that inertia is the tendency of an object to resist a change in its motion.
2	Student achieves any two of the three objectives above.
1	Student achieves one of the three objectives above.
0	Student achieves none of the three objectives above.

Materials:

- A toy car, such as a matchbox car or anything like it that can roll
- A toy figure of a person small enough to sit on the car (a clay figure will work as well)
- A piece of cardboard or wood about a meter long to use as a ramp
- Something on which to prop the ramp, such as a stack of books or the seat of a chair
- An object big and heavy enough to stop the car from rolling, such as a book or a meter stick taped to the floor



Student Handout: *Inertia and Unbalanced Forces*

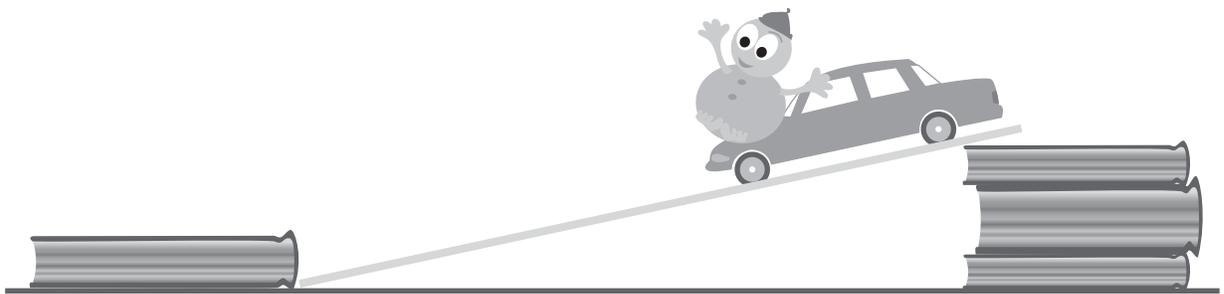
This activity will help you learn about Newton's First Law of Motion. In this experiment you will discover the properties of *inertia* and *motion*, and see how they have very important real-life applications.

Procedure: Sudden Impact

Use a separate sheet of paper to take notes and follow the instructions:

1. Place the car on a flat, steady surface like a desk top. Place the figure of a person on the car. **Important:** don't press it down so it sticks; just let it rest there.
2. Observe the car. Are there any forces acting on it? What about the figure? Does Newton's First Law apply here? Write down your thoughts.
3. Place one end of the board on a stack of books or the edge of a seat to create a ramp. Make sure there is plenty of room at the base of the ramp for the car to roll.
4. Using Newton's First Law, predict what will happen when the car rolls down the ramp and record this on your worksheet.
5. Place the car and figure at the top of the ramp. Let go, allowing the car and figure to roll down. Observe what happens, and record it.
6. Now place a heavy object such as a book near the bottom of the ramp, so that the car will hit it. Again, using Newton's First Law, predict what will happen to the car, the figure, and the book when the car hits the book.
7. Repeat the experiment above, again making sure the figure is placed on the car, not stuck on it. Record your observations. What happened to the book, the car, and the figure? Were your predictions accurate?
8. How is this experiment applicable in real life? If you were a car designer, what kind of feature would you add to a car after performing this experiment?
9. Now replace the heavy book with a wadded up piece of paper, again making sure it is in the path of the car. Using Newton's First Law, predict what will happen when the car, the figure, and the paper wad impact. Record your prediction.
10. Repeat the experiment, recording your observations of the car, the figure, and the paper wad. Was this situation different than before? If so, what specifically was different, and why did this change the outcome of the experiment? If nothing changed, why not?

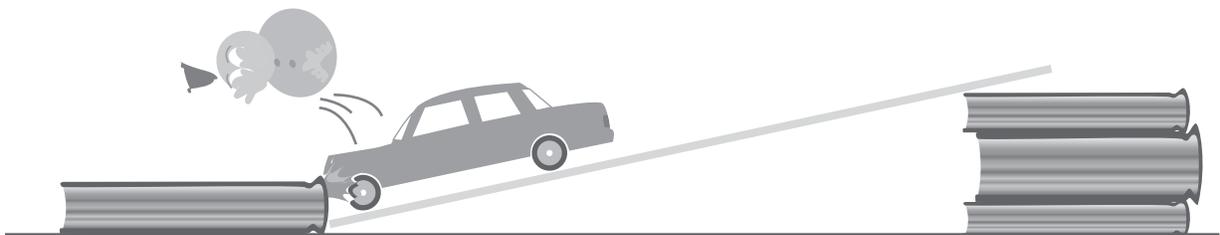
Example drawings that could represent the student's predictions and/or observations for question 7.



a. The small figure is not attached to the car as it rolls down the ramp.



b. The small figure and the car accelerate down the ramp.



c. At the bottom, the car is stopped by the stack of books, but the small figure continues to move.

Ouch!

References for all Four Posters:

Copies of these materials, along with additional information on Newton's Laws of Motion and Law of Gravitation, are available on the Swift Mission Education and Public Outreach Web site:

<http://swift.sonoma.edu/>

- NASA Web sites:
NASA's official Web site - <http://www.nasa.gov>
Swift Satellite - <http://swift.gsfc.nasa.gov>
- NASA Education Resources:
The Space Place - <http://spaceplace.nasa.gov>
Imagine the Universe! - <http://imagine.gsfc.nasa.gov>
- NASA's Central Operation of Resources for Educators (CORE):
<http://education.nasa.gov/edprograms/core/home/index.html>
Check out these videos:
"Liftoff to Learning: Newton in Space" (1992), \$15.00
"Flight Testing Newton's Laws" (1999), \$24.00
- NASA's Space Science Education Resource Directory:
<http://teachspacescience.org>
- Newton's Laws of Motion:
<http://www-istp.gsfc.nasa.gov/stargaze/Snewton.htm>
<http://www.grc.nasa.gov/WWW/K-12/airplane/newton.html>
- Newton's Law of Gravitation:
<http://csep10.phys.utk.edu/astr161/lect/history/newtongrav.html>
- Newton in the Classroom:
<http://www.physicsclassroom.com/Class/newtlaws/newtlto.html>
<http://www.glenbrook.k12.il.us/gbssci/phys/Class/newtlaws/u2l1a.html>
- The Nine Planets:
<http://seds.lpl.arizona.edu/nineplanets/nineplanets/nineplanets.html>
<http://seds.lpl.arizona.edu/nineplanets/nineplanets/data1.html>

<http://swift.sonoma.edu>

