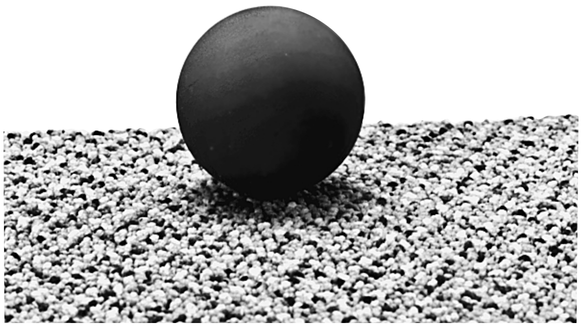
BOUNCEABILITY

Students investigate the bouncing of balls to determine why some are better bouncers than others.



A racquetball on carpet

GRADE LEVELS

Science activity appropriate for grades 4–7
Cross-Curricular Integration intended for grades 4–6

KEY SCIENCE TOPICS

- elastic potential energy
- gravitational potential energy
- kinetic and potential (stored) energy

STUDENT BACKGROUND

This activity should not be used as an introductory lesson on energy. Students should be familiar with kinetic energy, elastic potential energy (springs and rubber bands), gravitational potential energy, and heat. They should have investigated other stored energy toys in Teaching Science with TOYS activities such as "Push-n-Go®" and "Physics with a Darda® Coaster."

KEY PROCESS SKILLS

• measuring	Students measure the heights of ball bounces.
• making graphs	Students graph their data.
• controlling variables	Students plan an experiment to assess the bounceability of various balls.

TIME REQUIRED

Setup	5 minutes
Performance	80 minutes
Cleanup	5 minutes

Materials

For the "Procedure"
Per group of 3–5 students

- 1 each of a variety of balls such as tennis, golf, rubber, Styrofoam™, hi-bounce, metal, clay, and racquetball

- a variety of surfaces to bounce the balls on, such as carpet, grass, flooring tiles, ceiling tiles, metal plate, cardboard, cork, foam pad, and Styrofoam™

➤ *The exact number of balls or surfaces is not important.*

- 1 meterstick
- chart paper for graphs and colored markers
- (optional) construction paper

For "Variations and Extensions"

❶ All materials listed for the "Procedure" plus the following:
- access to a refrigerator or radiator (or other heater)

❷ Per class
- 1 Hoppity Popper or racquetball with top third cut off

➤ *Hoppity Popper is available from American Science and Surplus, P.O. Box 48838, Niles, IL 60714-0838.*

❸ Per class
- 1 Smart Ball™ (by Applied Elastomerics), Splat Ball, or Jelly Ball

➤ *These are all basically the same toy by different manufacturers.*

Safety and Disposal

No special safety or disposal procedures are required.

Getting Ready

1. (optional) Ask students to bring balls from home.
2. Put numbered lists of the balls and surfaces that will be used on the board.
3. For young students, determining how high the ball bounced in centimeters may be difficult. If this is the case, mark the metersticks off into 10-cm sections and wrap each section in a different color of construction paper. The students can then record the ball's bounce height as "blue," "yellow," or some other color, depending upon which color section it bounces into.

Introducing the Activity

Remind the students that they have already investigated several "stored-energy" toys. Review the concepts of kinetic and potential energy using one or more of these toys. For instance, demonstrate a spring-up toy and have the students describe the energy transformations that take place.

Present the following ideas to your students: "A ball would seem to be the simplest possible stored-energy toy; however, we did not begin with it because it is really a lot more complicated than you might think. Today we want to investigate the bouncing of balls to try to determine why some are better bouncers than others."

Part A: Discussing the Variables

1. Show the students the balls they will be testing. Ask them to think about which one will be the best bouncer, then take a vote. Randomly select a few students who voted for different balls. Ask each of these students to explain to the class his or her reasons for selecting a particular ball.
2. Ask the students what variables might affect how high a ball bounces. Some ideas may have come out as students explained their choices in Step 1. If so, write these on the board, then encourage the students to brainstorm other ideas. Possible variables include the material the ball is made of, its temperature, whether it is dropped or thrown, the height from which it is dropped, and the surface that it hits. At this point, do not try to limit the students to ideas that you think are "reasonable."

Part B: Planning the Experiment

If your class does not have prior experience with planning experiments, you could develop the plan through a whole group discussion, rather than through small group work.

1. Tell the students that today you are going to investigate two of the variables that affect how high a ball bounces: the material the ball is made of and the surface on which it is bounced. Tell the students that the first step is to design an experiment that allows them to test both of these variables.
2. Divide the students into groups of three to five. Ask each group to figure out how they could do an experiment to determine which surface makes the ball bounce highest. Depending on their prior experience, you may want to remind them to control variables.
3. Once each group has completed their plan, select one group to explain their plan to the class. Get the rest of the class to critique it. Is it a good plan? Have they forgotten to control one of the variables?

