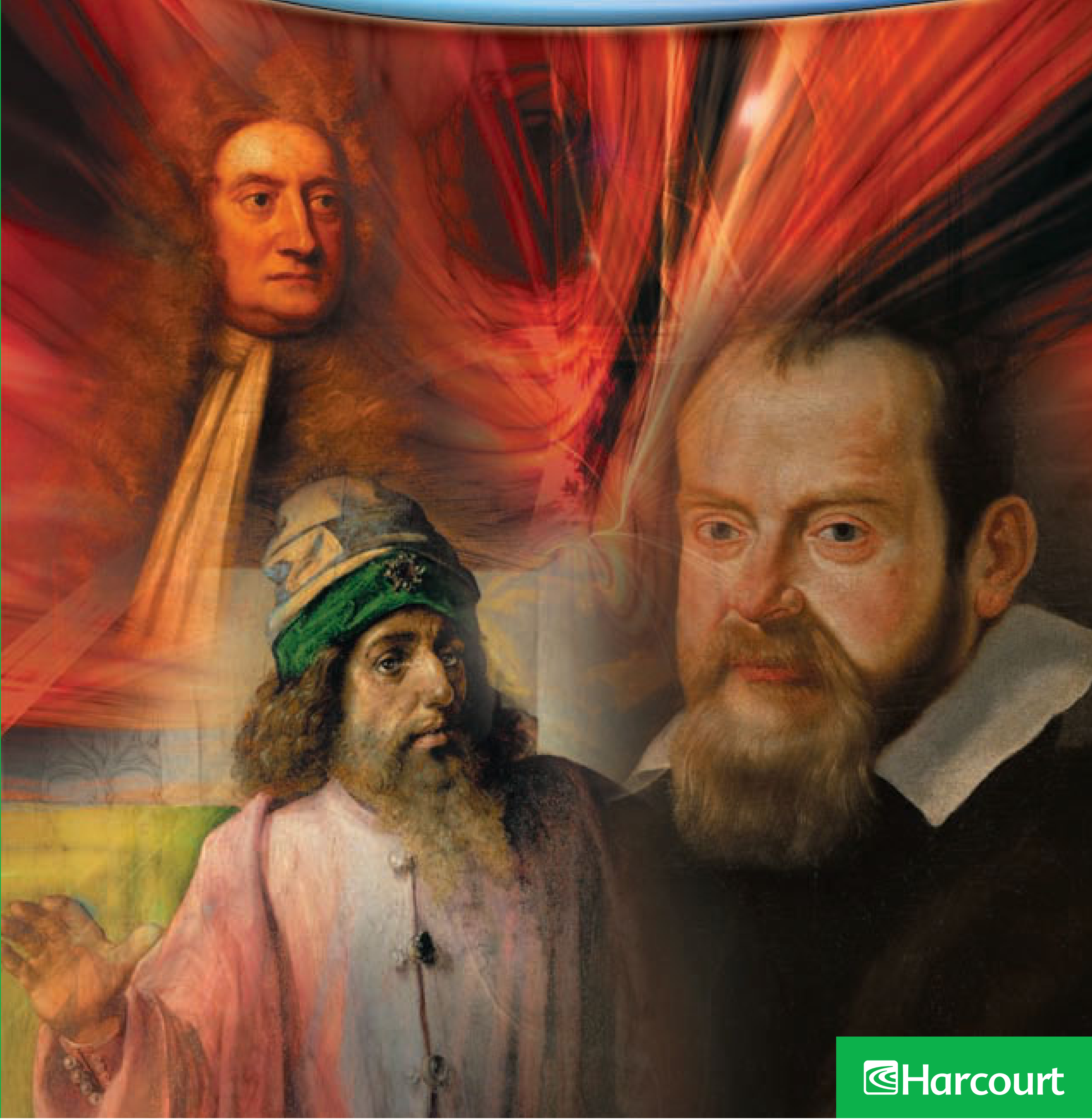
Thinking About Motion



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Thinking About Motion

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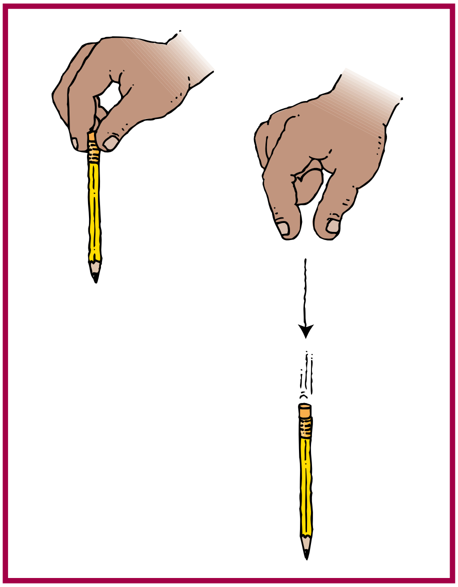
Aristotle and Motion

Think about dropping a rock while you are walking. What do you expect to happen? You expect the rock to fall and hit the ground. But why does this happen? Is some strange force at work? What path does the rock follow on its way to the ground? Does it fall straight down? In ancient times, people known as philosophers thought about questions like these.

In the days of the ancient philosophers, there were no microscopes or telescopes. No one could make exact measurements. People didn't do controlled scientific experiments. In those days, philosophers depended on the power of the mind to find truth. The Greek philosopher Aristotle was one of the most important of these early thinkers.

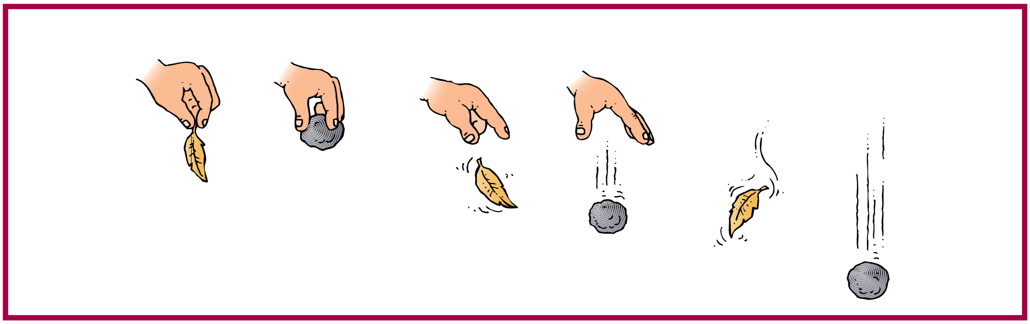
Aristotle and Motion on Earth



Aristotle thought that all motion on Earth occurred in a straight line. Here, a dropped pencil travels in a straight line as it falls to the ground.

Aristotle was the son of a medical doctor. He was born in 384 B.C. in northern Greece. He went to school at Plato's Academy. Then he became a teacher there.

Aristotle's Ideas About Weight and Falling Speed



Here, the heavier stone falls to the ground faster than the feather. Does this really happen? Keep reading to find out.

Aristotle's interest in the structure of living things was encouraged by his father. That interest helped Aristotle develop strong observation skills. He went on to apply his observation skills to a wide range of topics. Those topics included politics, nature, ethics, astronomy, and physics.

In time, many of Aristotle's teachings in physics would be proved wrong. His errors included thinking that

- all motion on Earth occurs in a straight line (called linear motion).
- an object continues in motion only as long as something acts on it to keep it moving.
- a heavy object falls faster than a light object.
- Earth is at the center of the universe.

