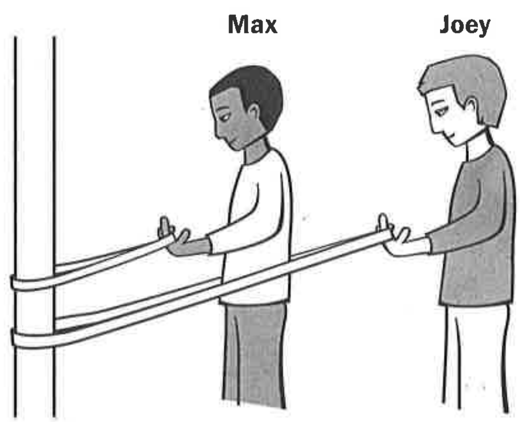
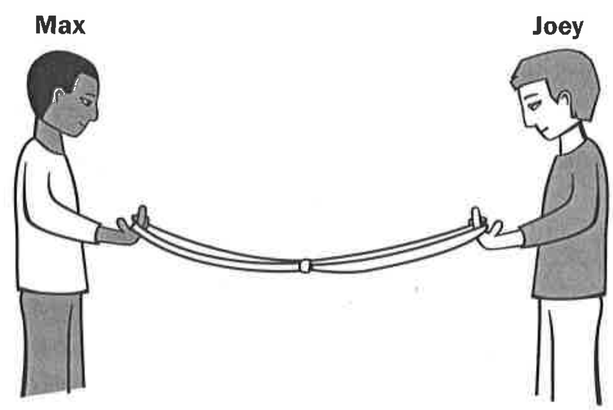
Finger Strength Contest

Max and Joey are having a strength contest (**see illustration at right**). They are using two identical rubber bands to test how much of the rubber band each of them can pull with one finger. They each slip one end of a rubber band around a pole and pull as hard as they can. Joey is able to stretch the rubber band twice as much as Max.



Next, the boys tie two new identical rubber bands together (**see illustration at right**). On the count of three, Max and Joey both pull in opposite directions as hard as they can.



Max's rubber band stretches 16 cm. How far do you think Joey's rubber band will stretch? Circle your answer.

A 32 cm

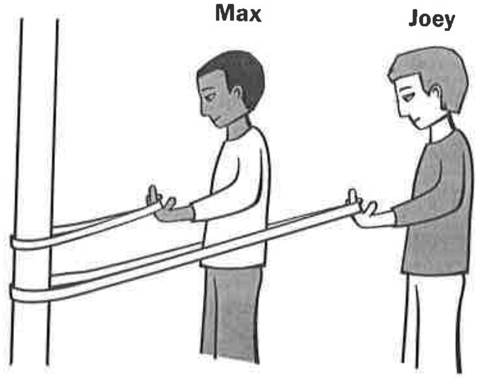
B 16 cm

C 8 cm

Explain your thinking. What reasoning did you use to decide how far Joey's rubber band will stretch?

Finger Strength Contest

Teacher Notes



Purpose

The purpose of this assessment probe is to elicit students' ideas about forces. The probe is designed to reveal whether students recognize a situation in which the force applied by one object on another is equal, but opposite, to the force applied by a second object back on the first.

Related Concepts

interaction, Newton's third law

Explanation

The best answer is B: 16 cm. Joey's rubber band will stretch the same amount as Max's rubber band. This is consistent with Newton's third law: The force applied by one object on another is always equal but opposite to the force applied by the second object back on the first. Force is an **interaction** between two objects and is not a property of a single object. The rubber bands serve as a visual reminder that the forces between objects are always equal, but opposite. Joey can only pull on the rubber band as hard as Max pulls.

Administering the Probe

This probe is best used with upper middle school and high school students. Consider demonstrating the probe with real rubber bands before administering it. Demonstrate both activities shown on page 127—that is, (A) each boy pulling on a pole (you might use a table leg) and (B) the two boys pulling in opposite directions.

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.

9–12 Motions and Forces

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

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

9–12 Motion

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

Related Research

- Research studies show that students tend to think of a force as a property of single objects rather than as a relationship between two objects. A paired "reaction force" is generally not recognized (Driver et al. 1994).
- A study by Brown (1989) showed that high school students enter physics courses with erroneous preconceptions of Newton's third law. These preconceptions are persistent, and they are difficult to overcome with traditional techniques alone. "The data from the study support the hypothesis that the persistence of preconceptions concerning the third law may result from students' general naive view of force as a property of single objects [rather] than as a relationship between two objects" (Brown 1989, p. 357).
- Some students are apt to use the intuitive rule "more A, more B." Because one boy stretches the single rubber band more than the other boy (as in the top illustration on p. 127), when the boys are on opposite ends of two rubber bands that are tied together (the bottom illustration on p. 127), students are apt to think the boy who stretched the single rubber band more will also stretch the tied-together rubber bands more (Stavy and Tirosch 2000).
- Even teachers can have difficulty in understanding Newton's third law because of the way it was taught to them in traditional classrooms. Action-reaction pairs are often misunderstood as referring to forces acting on a single object (Hughes 2002).

Suggestions for Instruction and Assessment

- Students can easily test their ideas by using identical rubber bands or spring scales. Students should not pull as hard as they can because the rubber bands will likely break or the spring scales may be overloaded. Ask students to try to pull each rubber band (when connected end to end) by a different amount and then observe what happens.
- One way to talk about Newton's third law is to refer to it as the "symmetry principle." According to Bob Prigo, a physicist at Middlebury College, "all forces share a beautiful symmetry property–all forces come in pairs. There is no such thing as a single force. What's more, the pairs are of equal strength and are always oppositely directed. It is important to note, however, that these force pairs are always exerted on different objects" (Prigo 2007, p. 14).
- Equal forces can be illustrated by pushing off of bathroom scales. Take two identical bathroom scales and have two students hold the scales vertically out in front of themselves and against each other so the scales are zeroed. Have the pair of students push on each other, scale to scale. When all motion between the partners has stopped, read the separate scale readings and compare. Repeat by pushing harder. Repeat by pushing more lightly. The "forces," as read off the scales, should be identical in all cases (Prigo 2007).
- Many physics textbooks treat Newton's third law of motion only in passing, often as an addendum to the section covering the con-

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

servation of momentum. Teachers should be aware that most students confuse the forces described in the third law with momentum and tend to view force as a property of single objects rather than as a relationship between two objects (Roach 1992).

- Consider rewording Newton's third law of motion for your students (Roach 1992). Many textbooks state that Newton's third law is that "for every action there is an equal and opposite reaction." A better way to state Newton's third law is to say, "When one object exerts a force on a second object, the second object exerts a force on the first that is equal in size and opposite in direction" (McLaughlin and Thompson 1997, p. 110). This phrasing of the third law makes it very clear that there are two objects involved.

References

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