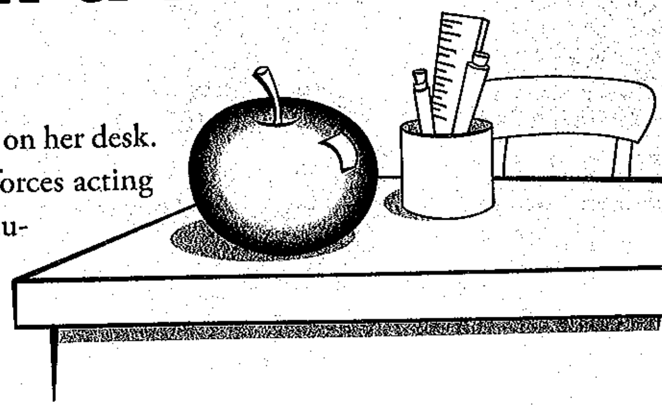
Apple on a Desk



Mrs. Canales pointed to an apple sitting on her desk. She asked her students to describe any forces acting on the apple. This is what some of her students said.

Archie: "The only force acting on the apple is air pressure."

Sam: "There is one force acting on the apple. Gravity is the force that pulls on the apple."

Soledad: "There are two forces: the desk pushes up on the apple and gravity pulls downward on the apple."

Misha: "There are many forces acting on the apple; but, it is the holding force in the apple that keeps it on the desk."

Tess: "There are no forces acting on the apple because the desk stops any forces from acting on it."

Which student do you most agree with? ____________________

Explain your thinking. What rule or reasoning did you use to decide if there were any forces acting on the apple?

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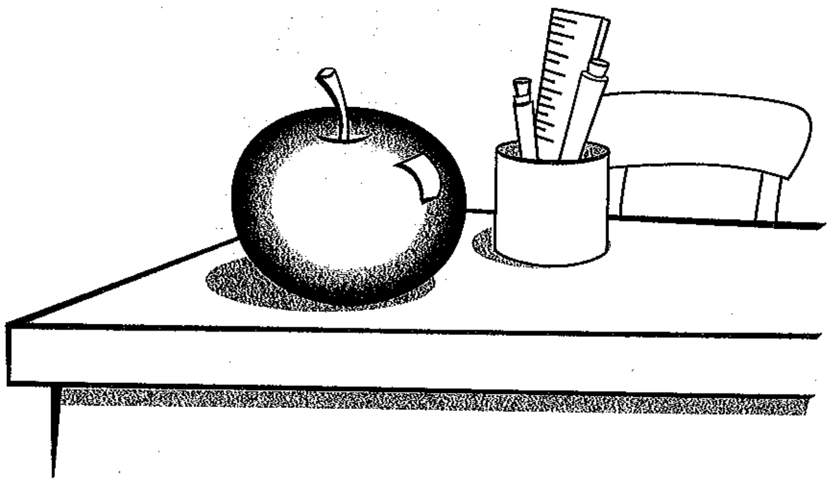
Teacher Notes



Purpose

The purpose of this assessment probe is to elicit students' ideas about forces. The probe is designed to find out whether students recognize that balanced forces act on a stationary object.

Related Concepts

balanced forces, force, gravity

Explanation

The best response is Soledad's: There are two forces: The desk pushes up on the apple and gravity pulls downward on the apple. Forces come in pairs. The force of gravity acting on the apple is the result of the matter in the Earth pulling on the matter in the apple. When the apple is set on the table, the table exerts a force upward on the apple equal to the force exerted downward, which is the pull on the apple. At a microscopic level, when the apple is placed on the table, the individual molecules of the table's surface adjust their positions in much the same way that the individual springs in a bedspring mattress change position to support a sleeping person. This force on the apple exists because the apple is in contact with the surface of the table. When the apple is removed, the molecules of the table return to their original positions, as happens when a sleeping person rises from bed in the morning.

This force of the table on the apple is less obvious in our everyday experience. Forces such as that exerted by the table are difficult to detect or conceptualize because many of the structures we live among (tables, floors, walls, etc.) are rigid and thus show no apparent give and take when objects are placed on them. The fact that the apple is not moving indicates that another force besides gravity must be present. In order for any object's motion to remain unchanged, all of the forces on that object must balance. In the case of the motionless apple, the downward gravitational force is balanced by an upward force supplied by the only other object in contact with the apple—the table. Air pressure also creates a force on the apple, but since air pushes on the apple almost equally in all directions, the effects of the air's force are not noticeable in this case.

Curricular and Instructional Considerations

Elementary Students

Elementary school instruction is primarily focused on describing the position and motion of objects and discovering the various kinds of forces that affect the motion of objects. Students develop the notion of forces as pushes and pulls on an object. Most of their learning about objects at rest is observational, with explanations coming later. They notice that things fall if not held up, and they later connect this to the words and concepts of *gravity* and *force,* including the notion that the Earth pulls on an object.

Middle School Students

Students at the middle school level engage in concrete experiences from which a more comprehensive understanding of force will develop in high school. Students develop the notion of balanced and unbalanced forces and describe the forces acting on objects. Instruction needs to include the idea that forces can be active or passive, because students at this age tend to equate force with motion and think there is no force acting on an object that is not moving.

High School Students

As students in high school begin to appreciate the particulate nature of matter and its minuteness of scale, they can also begin to understand the qualities of the electromagnetic forces that are dominant among atoms and their smaller particles. However, students may resist ideas about the importance and strength of these forces in their everyday experiences, especially as they relate to inanimate objects. This probe is useful in identifying students' ideas about forces, either before or after physics instruction.