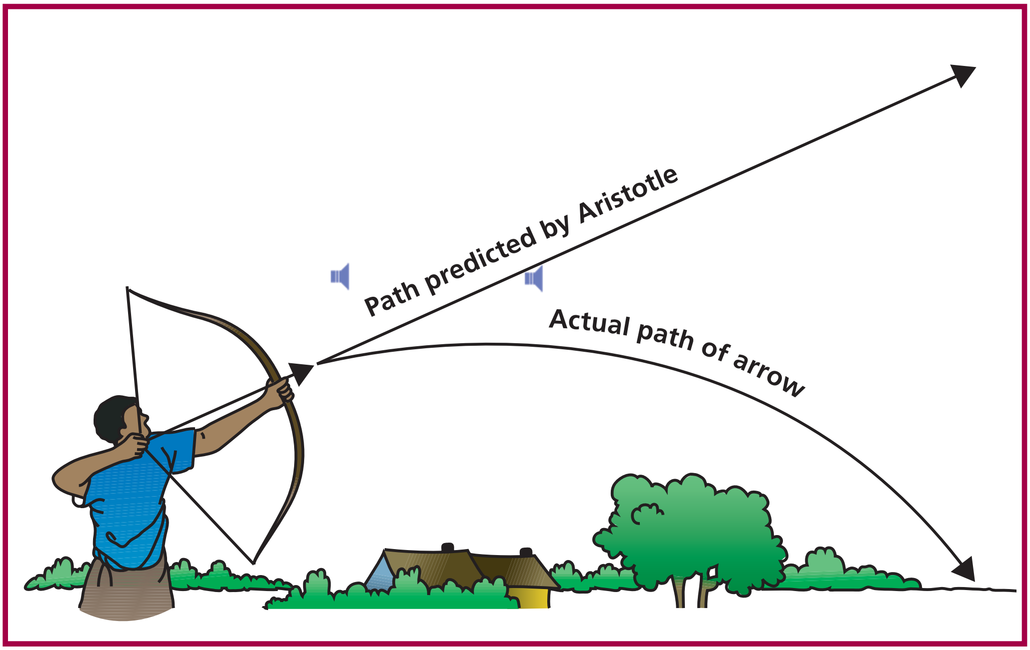
Remember that these beliefs were based on observation and thought. Experimental data or results did not exist. Almost 2,000 years would pass before scientific advances would allow people to test and disprove Aristotle's ideas on force and motion.

Problems with Aristotle's Ideas

Aristotle's ideas were accepted as the truth for hundreds of years. At a quick glance, his ideas seem to be common sense. For example, a rock dropped from an outstretched hand does fall in a straight line. It seems logical that a heavy stone should fall faster than a much lighter block of wood. However, there are problems with Aristotle's ideas.

Think about an archer who shoots a flaming arrow into the night sky. The curving path of the arrow's flight is shown in the illustration below. This curved path does not agree with Aristotle's belief that all motion on Earth must be in a straight line.

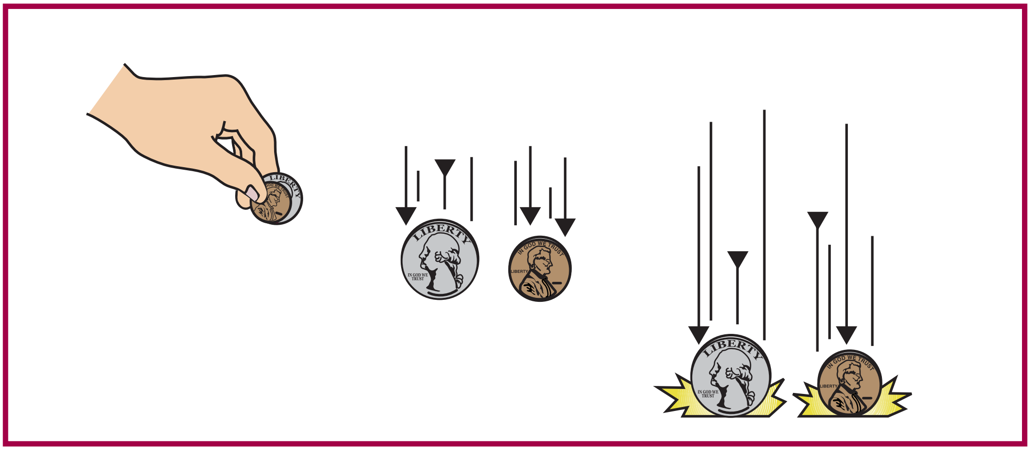
Was Aristotle Wrong About Straight-Line Motion?



The arrow does not follow the straight-line path predicted by Aristotle.

Have you ever dropped a penny and a quarter at the same time from the same height? Try it, and you will see that the two coins hit the ground at the same time. This result does not agree with Aristotle's ideas. According to Aristotle, the heavier coin should strike the ground first.

Was Aristotle Wrong About Falling Objects?



A quarter weighs more than a penny. Yet when you drop both coins from the same height, they hit the ground at the same time.

