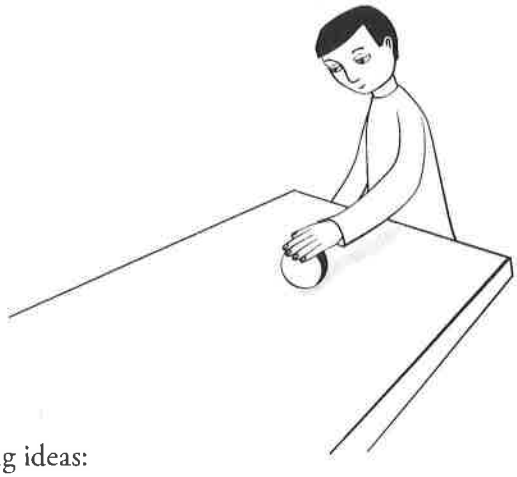
Just Rolling Along

Jerome rolled a rubber ball across a very long table by giving the ball a very light push and then letting it roll across the table on its own. Six of his classmates observed the ball as it rolled.



Jerome wondered what happened to the speed of the ball after it left his hand. He asked the other students if they think it is possible to make the ball roll at a constant speed (*constant speed* means the ball is neither slowing down nor speeding up).

The students in Jerome's group shared the following ideas:

Anna: "It is not possible to make the ball roll at a constant speed."

Dev: "It is possible for the ball to roll at a constant speed if you tilt the table slightly downward."

Tad: "It is possible for the ball to roll at a constant speed if you tilt the table slightly upward."

Jack: "It is possible for the ball to roll at a constant speed if you make the table perfectly flat."

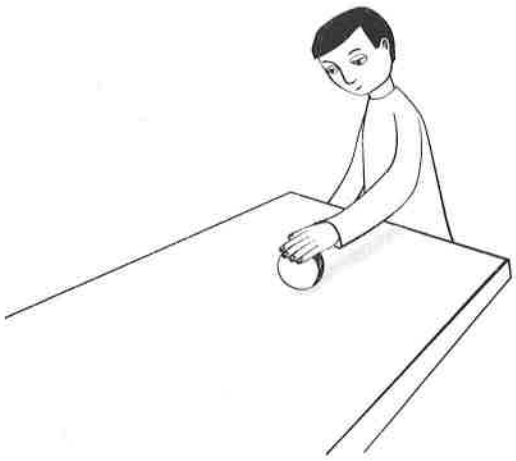
Byron: "It is possible for the ball to roll at a constant speed if you roll the ball really fast."

Talia: "It is possible for the ball to roll at a constant speed if you roll the ball really slow."

Circle the name of the student you think has the best idea. Explain why you think that is the best idea.

Just Rolling Along

Teacher Notes



Purpose

The purpose of this assessment probe is to elicit ideas about uniform motion. The probe is designed as a starting point to encourage students to use evidence and observations to support their ideas. The goal is for students to eventually develop and then test an operational understanding of the concept of speed.

Related Concepts

constant speed, displacement, speed, time intervals, uniform motion

Explanation

The best answer is Dev's: "It is possible for the ball to roll at a constant speed if you tilt the table slightly downward [at a very small angle])". When level, the ball slows down and when at a steep angle, the ball speeds up. One can then reason (and then verify experimentally) that there must be an angle at which the ball neither speeds up nor slows down.

The correct answer can also be found by analyzing forces. There is an angle at which the frictional force is balanced by the component of the gravitational force along the direction of the ball's motion. When the table is level, the ball will slow down because the friction force by the table is acting on the ball. This force acts opposite the direction of motion. In addition, when the table is level, there is no gravitational force acting in the direction of motion.

Administering the Probe

This probe is appropriate for middle school and high school students. Make sure that students, particularly middle school students, understand what the term *constant speed* means even though it is defined in the probe. Have props (rubber ball and long table) available to illustrate the context of the probe. This probe can be used with the P-E-O strategy: *predict, explain* the reason for your prediction, and *observe*; if students' observations do not

fit their predictions, students revise their predictions and explanations (Keeley 2008). To observe this motion, students will need to roll the ball slowly. If the table is tilted too much, then the ball will continuously speed up. With just a small tilt, they should be able to find the place where part of the gravitational force that pulls the ball down the incline is offset by the rolling friction acting on the ball by the table.

This probe can be answered and tested from a purely kinematics point of view, without requiring an explanation of forces on the part of the teacher or students. It can also be used as a probe in Section 2, "Forces and Newton's Laws," if you are interested in probing further for students' explanations of the forces involved.

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

5–8 Motions and Forces

★ The motion of an object can be described by its position, direction of motion, and speed.

Related Ideas in *Benchmarks for Science Literacy* (AAAS 1993, 2009)

6–8 Motion

- An unbalanced force acting on an object changes its speed or direction of motion, or both

9–12 Motion

★ Any object maintains a constant speed and direction of motion unless an unbalanced outside force acts on it.

Related Research

- Many researchers have found that substantial numbers of students are strongly committed to the idea that constant speed implies that a constant force is being applied to a moving object (Driver et al. 1994, p. 158).
- This probe addresses a particular "problematic facet" (Minstrell 1992) that objects—even objects rolling on horizontal surfaces—slow down because of gravity. Students do not see the need to have the force that is changing the motion be related to the direction of motion.

Suggestions for Instruction and Assessment

- This probe can be used at the start of a unit on kinematics—the branch of physics that deals with the motion of a body or system without reference to force and mass—as a way to elicit ideas that students have prior to instruction. If used in this way, it should be immediately followed up with a hands-on experiment in which students test their predictions and provide supporting evidence for their ideas.
- Students will develop a wide variety of reasons to support their prediction (even if it is not correct). Understanding that there must be a point where the ball neither speeds up nor slows down is similar to understanding a "point of inflection" in mathematics and can be quite difficult for some students. These students would benefit from taking measurements, such as comparing the time it takes the ball to move across the first half of the table with the time it takes the ball to travel across the second half of the table. They should then be led to adjust the tilt of the table until these two times are the same.
- It is important for teachers to listen carefully to how students use key words such as *force, momentum,* and *energy.* How students use these words can provide a window into student thinking about ideas not yet introduced in the unit. Rather

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

than correcting any inaccurate uses, ask students what they mean by these terms and then redirect them to use more direct descriptions of the motion (such as speeding up, slowing down, or moving at constant speed).

- Be aware that many students will try to bring the concept of force into their explanations and therefore may have a difficult time observing the motion without a bias.
- This probe can be used in postinstruction to see if students have developed an operational definition of speed and if they understand how to design an experiment to test an idea.
- Be careful when using this probe that you do not imply that objects—even objects rolling on horizontal surfaces—slow down because of gravity, As described by some of the "facets of student knowledge" (see Minstrell 1992), some students do not see the need to have the force that is changing the motion be related to the direction of the motion.

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