

6. Objects change their motion only when a net force is applied. Laws of motion are used to calculate precisely the effects of forces on the motion of objects. The magnitude of the change in motion can be calculated using the relationship $F = ma$, which is independent of the nature of the force. Whenever one object exerts force on another, a force equal in magnitude and opposite in direction is exerted on the first object.

The Benchmarks for Science Education

1. Things move in many different ways, such as straight, zigzag, round and round, back and forth, and fast and slow.
2. The way to change how something is moving is to give it a push or a pull. Changes in speed or direction of motion are caused by forces. The greater the force is, the greater the change in motion will be. The more massive an object is, the less effect a given force will have.
3. Changes in speed or direction of motion are caused by forces. The greater the force is, the greater the change in motion will be. The more massive an object is, the less effect a given force will have.
4. An unbalanced force acting on an object changes its speed or direction of motion, or both. If the force acts toward a single center, the object's path may curve into an orbit around the center.
5. Whenever one thing exerts a force on another, an equal amount of force is exerted back on it.

Glossary

Acceleration - is the rate at which the speed (velocity) of an object changes per unit of time.

Force - is the capacity to do work or cause physical change that can produce an acceleration of a body in the direction of its application.

Friction - is resistance to the sliding, rolling, or flowing motion of an object because of contact with another object caused by the molecular attraction between the two surfaces.

Horse and Cart Paradox - how can a horse pull a cart if the cart exerts an equal and opposite force on the horse? The solution to this paradox is that there are two other force pairs that are involved, the forces between the wheels of the cart and the ground and the forces between the hoofs of the horse and the ground. Because the frictional force between the horse and the ground is greater than those of the cart and the ground, the horse pulls the cart.

Inertia - The tendency of a body to resist acceleration; the tendency of a body at rest to remain at rest or of a body in motion to stay in motion in a straight line unless acted on by an outside force.

Mass vs. Weight - mass is a measure of inertia and is related to the quantity of matter in a body while weight is the force with which a body is attracted toward the earth.

Newton, Sir Isaac, 1642-1727 - is an English mathematician and scientist who formulated the theories of universal gravitation, terrestrial mechanics, and color.

Newton's First Law - if the vector sum of the forces acting on an object is zero, then the object will remain at rest or remain moving at constant velocity. The concept of inertia is implicit in this law. Vectors include the magnitude and direction of the forces.

Newton's Second Law - a net force on an object will accelerate the object at a rate proportional to the strength of the force and in the same direction as the force, but inversely proportional to the mass of the object. This law defines inertial mass.

Newton's Third Law - an object experiences a force because it is interacting with some other object, and that the force exerted by object 1 on object 2 must be equal to the force exerted by object 2 on object 1 but in the opposite direction. The pair of forces of action and reaction act on different objects and it is the vector sum of all the forces acting on an object that determines if the object accelerates.

Review and Extension Questions

1. How can the motion of an object be described?
2. How can the motion of an object be represented visually?
3. What can cause changes in the speed or direction of motion of an object?
4. How is the motion of an object affected if a greater the force is applied?
5. If there is no unbalanced force acting on an object, what will happen to the object?
6. How will the relative motions of two objects compare if the same force is applied to both objects when one of the objects is more massive than the other object?
7. What will happen if another force acts on an object in the same direction of its motion?
8. What will happen if another force acts on an object in the opposite direction of its motion?
9. Describe an example of how one thing exerts a force on another causes an equal amount of force to be exerted back on it.
10. In the "Horse and Cart Paradox," why is the horse able to pull the cart if Newton's Third Law states that the cart must exert an equal and opposite force to the pull of the horse?

Science Fundamentals

Newton's Wagon

Understanding Motion

TEACHER'S GUIDE

Video Purpose

This video is designed to develop students' understanding of the concept of motion by using common examples that motivate students to learn more. This video may be used to introduce new concepts, to support learning activities, or to assist with summarizing concepts.

Traditionally, motion is usually taught using expository methods, with the use of routine demonstrations. The role of the student is a passive one, and they never experience a conflict between their views and the views that are being taught. Students will say that objects fall at the same rate, because they have learned it from a book, but they are unable to separate the additional effects of air resistance that is needed in order to believe that it is true. Not acknowledging students' entry-level conceptions and understanding can leave students' conceptions unchanged. It is important to create conceptual conflict between students' naive conceptions and the scientific conception.

