Bouncing Basketballs: How Much Energy Does Dribbling Take?

Experimental Procedure

This project follows the Scientific Method. Review the steps before you begin.

Note: In addition to doing a physical experiment, you can also run a computer simulation of a bouncing ball as part of this project. See the Simulate a Bouncing Basketball with Code section at the end of this procedure.

Videotaping the Basketball Bounces

1. Prepare the wall, or other vertical panel, next to the first surface you want to test so that you can measure the height of the basketball's bounce.
    a. On the wall next to the surface, use a tape measure and the blue painter's tape to mark every 20 centimeters (cm), starting from the floor and going up to 100 cm. You should end up with five tape marks, as shown in Figure 3.
    b. *Note:* You can make the tape marks longer than the ones in Figure 3, so they will be easier to see in the video recording. Remember to put the *top edge* of the tape at the every 20 cm mark.

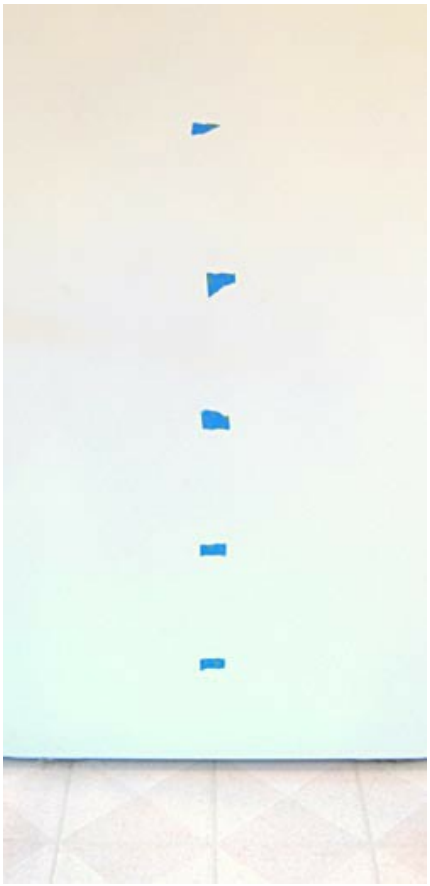

Image Credit: Teisha Rowland, Science Buddies / Science Buddies

Figure 3. On a wall or other panel next to the surface you want to test, place strips of painter's tape every 20 cm, starting from the floor and going up to 100 cm. The test surface shown here is linoleum, and the tape was placed on a refrigerator.

2. Set up the video camera so that all of the marked measurements and the floor are in view. It is best to record the bounce as straight on, or as evenly framed in the viewfinder, as possible. You can either have a volunteer run the camera for you, or set the camera up on a tripod.
    a. *Tip:* If you use a mini tripod, you need a raised surface nearby, such as a chair, to set the tripod and camera on.
3. Test the basketball on the surface:
    a. Either ask your volunteer to start the video camera or, if you do not have a volunteer, begin recording with the video camera on its tripod.
    b. If you are using note cards to visually keep track of your trials, show a note card with the trial number written on it in front of the camera briefly, before you do the experiment. Alternatively, you can just say the trial number so you can hear it later on the recording. (The first trial you do will be Trial 1.)
    c. Hold the basketball so that the bottom of it is lined up with the top edge of the highest tape mark you made, as shown in Figure 4. Also hold the ball close to the wall, not more than about 5 cm away.
        i. Make sure your body is not blocking the camera's view of the basketball and the tape-marked wall.
        ii. *Tip:* If you have a volunteer helping you, ask them to check if the bottom of the basketball looks lined up with the top edge of the tape mark when looking through the camera.
    d. Drop the basketball. (Do *not* push it down.)

e. Let the basketball bounce back up and then hit the ground a second time before you catch it in your hands and stop recording it.

Image Credit: Teisha Rowland, Science Buddies / Science Buddies

Figure 4. To record the basketball's bounce, hold it so that the bottom of the ball is lined up with the top tape mark, at 100 cm, before dropping the ball.

4. Repeat step 3 at least nine more times with the surface you just tested, for a total of at least ten trials of this surface.
    a. If, in any of the trials, it looks as if the ball did not bounce straight back up, but went slightly to the side, then do an additional trial.
5. Repeat steps 1 to 4 with the other surfaces you wanted to test.
    a. You need to test at least three surfaces total, including at least one hard and one soft surface. The surfaces you test should all be flat.
    b. For consistent results, try to hold the basketball for each trial the same distance from the wall and also position the camera at the same approximate height (keeping the camera and tripod placed on the same chair and then moving the chair to the new surface is a good way to do this).
    c. *Note:* If you are testing a surface that is at a very different temperature (such as concrete outside on a cold day), you will want to do your trials quickly so that the ball does not change temperature. A change in the ball's temperature can affect how it bounces. You could try doing one trial at a time and bringing the basketball inside in between the trials to let it warm back up.

Analyzing Your Results

1. Once you have finished testing the surfaces, make a data table in your lab notebook similar to Table 1. You will record your data in this data table. Table 1 has already been partly filled in as an example — fill in the exact surfaces you tested in your own data table. For each surface, describe how hard it is in the "Hardness" column. See examples in Table 1.

	Surface	Hardness	Drop Height (cm)	Bounce Height (cm)	Height Difference (cm)	Average Height Difference (cm)
Trial 1	Carpet	Soft				
Trial 2						
Trial 3						
etc.						
Trial 1	Wood	Hard				
Trial 2						
Trial 3						
etc.						
Trial 1	Concrete	Very Hard				
Trial 2						
Trial 3						
etc.						

Table 1. In your lab notebook, make a data table like this one to record your results.

