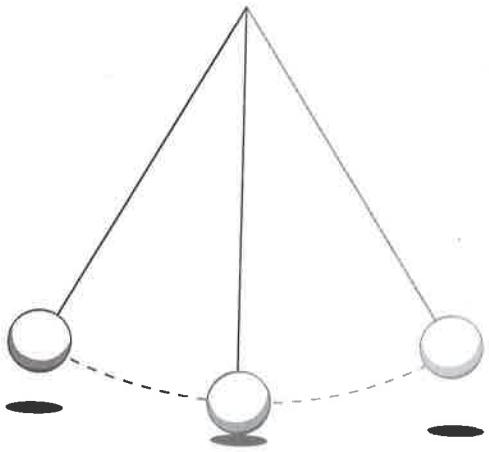
The Swinging Pendulum

Gusti made a pendulum by tying a string to a small bob. He pulled the bob back and counted the number of swings the pendulum made in 30 seconds. He wondered what he could do to increase the number of swings made by the pendulum. If Gusti can change only one thing to make the pendulum swing more times in 30 seconds, what should he do? Circle what you think will make the pendulum swing more times.



A Lengthen the string.

B Shorten the string.

C Change to a heavier bob.

D Change to a lighter bob.

E Pull the bob back farther.

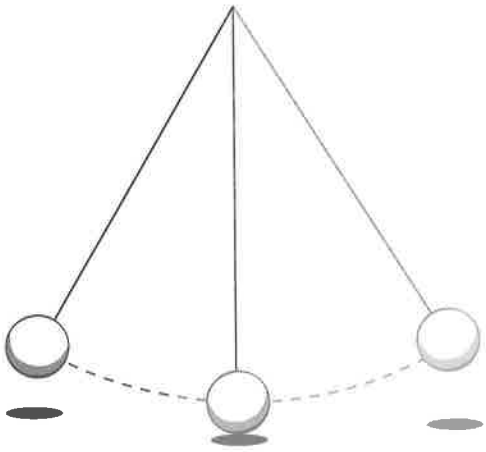
F Don't pull the bob back as far.

G None of the above. All pendulums swing the same number of times.

Explain your thinking. What rule or reasoning did you use to select your answer?

The Swinging Pendulum

Teacher Notes



Purpose

The purpose of this assessment probe is to elicit students' ideas about pendulums. The probe is specifically designed to find out what variables students think affect the time it takes a pendulum to swing back and forth. In addition, if students have an opportunity to test the predictions they make for this probe, the probe can also be used to determine whether students recognize the need to control all but one variable.

Related Concepts

pendulum, periodic motion, variables

Explanation

The best answer is B: Shorten the string. Adding more weight (or mass) does not make a difference for the same reason that two objects that weigh differently will fall with the same acceleration. (See the Teacher Notes for probe #36, "Free-Falling Objects," on pp. 168–170). The initial height of the swing also does not make a difference for angles that are relatively small (less than about 40 degrees). This is because the higher the swing the more distance the bob has to travel, but the bob is also moving faster. If the bob is released from a small angle, then it will move slower, but does not have to travel as far. (*Note:* In the study of motion of pendulums, it is assumed, even with older students, that the angle of release is never above about 40 degrees. Larger-angle pendulums will behave differently because the period of motion is no longer a constant.)

Students who are learning about pendulums for the first time will discover through experiment that the period of a pendulum (the time it takes for a bob to swing back to its point of release) depends only on the length—that is, the distance from the point of support to the center of mass (also called center of gravity) of the bob. If students think about air resistance acting on the bob, then they may also select C (change to a heavier bob). However, in most cases, students who select C are not think-

ing about air resistance when they choose this option (you will need to check their reasoning). (*Note:* The dependence of the period on the length of the string (or wire) is true only (a) for small angles, i.e., less than about 40 degrees, and (b) if the mass of the bob is much greater than the mass of the wire.)