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Video Activities:

1. **Newton’s Cradle** -demonstrates energy transfer and losses do to friction that cause motion to slow down and stop.
3. **Toy Car** - shows the effect of frictional forces on motion.
4. **And They’re Off** - is an investigation of friction which introduces Newton’s Second Law.
5. **Dolly Jump** - show action and reaction are opposite.
6. **Balloon Rocket** - demonstrates unbalanced forces.
7. **Newton’s Wagon** - is a discrepant (counterintuitive) event designed to arouse interest by conflicting with expectations and understanding and to stimulate interest in other possible explanations. Demonstrates the “Horse and Cart” paradox.

Student Naïve Conceptions

As students grow up they have many experiences for which they form explanations based on a variety of anchoring experiences, such as, running and jumping, pushing objects and bicycles. While these explanations make sense for the student, they may conflict with the results of science investigations, and they are sometimes called naïve conceptions. Student’s naïve conceptions should not be treated as wrong as such but as conceptions based on insufficient analysis of their experiences. The activities in this video are designed to help students recognize their explanations and develop a more analytic view. Students in middle school are usually at different points in their conceptualization of force and motion. Everyday experience suggests that objects set into motion eventually come to a stop when no obvious external force acts on them. Other common naïve conceptions include: the state of rest is fundamentally different from the state of motion, constant motion requires a constant force, if a body is not moving there is no force acting on it, and that

friction, not inertia, is the principle reason objects remain at rest or require a force to move. These naïve conceptions about the causes of motion can persist if they are not appropriately addressed.

Telling or showing students the explanations that science uses may not change their beliefs. There are several strategies that can be used to facilitate a deeper understanding. Students need to become aware of their own preconceptions about a concept and expose these beliefs by sharing their ideas with other students in small groups in an uncritical environment to help them begin a deeper analysis of their experiences. They should be encouraged to make predictions based on their conceptions before activities begin. This will help students to begin to confront and test their beliefs and provide motivation for looking for other plausible conceptions. Students need to have time to work toward resolving conflicts between their ideas and their observations, thereby accommodating new concepts. Students need opportunities to extend new concepts by trying to make connections between the new concept and other situations in their daily lives. Students should also be encouraged to go beyond these initial steps by choosing additional questions or problems related to the concept to expand their understanding. These strategies are used to organize suggested activities into the following groups: exposing beliefs, committing to outcomes, confronting beliefs, accommodating concepts, extending concepts, and expanding inquiry.

Sample Support Activities

Exposing Beliefs

Use an activity like “Think, Pair, and Share” to have students begin thinking about their explanations of topics, such as, of why things start or stop moving, and then share their ideas with a partner. Two pairs can then be combined to share their views and each group of four can have a one person share the different explanations. Moving from small to whole group in a secure and uncritical environment gives students an opportunity to see that others are also uncertain and bring a variety of views to their experience.

Committing to Outcomes

Use the different activities in the video as opportunities to have students predict what they think will happen, for example, the introductory “And They’re Off” activity. Simply stop the video just before the professor releases the cars and have students share with a partner or write their predictions of what will happen. It is important that they make a verifiable commitment so that they can begin to address their beliefs.

Confronting Beliefs

Have students test their ideas by recreating one of the activities on the video or related activities that they found interesting. For example, pairs of students could construct the “Balloon Rockets” or other video activities and describe their observations and explanations. Working in small groups, students could then debate their explanations, conduct interviews, and check written materials before presenting their results. This is an opportunity for students to confront their beliefs.

Accommodating Concepts

Students need to begin to question their observations and their discussions to help them process information and begin to make sense of the explanations behind the observations. Debating the “Horse and Cart Paradox” will help students probe their understanding of Newton’s three laws of motion. During this time, students begin to resolve the

conflict that may exist between beliefs and observations. Class presentations of observations of activities and explanations along with carefully posed teacher questions and follow-up small group discussions will assist with the process of accommodating new concepts.

Extending Concepts

Asking students to give examples of where they have seen the concept discussed or demonstrated or giving examples of how they think the concept is connected to other situations will help students extend their understanding of the concept.

Expanding Inquiry

To encourage students to continue thinking about the concept, opportunities should be provided that invigorates them to investigate additional questions and problems that interest them.

Correlations to National Standards

The video activities and content address the following National Science Education Standards or The Benchmarks for Science Education *

National Science Education Standards

1. An object’s motion can be described by tracing and measuring its position over time.
2. The position and motion of objects can be changed by pushing or pulling. The size of the change is related to the strength of the push or pull.
3. The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph.
4. An object that is not being subjected to a force will continue to move at a constant speed and in a straight line.
5. If more than one force acts on an object along a straight line, then the forces will reinforce or cancel one another, depending on their direction and magnitude. Unbalanced forces will cause changes in the speed or direction of an object’s motion.