

PSI:

PHYSICAL SCIENCE INVESTIGATION



Teacher's Lesson Description

Title	On The Ball
Brief Description of the Videos	Dante performs a demonstration of the conservation of momentum and kinetic energy as a collision occurs when a small rubber ball (tennis ball or a small basketball) is held on top of a normal basketball several feet from the ground. Both are dropped. As they bounce, the basketball rebounds from the floor and propels the smaller ball much higher than its initial height. The experiment is repeated with three different sized balls with exciting results.
Time Needed	The experiment can be completed in one 45 minute class period. Longer times can be used for extended experiments and discussions.
Ohio Science Benchmarks Addressed in This Activity	Grades 6-8 PS Benchmark B Grades 6-8 SI Benchmark A Grades 6-8 SW Benchmark A
Ohio Grade Level Indicators Addressed in This Activity	Grade 7 SI Indicators 1, 2, 3 Grade 8 SW Indicator 1
Concepts Developed	Momentum can be transferred through collisions. Conservation of momentum and kinetic energy.
Lesson Rationale	This lesson demonstrates that the energy that a dropping object has (its kinetic energy,) can be transferred to another falling object when the two collide. That is, momentum can be transferred through collisions. This lesson will guide students through Scientific Ways of Knowing and the inquiry process.
Background Knowledge for Teachers	Teachers need to know the following concepts:

	<ul style="list-style-type: none"> • Kinetic Energy-- The energy possessed by a body because of its motion, equal to one half the mass of the body times the square of its speed. • Momentum- -the product of the mass and velocity of an object ($p = mv$). • The law of conservation of momentum is a fundamental law of nature, and it states that the total momentum of a closed system of objects (which has no interactions with external agents) is constant. One of the consequences of this is that the centre of mass of any system of objects will always continue with the same velocity unless acted on by a force outside the system • Momentum can be transferred through collisions. • Predicting the result of the collision will necessarily include variables like the height from which the balls are dropped, the relative masses of the balls, the elasticity or "coefficient of restitution" of the objects - how much they deform and rebound • There are unbalanced forces at work, too. The larger ball generates more force ($F_1 = M_1 a > F_2 = M_2 a$ if $M_1 > M_2$) when dropped, and has more momentum ($P_1 = M_1 v > P_2 = M_2 v$) when it hits and rebounds, so, on the rebound, transferring this greater force/greater momentum to the smaller mass results in the larger rebound. If the larger ball were placed on top, then the collision and rebound would look much different.
Classroom Procedures	<ul style="list-style-type: none"> • Start the demo by showing the first part of the video. • Ask the students about the dropping of a single basketball. Have them discuss the factors that impact its bounce. • Drop a single basketball and continue the discussion. • Next show the second part of the video. Discuss what will happen when the two basketballs are dropped together.

	<ul style="list-style-type: none"> • Show the two basketball video. Try this in the classroom too. • Discuss the results and start discussion and get student predictions about dropping a small ball and a regular basketball. • Show the next part of the video. If you have the room and the basketballs try this part too. • Ask students why the mini-ball was “launched” when it was dropped on top of the falling basketball. Discuss what was going on here. • Show the next video segment. Discuss what will happen now. (Students may be able to guess the correct result without understanding the principles involved. See if they can come to an understanding of the transfer of momentum that includes the mass of the object as the variable.) • Show the video of the three balls being dropped together. Only try this if you have a large gym or are outside. Discuss why the small ball was “launched” so high. • Show the science explanation part of the video ONLY after the students have fully discussed and understand the possible explanations. The transfer of energy is the key to this experiment. If they do not understand this concept, it needs to be repeated. <p>You can also try dropping the basketball on top of the tennis ball. Notice that collisions can also act to remove energy from a ball. Other investigations can be done in which the elasticity, or “bounciness” of the balls can be changed, relative masses can change, drop heights can be varied, all resulting in opportunities for inquiry through student predictions and investigations.</p>
Materials Needed	<ul style="list-style-type: none"> • A regulation basketball, • A small basketball, • A tennis ball. • A tape measure can also be useful.

	<ul style="list-style-type: none"> • Eye protection
<p>Science Connections</p>	<p>Why does this happen? Think about the basketball bouncing off the floor.</p> <p>A dropped ball accelerates down pulled by gravity.</p> <p>If the center of the ball drops by one meter it hits the floor with a speed about $V_1 = 4 \text{ m/s}$.</p> <p>When the ball hits the floor the ball changes shape and pushes against the floor. At the same time, the floor pushes up on the ball slowing its downward speed at first and then accelerating it back up. If no energy is lost as heat when the ball deforms, then the ball leaves the floor heading up at the same speed with which it hit the floor, 4 m/s. It then rises to the same height from which it was dropped. If any energy is lost then the ball leaves the floor at a slower velocity and rises to a lower height (This is what actually happens).</p> <p>The ratio of the speed after the collision, v_a, to the speed before the collision, v_b, is called the coefficient of restitution. $COR = v_b/v_a$.</p> <p>Now let's look at two balls, a smaller ball and a basketball being dropped, one on top of the other.</p> <p>The lower basketball behaves as described above. Bouncing upward off the floor at $V_1 = 4 \text{ m/s}$. The smaller ball is still falling at $V_1 = 4 \text{ m/s}$.</p> <p>The smaller ball bounces off the basketball. It comes in at 8 m/s and it bounces up at $2V_1 = 8 \text{ m/s}$. This means it is going upward 8 m/s faster than the basketball.</p> <p>This is a general result, when a light ball is dropped onto the floor on top of a heavy ball and no energy is lost to heat then the light ball will bounce upward at three times the velocity with which it would have hit the floor if dropped alone.</p> <p>This becomes even more impressive when you realize how high the light ball will bounce. The</p>

	<p>maximum height of a ball thrown straight upward occurs when the ball stops at the top of its trajectory. All of its energy is potential energy, $E = mgh$ where g is the acceleration of gravity, m is the mass of the ball and h is the height. The energy as the ball leaves the floor is kinetic energy, $E = 1/2 mv^2$. When this kinetic energy is converted to potential energy then $1/2mv^2 = mgh$, and $h = 1/2 v^2/g$. So the height is proportional to the velocity squared. Thus the smaller ball could go up to as much as nine times higher than the height from which it is dropped!</p>
<p>Additional Web Resources</p>	<p>Scientific Explorations with Paul Doherty http://www.exo.net/~pauld/activities/physics/bouncingballs.html</p> <p>Gravity Assist--Getting a boost from a collision: http://www.exo.net/~pauld/activities/astronomy/gravityassist.html</p> <p>The basketball trick from Exploratorium physicist Paul Doherty http://www.exploratorium.edu/baseball/baseketball.html</p> <p>A video version of the basketball experiment by Robert Krampf http://www.wonderhowto.com/how-to/video/how-to-bounce-a-tennis-ball-higher-than-a-house-210079/</p> <p>An explanation of the bouncing basketballs by The Physics Circus from the UCSB Physics Department http://www.physics.ucsb.edu/~circus/energydemo.htm</p> <p>Toys like “The Astro Blaster” can dramatically demonstrate the effects of transferring momentum through multiple stages of highly elastic collisions. Be sure to wear ANSI-approved goggles whenever you experiment with collisions!</p>

Ohio Science Standards Abbreviations:

ES – Earth/Space Science

LS – Life Sciences

PS – Physical Sciences

SI – Scientific Inquiry

ST – Science and Technology

SW – Scientific Ways of Knowing