Galileo

After the death of Aristotle, almost 2,000 years would pass before there were advances in our understanding of motion. These advances would come from Galileo Galilei. Galileo was born in Pisa, Italy, in 1564. Galileo's father wanted him to be a doctor. Although Galileo might have become a great doctor, the world is fortunate that he studied mathematics instead.

Galileo is credited with two very important advances in the study of motion. According to Galileo:

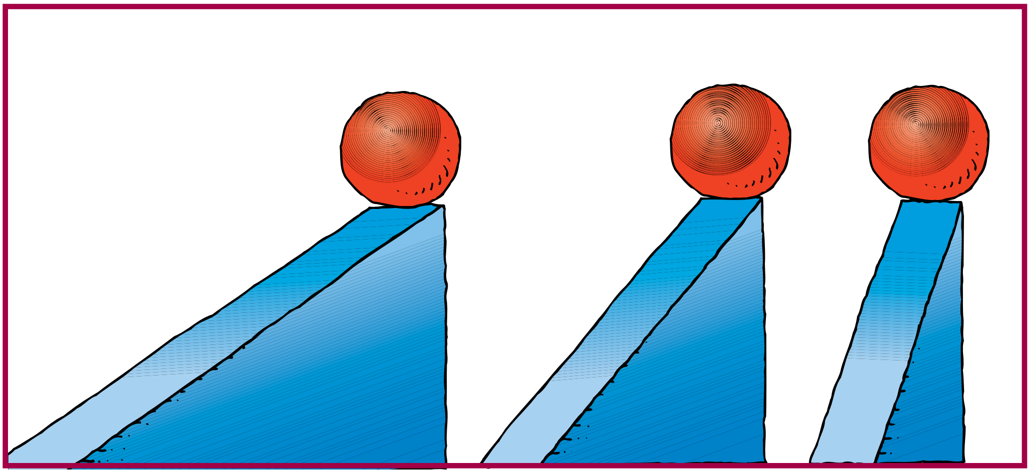
- the motion of a falling object does not depend on its mass.
- some objects fall at different speeds because of a force called friction.

Galileo arrived at these and other conclusions through the use of mathematics, observations, thought experiments, and actual experiments. A thought experiment is one that is carried out in the mind.

To study the acceleration of an object caused by gravity, Galileo used logic and an experiment involving ramps and balls. The picture below shows part of the experiment.

This may seem surprising, but Galileo found that the speed of each ball at the end of each ramp was the same.

Galileo's Gravity Experiment



How do you think the speed of the ball at the end of each ramp differs?

This meant that he could use the ramps to “slow” an object’s fall so that he could study its acceleration caused by gravity.

Galileo then used a thought experiment to extend this test result. He imagined that the ramps used in the experiment were vertical, like a cliff. He knew that the speed of the ball at the end of this “ramp” would be the same as before the ramps were made vertical. This meant that if he could measure the acceleration of the ball as it rolled down the ramp, he could measure the acceleration caused by gravity. By using the ramps and a special clock of his own design, Galileo was able to do just that.

Galileo also found out that a force acts on moving objects to slow them down. He noted that a ball rolling across a flat surface would gradually be brought to a stop by a force. Today this type of force is known as friction.

The story is often told about how Galileo dropped cannonballs from the Tower of Pisa. He supposedly did this to show that mass does not affect how fast something falls. Did he really drop things from the Tower of Pisa? No one knows for sure. But he did experiment with objects of different masses and discovered something that seems very strange: heavier things do not fall faster than lighter things!

Galileo also understood that the force of air resistance could affect the speed of an object’s fall through the air. He would have correctly explained that air resistance, and not the different masses of objects, causes a feather to fall more slowly than a rock does.

Newton Finds The Laws

Galileo made some great advances in understanding force and motion. There were, however, many more questions to answer. For instance, no one knew how hard something had to be pushed in order for it to move. And if an object did move, no one knew how fast it would move. Exactly how were force and motion related? These questions would soon be answered by another one of science's great thinkers: Isaac Newton.

Isaac Newton was born in England in 1642. He accomplished great things in his life in spite of many hardships. Before Newton was born, his father died. As he was growing up, his mother and stepfather mostly ignored him.

During his early education, Newton did not seem to be a promising student. He did, however, seem to have a love of learning. In college he became familiar with the works of Aristotle, Galileo, and many others. Newton applied his knowledge and ideas and began to revolutionize the fields of mathematics and science.