A reasonable experimental plan is to drop each ball from a standard height (such as 1 m) measured from a standard position on the ball (say, the bottom), and then "eyeball" the rebound height when the ball bounces. Whatever dropping height and measuring position on the ball you choose, make sure that all students are consistent.

4. After one good plan is established, ask if any other group has a different idea.
5. If several different plans are proposed, explain to the class that they must choose one plan for everyone to follow so that they can then compare data afterwards.

Part C: Conducting the Experiment

Students should conduct the experiment in their small groups. Each group will need a Ball Dropper, an Initial Height Checker, and one or several Rebound Height Checkers to perform the following jobs:

- *Ball Dropper—to hold the meterstick and drop the ball;*
- *Initial Height Checker—to stand back and make sure the initial height is right; and*
- *Rebound Height Checkers—to note the rebound height.*

A possible way to collect a large quantity of data is as follows:

1. Set up the various surfaces to be tested at different locations around the room.
2. If sufficient wall space is available, tape metersticks to the wall, or tape lengths of paper to the wall so that the Rebound Checkers can mark the paper and measure the height.
3. Assign each group a different kind of ball (or two balls if you have a sufficient quantity of different ones).
4. Have the groups rotate through the locations with different surfaces, testing their ball(s) at each stop.
5. Instruct each group to make a bar graph of their data on chart paper large enough for the whole class to see. They should have a bar for each surface, and the height of the bars should show the height achieved by the bouncing ball. To facilitate comparisons, each group should use a vertical scale of 0 to 100 cm. Have groups post graphs on the wall. For sample graphs, see the Sample Graphs sheet (provided). This sheet is for your reference only; students should make their own graphs.

Make sure all groups put the surfaces on the chart in the same order to facilitate comparisons. Color-coding can be used to increase readability. For instance, all bars representing carpet might be green and all bars representing Styrofoam™ yellow. Colored markers can be used or strips of construction paper cut in advance which can then be trimmed to the appropriate length and taped on the chart.

Class Discussion

Whether you do most of the talking or the students do will depend on their background in energy concepts.

Explain to students that they have clearly demonstrated that not all balls bounce equally and that the surface does indeed have an effect on how high the ball bounces. Discuss the energy transformations that take place as the ball falls and then bounces back. Ask students what kind of energy the ball has before you drop it, while it is falling, and just before it hits the floor. "Why doesn't the ball come back to its original position? Did it lose energy?" (See the "Explanation.")

Now help students apply these ideas to understanding the data on the graphs. Which ball is the best bouncer overall? Remind students that only balls dropped on the same surface should be compared. Saying that a tennis ball dropped on carpet bounces better than a Ping-Pong™ ball dropped on rubber padding doesn't tell you much.

Some of these observations may emerge from your discussion:

- Students may note that the hi-bounce ball is rarely the best bouncer on any surface, but is reasonably consistent from surface to surface.
- Ask students to look at how each of the balls bounced on the foam and the metal. They should observe little variation from one ball to another on the foam. You can explain that the foam deforms easily, so the stiffness of the ball doesn't matter much. Students should observe the biggest variation on the metal plate, because it deforms very little.
- Students may observe that the clay bounces significantly only on the foam and does not bounce at all on the metal and floor tile. The clay loses its kinetic energy in a permanent shape change when it hits hard surfaces, so it can't bounce back up.

Continue the discussion as long as the students are interested in thinking about the reasons why different kinds of balls bounced differently on the test surfaces.

Explanation

The following explanation is intended for the teacher's information. Modify the explanation for students as required.

Before the ball is dropped, it has an amount of gravitational potential energy that depends on its height above the floor. As the ball falls, this potential energy is gradually turned into kinetic energy. The greater the ball's speed as it falls, the greater the kinetic energy. On the way back up, the kinetic energy is being turned back into potential energy. At the top of the bounce, the ball's energy is once again all potential energy. Since the ball does not bounce back to its starting height, it has less potential energy now.

