GRAPPLING WITH GRAVITY

There is little that's more awe-inspiring in a basketball game than a gravity-defying slam dunk. It takes an amazing amount of athleticism to achieve these showy feats, as well as a healthy knowledge of physics. Explore some of these physics based activities to see how you can capture some of this rim-rattling magic.

Pro tip: This activity can be done at home or in a classroom. It can be done by an individual student, a small student group, or a family.

HERE'S WHAT YOU'LL NEED:

- **Ball** *(or round object)* **that's easy to hold in your palm**
- **Ball** *(or round object)* **that's just a bit too big to hold comfortably in your palm**
- **Disposable paper or plastic cup**
- **Heavy duty string/nylon cord**
- **Scissors**
- **Hole punch** *(optional)*

WARM-UPS

Slam dunks are showstoppers of a game, and are such awesome photographic opportunities that they are often immortalized on posters or magazine covers. There's even an entire exhibition of fantastic and physics-defying dunks every year at the NBA Slam Dunk contest. Are these goals truly physics-defying, though, or do they actually employ such an understanding of physics that they only seem superhuman?

There are two main principles that factor into slam dunks—center of gravity and centripetal force. The center of gravity is the exact midpoint of a body or object where the weight is evenly dispersed and all sides are in balance. Where do you think the center of gravity is on humans?

You've probably noticed that NBA players greatly extend their arms and legs as they vault themselves to the goal. To figure out why, try this experiment. Standing with your feet hip width apart, see how high you can reach with both arms stretched above your head. Now, try it with only one arm stretched up. In which position were you able to reach higher? What would cause this?

Next, take the two different sized balls (or pieces of fruit, or other round objects) you collected. Using the smaller one, grip it in your palm and move your arm. Try moving your arm in a circular fashion through your shoulder—almost like a windmill or rock star jamming out on a guitar solo. Were you able to maintain control of the ball easily or did you feel like you had to grip really hard?

Now repeat these tests using the larger ball—the one that is slightly too big for you to comfortably hold in your palm. Repeat the rotational motion with your arm while palming this ball. Are you able to hold onto it? If you are, does it feel like it's about to slip from your hand at any point but it still remains? What do you think might cause this? Do you think basketball players experience the same thing?

Now that you have experimented keeping a ball that was too large to hold traveling in a circular path, and hopefully did so successfully, you may have noticed some science at play. To understand what is going on, we should look at what forces were involved. A force is an interaction with an object that when left unopposed changes the motion of the object.

What was interacting with the ball to keep it moving? What kept the ball in your hand when it was too large to hold over your head? Where was the center of the rotation when you spun the ball around?

You may be discovering that you have better basketball skills than you originally thought or that science is on your side and helping you out. There is still more to discover though.

GAME TIME

Now that you've experimented a bit with using forces to keep a ball traveling in a circular path without dropping, see if you can take this knowledge to more daring heights. With a little bit of practice, you're going to make a cup full of water seemingly defy gravity!

PRO TIP: This activity is definitely going to get a little messy, so it's best to practice it outside. If the weather prevents this, have a teacher, parent, or adult find a safe space indoors where it's okay for you to spill some water. (Don't forget to clean up after yourself when you're done!!)

Begin by taking a paper or plastic cup and use the scissors or hole punch to cut two holes near the top of your cup. The holes should be directly opposite each other. Cut a piece of string or cord that's about as long as you are tall. Tie one end of the string to each hole in the cup so that it forms a long handle. You may want to use a little tape to reinforce the connections.

Before you add any water to the cup, try twirling it to get the hang of how it feels. You may need to add something with a little bit of mass to the cup so you can practice twirling it. Peas, jellybeans, and grapes are all easy to clean up if they come crashing to the ground. There are two different ways that you can spin the cup to demonstrate centripetal force. One way is to spin it in a vertical circle, or with the cup moving parallel to the ground. Imagine that the circle the cup is making is like a frame around you. The other way to spin it is in a horizontal circle, or above your head like a lasso.