Newton is famous for developing three laws that describe motion. Although you may not know it, you already have a basic understanding of these laws.

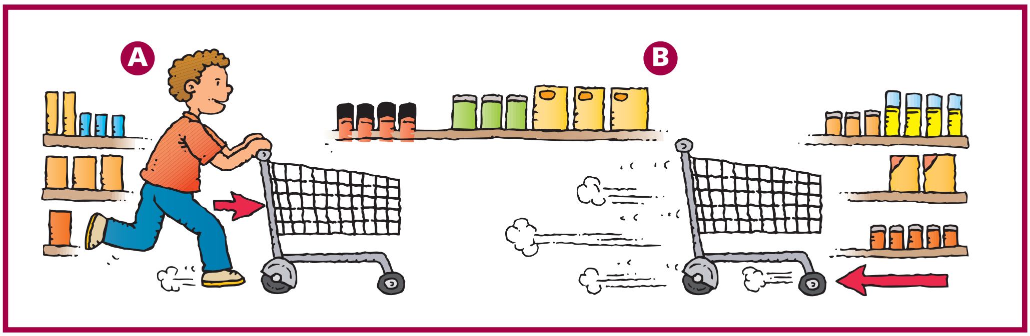
Think about a recent trip to the grocery store. You might recall how easy the empty cart was to push. The push (or force) you applied to the motionless cart made the cart move. The cart was probably not as easy to push after it was filled with items. In fact, you might remember having to push much harder (apply more force) to make the cart move. The rolling, heavily loaded cart was probably not easy to bring to a stop and may have kept moving even after you stopped pushing on it. This might seem confusing, but it's not when you know Newton's laws of motion.

Newton's First Law of Motion

Newton's first law is a restatement of something that Galileo said. Objects in motion continue in motion in a straight line, and objects at rest remain at rest unless they are made to do otherwise by a force that is exerted on them.

Does this mean that the shopping cart will roll forever in a straight line after it is pushed? Think about that. Is there a force acting on the rolling cart to stop it? The answer is yes—the force of friction. Both Galileo and Newton knew that friction acts on moving objects. Friction acts opposite to the cart's motion and brings it to a stop.

Forces on a Shopping Cart



(A) The push (force) applied by the boy accelerates the motionless cart. (B) Friction acting opposite the cart's motion will bring the cart to a stop.

What about objects at rest? Think about a dinner plate resting on a table. Is it possible for the plate to begin moving on its own? Of course not. Unless something applies a force to the plate, it will not move. This is what is meant by an object at rest will remain at rest (unless a force acts on it).

Newton's Second Law of Motion

Look around. Most of the motion you see involves change—change in speed and direction. When an object's motion changes, it is said to accelerate.

Now let's return to the shopping cart. When a motionless cart is pushed, it begins to move. Because the cart's motion is changing, the cart is accelerating. If you pushed harder on the motionless cart, it would move with a faster speed than it did before. In other words, the greater the force that is acting on the cart, the greater the cart's acceleration is.