Administering the Probe

This probe is most appropriate for middle and high school students. A visual prop such as an actual apple on your desk can be used to enhance the prompt. In addition to the explanation, consider asking students to draw a labeled diagram to show the forces and their directions.

Related Ideas in *National Science Education Standards* (NRC 1996)

K–4 Position and Motion of Objects

- The position and motion of objects can be changed by pushing or pulling.

5–8 Motion and Forces

★ If more than one force acts on an object along a straight line, then the forces will reinforce or cancel one another.

9–12 Motion and Forces

★ Whenever one object exerts force on another, a force equal in magnitude and opposite in direction is exerted on the first object.

★ Gravitation is a universal force that each mass exerts on any other mass.

Related Ideas in *Benchmarks for Science Literacy* (AAAS 1993)

K–2 Forces of Nature

- Things near the Earth fall to the ground unless something holds them up.

3–5 Forces of Nature

- The Earth's gravity pulls any object toward it without touching it.

6–8 Forces of Nature

- Every object exerts gravitational force on every other object.

9–12 Forces of Nature

- Gravitational force is an attraction between masses.
- Electromagnetic forces acting within and between atoms are vastly stronger than the gravitational forces acting between the atoms.

9–12 Motion

★ Whenever one thing exerts a force on another, an equal amount of force is exerted back on it.

Related Research

- Students tend to distinguish between active objects and objects that support or block or otherwise act passively, such as a table. Students tend to recognize the active actions as forces but often do not consider passive actions to be forces. Teaching students to integrate the concept of passive support into the broader concept of force is challenging, even at the high school level (AAAS 1993).
- Some students believe that if a body is not moving, there is no force acting on it (AAAS 1993).
- Students have difficulty understanding that all interactions involve equal forces acting in opposite directions on the separate, interacting bodies. They tend to believe that animate objects (like a person's hands) can exert forces whereas inanimate objects (like tables) cannot (AAAS 1993).
- Some research has shown that teaching high school students to seek consistent explanations for why objects are at rest can help them understand that both "active" and "passive" objects exert forces. Showing students that apparently rigid or supporting objects actually deform might also help them to understand the at-rest condition (AAAS 1993).
- Elementary school students typically do

★ Indicates a strong match between the ideas elicited by the probe and a national standard's learning goal.

not understand gravity as a force. If students do view weight as a force, they often think it is the air that exerts this downward force (AAAS 1993).

- The way children think about forces is related to their meaning for the word *force*. Some students associate force with coercion, physical activity, muscular strength, or living things (Driver et al. 1994).
- Students generally appear to think of force as a property of a single object rather than as a feature of interaction between two objects (Driver et al. 1994).
- Using the example of a book on a table, many students, including high school students, merely think of the table as being in the way, rather than exerting a force (Driver et al. 1994).

Suggestions for Instruction and Assessment

- Provide students with a sequence of scenarios that demonstrate that surfaces deform in a springlike fashion when objects are placed on them and that the tendency of surfaces to return to their original shape causes them to exert force on the object. This type of "bridging analogy" is especially effective with high school students when begun by showing a single spring pushing up on an object, then extended to gradually stiffer objects. By placing a heavy book on this progression of objects, show students how a bedspring, a sponge, and a pair of metersticks spanning a gap between tables all deform in a springlike manner to exert an upward force on the book (Clement 1993; Minstrell 1982).
- Use examples in instruction and assessment that depict inanimate objects exerting forces on other objects, rather than only involving humans or vehicles as agents of force. Students tend to equate forces with animate objects like people, rolling balls, and wheeled vehicles and thus need multiple opportunities to associate forces with inanimate objects, such as a book resting on a table or a box on the floor.
- The difficulty with younger children is convincing them that any forces at all are acting on a stationary object. Ask them, What would happen if the desk did not support the apple? If they reply that it would fall, ask them, What prevents it from falling? To conceptualize the idea that a force must be exerted, take turns placing a heavy object, such as a brick, in students' hands. Ask the students what they need to do to keep the brick steady and not moving. They should notice that they have to press upward on the brick. Explain how this opposes the downward force of gravity. The downward force and the upward push of their hands are balanced when the brick does not move. If they push harder or relax their muscles, the forces will be unbalanced and the brick will move downward or upward.
- Describing force as an interaction between a pair of objects is often difficult for students to grasp. Encourage students to identify all forces as interactions by

naming them as the force of one object on another. This method of describing forces is obvious to students when they refer to examples such as "Shawna's push on Jason," but it is much less obvious and more powerful when students must refer to forces such as "Earth's pull on the apple," or "the table's push on the apple." Asking what is pushing and what is pulling should include mixed examples of cases in which there is motion and cases in which there is no motion.

- In later grades, apply force diagrams frequently, but carefully, in relation to these topics. These diagrams are a vital tool for both learning and assessment, but they can also reinforce student misconceptions if they do not clearly isolate one object at a time and depict the forces acting solely on that object. Such diagrams reveal especially rich information about student thinking when students label each force with the objects involved in the interaction and indicate the relative strengths of forces with arrow lengths (Arons 1997).
- Because student beliefs about the inability of inanimate objects to exert forces can be strikingly firm, simply telling students that this is not so stands a good chance of leaving these students with misconceptions. Instead, work to assess and reflect students' ideas through probing questions and discussion, being careful not to evaluate them. Highlighting ideas of theirs that may contradict visible evidence or other ideas through this type of careful reflective discussion stands a much greater chance of helping students change their initial ideas.

Related NSTA Science Store Publications and NSTA Journal Articles

American Association for the Advancement of Science (AAAS). 1993. *Benchmarks for science literacy.* New York: Oxford University Press.

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Related Curriculum Topic Study Guide

(Keeley 2005)

"Forces"

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