When you're done practicing (and are no longer losing small bits of food everywhere), fill the cup about halfway full of water. Begin by trying to spin the cup vertically, in a big circular arc in front of yourself. How difficult is it to spin it so that the water stays in the cup? How fast do you have to spin it to achieve this? (If the water spills out of your cup, just add more water as needed!) If you're struggling to spin it without spilling it at all, try changing the speed at which you spin it or the amount of water in the cup.

If you've mastered spinning the cup vertically, try spinning it horizontally like a lasso above your head. How fast do you have to spin it to achieve this? (If you're finding it difficult to spin the cup of water horizontally, try thinking of it exactly as a lasso. Begin by spinning it vertically, and then—while still maintaining full speed—start angling it slowly upwards until it is horizontal over your head.)

ANALYZE THE REPLAY
What happened?

How long did it take you to successfully spin the cup without spilling any of the water? What were the techniques you had to change or adapt as you practiced it? What do you think would happen if you added more water? How do you think the experiment would change if you made the string longer or shorter?

How do you think spinning water in this windmill pattern is like an OKC Thunder player scoring two points with a rim rocking dunk?

To understand how the water seemingly defied gravity, and how Thunder players can soar over an opponent without losing the ball and then dunk it, we need to look at what forces are at play.

Let's just focus on the spinning of the ball up and over the opponent. Many of the same forces are involved as are used to make the water hang in the cup without spilling on your head.

Everything is spinning around a center of rotation. In the case of the water and the basketball, this center is a shoulder. Your arm is applying a force to the object (the cup of water or the ball) putting the object in motion. Because your shoulder is the center of the rotation, that path becomes a curved path. Your arm uses the force of tension to hold the object in this curved path. The object is being pushed one way but another force keeping the object is a curved path. This is called **centripetal force,** and it describes a force that keeps an object moving in a curved path directed inward toward a center of rotation.

What are some other examples of times when you have experienced centripetal force?

OVERTIME
Let's take it further

You've mastered using centripetal force to spin one cup upside down without spilling the water—what if you could spin three or four cups at once, or even an entire bucket of water? Both of these things can be achieved! If you have an empty bucket on hand, do some stretches to really loosen up your shoulder sockets, and then see if you can spin the bucket all the way around in a vertical arc. If you can, put some water in the bucket and give it a go! Were you able to successfully make the water defy gravity, or did you end up with an impromptu shower?

If you want to develop a really elaborate party trick, you can actually make a tray to hold several cups that you can spin at once. You'll need a square foot of plastic or wood. With an adult's help, drill holes in all four corners that are big enough to fit whatever rope you're using. Then, attach your rope to all four corners and gather the four loose pieces together in a knot about 2 feet above the tray. Then, you can put one, two—maybe even four plastic cups on your tray and practice swinging the entire contraption around while you show off your knowledge of centripetal force.

Remember!! Practice any of this water spinning outside or in an approved space that can get wet, and always clean up any messes you make!

You can watch Rumble use the centripetal here: **Science Experiments with Rumble | Oklahoma City Thunder (https://www.nba.com/thunder/rumble/smo-experiments)**

COACH'S CORNER
Additional information and explanations for parents and educators

In this activity, students experimented with physical challenges that demonstrated the physics principles of **center of gravity** and **centripetal force.** Both of these are reasons NBA players are able to execute such incredible and jaw-dropping dunks in games and exhibitions. While the trajectory for one's center of gravity can't be changed once their feet leave the ground, it can be controlled to a certain extent—that is, with incredible physical fitness and personal awareness. This technique is a skill high jumpers hone in track and field, as well as one NBA players possess.

Using centripetal force to their advantage is what allows players to dunk the basketball into the net. Not only do they employ incredible fingertip and hand strength gripping the ball, but by moving their arm in a circular arc through their shoulder, the ball stays in their palm as they leap through the air exactly the same way the water stayed in the cup when students spun it around.

OKLAHOMA ACADEMIC STANDARDS: SCIENCE

STANDARDS	4th Grade	5th Grade	7th Grade
4.PS3.1: Energy	●		
4.PS3.2: Energy	●		
5.PS2.1: Motion and stability: Forces and interactions		●	
7.PS3.1: Energy			●