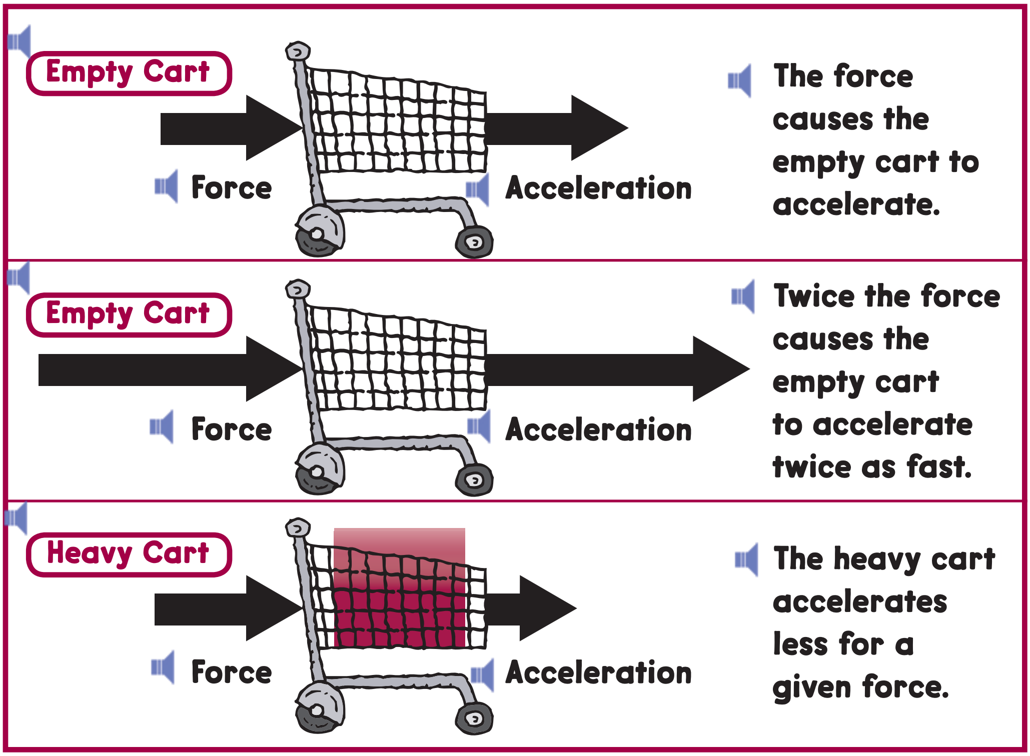
Recall what happened when the cart was full of items. It became much harder to push. The same push that sent the empty cart rolling along might barely move the heavily loaded cart. What does this mean? It means that a heavier object accelerates less than a lighter one when the same force is applied to both.

Newton summarized these observations in his second law of motion. In simple terms, the acceleration of an object depends on its mass and the force acting on it.

Remember that:

- as mass increases, acceleration decreases.
- as force increases, acceleration increases.

Examples of Newton's Second Law



These examples show that (1) as force increases, acceleration increases, and (2) as weight increases, acceleration decreases.

Newton's Third Law

As you walk, your shoes push against the ground. Although you may not know it, the ground also pushes back against your shoes. It is actually the ground that pushes you forward as you walk!

Newton's third law of motion describes these two forces. According to the law, when one object exerts a force on a second object, the second object exerts an equal and opposite force on the first object. These two forces are often called action and reaction forces. Note that the two equal and opposite forces act on different objects and do not cancel each other out.

Can you use Newton's third law to explain why it is so difficult to walk across an icy road? It is because the ice provides so little friction that it makes it almost impossible to exert an action force against it. When there is no action force, there cannot be a reaction force. Without the reaction force, you cannot move forward.

Universal Gravitation

Have you ever wondered what holds you down on the ground? It is gravity. More exactly, it is the huge mass of Earth attracting the much smaller mass of your body. Newton is credited with the discovery of universal gravitation.

Universal gravitation means that gravity extends everywhere throughout the universe. In fact, every object attracts every other object. So not only does Earth pull on you, you also pull on Earth.

Newton went on to use his laws of motion to explain the motion of the moon and the planets. Hundreds of years later, engineers and scientists use the same laws to design spacecraft that travel to some of these distant planets. Few people have had as great an effect on science and society as Isaac Newton.

Think and Write

1. Why were Aristotle's ideas about motion accepted for so long when many of them were incorrect?
2. How was Galileo able to disprove Aristotle's claim that a heavy object falls faster than a light object?
3. A girl pulls on an empty wagon, and it begins rolling. What would change if she gave an equal pull to a wagon that was filled with rocks?
4. **Persuasive Writing** Write a paragraph persuading car manufacturers to increase the efficiency of their vehicles by making them more aerodynamic. Use Newton's laws to support your ideas.

Hands-On Activity

Drop test Drop a sheet of paper from a height of 1 meter above the ground and observe the motion. Repeat this step using a book. (Note: the book should be held with its back cover parallel to the ground.) Predict what will happen if the paper is placed flat against the top cover of the book and then the book and paper are dropped together. (Note: the book must be larger than the paper.) Explain the results.

School-Home Connection

Motion list Share this reader with a family member. Make a list of common motions seen around the home. Choose two motions from your list. Use Newton's laws to explain the motion.

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LEVEL	See TG or go Online

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