Administering the Probe

This probe can be used with upper elementary and middle school students. Show students a pendulum, point out what the bob is, and demonstrate its swinging motion. With older students, consider referring to the mass of the pendulum bob instead of using the words *heavier* and *lighter* that now appear in the probe's distracters.

Related Ideas in *National Science Education Standards* (NRC 1996) and *Benchmarks for Science Literacy* (AAAS 1993, 2009)

This probe and the other probes in this section (probes #39–#45) do not explicitly target key ideas in the national standards documents. Both the *National Science Education Standards* and *Benchmarks for Science Literacy* deliberately did not include periodic motion as an important idea for science literacy. However, because simple pendulums are frequently used with elementary and middle school students to build on the notion of a "fair test" by introducing and practicing the skill of identifying and controlling variables, we decided it was important to include this "Other Topics" probe.

Related Research

- Students often think mass or weight is the primary factor affecting the period of a pendulum. Some think a pendulum with a lighter bob moves faster while others think that a pendulum with a heavier bob moves faster (Stepans 2008).
- Some students cannot distinguish the effects of gravity, air resistance, and friction from factors that affect the period of a pendulum (Stepans 2008).
- In a study by Carey et al. (1989) upper elementary and middle school students had difficulty understanding experimentation as a method of testing ideas. They tended to view experimentation as a method of trying things out or producing a desired outcome (AAAS 1993).
- Students of all ages may overlook the need to hold all but one variable constant (AAAS 1993).
- Although young children have a sense of what it means to run a fair test, they frequently cannot identify all of the important variables, and they are more likely to control those variables that they believe will affect the result. The more familiar students are with the topic of a given experiment the more likely they are to identify and control variables (AAAS 1993).

Suggestions for Instruction and Assessment

- This probe can be used to launch into an experiment where students need to identify and control different variables in order to determine which factor affects the time it takes for a pendulum to swing.
- With younger children, stress the need to conduct a "fair test." Ask students what needs to be kept the same in order to make the testing of their different ideas "fair." The notion of a fair test with younger children is a precursor to developing an understanding of variables and controls in later, more sophisticated experiments.
- This probe can be combined with "Grandfather's Clock," an everyday science mystery story (Konicek-Moran 2008) that helps students discover how lengthening or shortening a pendulum helps a clock keep time.

- It is not just the length of string that always determines the period (the time it takes to complete one back and forth swing). Help students be aware that it is possible to have the same string length and the same bob or different bobs with the same mass, yet have different periods. The period depends on the shape and orientation of the bob attached to the string. For example, a block shaped like  could have a string tied around its center (hung horizontally) or suspended from its top (hung vertically). When hung vertically, its center of mass (or center of gravity) is lower and the string length would have to be adjusted to account for that. If the string lengths were kept the same, the bob in the horizontal orientation would swing faster than the bob in the vertical orientation because their centers of mass are different. The length of a pendulum is always measured from the end of the string to the center of mass of the bob.
- With young children, avoid the use of terms like *period* and *frequency*. Instead ask them which pendulum swings more times in a given time interval (e.g., 30 seconds or one minute).

References

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

American Association for the Advancement of Science (AAAS). 2009. Benchmarks for science literacy online. *www.project2061.org/publications/bsl/online*

Carey, S., R. Evans, M. Honda, E. Jay, and C. Unger. 1989. An experiment is when you try it and see if it works: A study of grade 7 students' understanding of the construction of scientific knowledge. *International Journal of Science Education* 11: 514–529.

Konicek-Moran, R. 2008. *Everyday science mysteries: Stories for inquiry-based teaching.* Arlington, VA: NSTA Press.

National Research Council (NRC). 1996. *National science education standards.* Washington, DC: National Academies Press.

Stepans, J. 2008. *Targeting students' physical science misconceptions using the conceptual change model.* Saint Cloud, MN: Saiwood Publications.