2. Now watch your videos closely and fill in the "Drop Height (cm)" and "Bounce Height (cm)" columns in your data table with your results. Watch your videos on a computer or other large screen so you can make detailed observations. Because the actual drop heights and bounce heights will vary slightly from trial to trial, you need to determine them by examining the video carefully.
    a. Watch the videos for each trial using slow motion and/or pause the recording right before the basketball is dropped, and then when it is at the highest point in its first bounce.
        i. Right before dropping the ball, it is at its drop height.

ii. When the ball is at its highest point in its first bounce, it is at its bounce height.

b. Do your best to use the tape marks on the wall to help you estimate the drop height and the bounce height.

c. Always measure the drop height and the bounce height from the bottom of the basketball.

d. The drop height should be close to 100 cm, but you should review the videos to see if it was actually a little above or below 100 cm. For example, in one trial it might have been at about 105 cm, whereas in another trial it could have been closer to 95 cm.

e. Do not count any trials where it looks as if the basketball did not bounce straight up, but instead went off to the side.

3. Calculate the height difference for each trial and note it in your data table. To calculate the height difference, subtract the bounce height from the drop height.
   a. For example, if your drop height was 105 cm and your bounce height was 60 cm, your height difference would be 45 cm (since 105 cm - 60 cm = 45 cm).
4. Calculate the average height difference for each surface and record this in your data table. Do this by calculating the average height difference for all of the trials for a given surface.
   a. For example, if your height difference for ten trials with a surface were 60 cm, 63 cm, 65 cm, 64 cm, 61 cm, 60 cm, 60 cm, 65 cm, 63 cm, and 62 cm, your average height difference for that surface would be 62 cm (the sum of these numbers divided by ten, since there were ten trials).
5. Make a bar graph of the average height difference for each surface.
   a. Put the name of the surface on the horizontal axis (x-axis) and the average height difference (in cm) on the vertical axis (y-axis).
   b. You can make the graph by hand or use a website like Create a Graph to make a graph on the computer and print it.
6. Look at your data and your graph and analyze your results.
   a. How high did the basketball bounce relative to its drop height when dropped on the different surfaces? Which surface enabled the ball to retain the greatest height relative to the drop height, and bounce the highest? Which surface caused the ball to lose the most height?
   b. Based on your results, which surface do you think absorbed the least amount of energy from the basketball, enabling the ball to bounce the highest?
   c. Can you use your results to help explain why a basketball court has the surface that it does?

Simulate a Bouncing Basketball with Code

In addition to doing physical experiments, you can use a computer program to simulate a bouncing basketball. This lets you change things that you cannot change in the real world, like gravity! See the Variations section for more ideas about how you can use the code for your project.

1. Click the "Run" button below to animate a bouncing ball.
2. The simulation is written in a computer programming language called JavaScript. You can see the code below the animation window and even edit it yourself! The brown lines of text are comments that explain what the code does. Numbers, called variables, that you can change are shown in green.
3. Use the "Code" section after the simulation to change variables and see what happens to the ball.
4. Table 2 after the code explains what the different variables are. Note: entering strange values for some variables may

cause the ball to disappear or quickly go off screen, but try it and see what happens!

5. If the simulation stops working or you make a mistake in the code that you cannot fix, refresh the page to reset the code.

Simulation

Run

Code - edit the variables here and then run the simulation again!

```
// Change the values of variables below and see what happens in the simulation!

// Set the initial conditions to determine where the ball starts and how fast it is going.
var x0 = 2;  // initial horizontal position in meters (x=0 is the left edge of the animation window)
```

Variable	Units	Description	Code (change the underlined number)	Notes
x0	meters (m)	Initial horizontal position of the ball	var x0 = 2;	The left edge of the animation window is x=0 and the right edge is x=4. Entering values outside this range will cause the ball to start offscreen.
y0	meters (m)	Initial vertical position of the ball	var y0 = 2;	The bottom edge of the animation window is y=0 and the top edge is y=4. Entering values outside this range will cause the ball to start offscreen.
vx0	meters per second (m/s)	Initial horizontal velocity of the ball	var vx0 = 0;	A positive value for vx0 is like throwing the ball to the right. A negative value is like throwing the ball to the left. A value of zero means the ball will only move straight up and down, not to either side. If you make this value too big, the ball may go off screen very quickly.
vy0	meters per second (m/s)	Initial vertical velocity of the ball	var vy0 = 1;	A positive value for vy0 is like throwing the ball up. A negative value is like throwing the ball down. A value of zero is like dropping the ball without throwing it up or down. If you make this value too big, the ball may go off screen very quickly.

Variable	Units	Description	Code (change the underlined number)	Notes
g	meters per second squared (m/s^2	Acceleration due to gravity	cons g = 9.81;	Earth's gravity is 9.81 m/s^2. This means that for every second an object falls, its speed will increase by 9.81 m/s. Try changing this to a different value. Can you look up the gravity on other planets like Mars? What happens if you enter a negative number?
CR	none	Coefficient of restitution	const CR = 0.9;	This variable determines how "bouncy" the ball is. If CR=1, no energy is lost, and the ball will bounce back to its initial height. If CR=0, all the energy is lost, and the ball will not bounce at all. Real-world CR values should be somewhere between 0 and 1. Can you find a value such that the results of your simulation match your physical experiment? What happens if you enter a negative number or a number greater than 1, which is not physically possible in the real world?
ballRadius	meters (m)	The radius of the basketball	var ballRadius = 0.12;	Change this to change the size of the basketball in the animation.

Table 2. Variables you can change in the basketball simulation code.

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