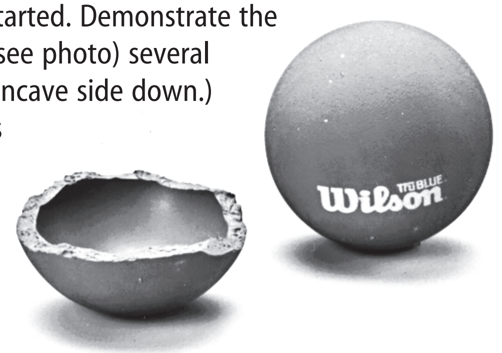
Since energy cannot be "lost," the missing energy must go into some other form of energy. The energy transfer happens during the interaction between the ball and the surface. Part of the energy goes into the sound waves that are produced when the ball hits the surface. Part of the energy is converted to heat in the ball and in the surface. You can observe this if you drop a ball of clay several times in rapid succession. The clay will begin to feel warmer.

What determines how high different balls bounce on the same surface? Much of the difference is a result of how much the balls deform and even more importantly how fast they "un-deform." During the bounce, the shape of the ball changes. This shape change takes energy, just as stretching a rubber band does. Flattening the ball is similar to compressing a spring. You get the energy of compression back as the shape goes back to normal. The clay doesn't bounce well because it stays deformed. If the ball is still partially deformed after it leaves the floor (or other surface), the energy that was stored in that deformation does not return to kinetic energy of the ball even though the ball does later return to its original shape.

What determines how high the balls bounce on different surfaces? During the bounce, both the shape of the ball and the shape of the surface are deformed. The height of the bounce is determined by how much energy of compression is returned as the shape of both the ball and the surface go back to normal. Each ball type and surface type interact differently, producing a unique result. Even so, some surfaces produce fairly consistent results with all types of balls. For example, all the balls bounce in the foam, because the foam deforms rather than the ball, acting much like a trampoline. In contrast, if the surface stays deformed as the Styrofoam™ may, then the energy that went into causing the deformation does not return to the ball.

Extensions

1. Test the prediction that temperature affects bouncing by cooling several balls in the refrigerator overnight or heating them by a radiator or other heater. Measure how high the heated or cooled balls bounce and compare this data with the "room-temperature" measurement.
2. Ask the class if there is any way a dropped (not thrown) ball can bounce back up higher than where it started. Demonstrate the Hoppity Popper or cut-off racquetball (see photo) several times. (Turn it inside out and drop it concave side down.) Ask for possible explanations of what is happening. After discussing students' ideas, explain the following: "When you turn the Hoppity Popper inside out, you are storing energy in it just like stretching a spring. When the Hoppity Popper hits the floor, it returns to its original shape and the energy you stored is converted to kinetic energy. Thus, as the kinetic energy is changed back into gravitational potential energy, it has enough energy to surpass its initial height."



3. Balls made of a soft polymer are marketed as Splat Balls or Smart Balls™. If thrown at the floor, these spread out almost completely flat then slowly reform. This is a very visible example of the deformation of the ball when it hits the floor.

If your ball stops working properly, wash it with soap.

Assessment

This assessment can be done either individually (written) or as a group (oral). If done as a group assessment, explain that all members of the group are responsible for the "answer," as any one of them could be asked by the teacher to respond.

Ponder one of the following questions:

1. Explain what playing basketball on a carpeted court would be like.
2. You and your friends are all set to play baseball, but you can't find the ball. Your little brother comes up with a tennis ball. You decide to try it. How will your game be different?
3. Some tennis tournaments are played on grass. How do you think those games are different from those played on a paved court?

Cross-Curricular Integration

Language arts:

- Read and discuss the book *The Pinballs,* by Betsy Byars (Scott Foresman, ISBN 0673801365). In the book, one of the foster children describes herself and the others as pinballs—they bounce from here to there, wholly dependent on those around them.
- Have students imagine what it would be like to be a certain type of ball and explain in writing how they would react to different surfaces and how the surfaces would affect their bouncing.
- Have the students invent and describe a brand new game using one of the tested balls and a surface other than the one it is typically used on.

Math:

- The activity involves measurement, graphing, and charting.

Physical education:

- Discuss why different kinds of balls are used in different sports.

Further Reading

Doherty, P. "That's the Way the Ball Bounces," *Exploratorium Quarterly.* Fall 1991. (Teachers)

Turk, J.; Faughn, J.; Turk, A. *Physical Science;* Saunders College: Philadelphia, 1991; pp 59–66. (Teachers)

Kaplan, N. "But That's Not Fair," *Science and Children;* April 1984. (Teachers)

Kirkpatrick, L.; Wheeler, G. *Physics: A World View;* Saunders College: Philadelphia, 1992; pp 117–132. (Teachers)

Radford, D. *Science from Toys;* Macdonald Educational: London, 1972; Chapter 7, Science 5/13. (Teachers)

Stone, H.; Siegel, B. *Have a Ball;* Prentice-Hall: Englewood Cliffs, NJ, 1969. (Students)

Contributors

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Sample Graphs