INNOVATION AT PLAY

MAGNUS EFFECT EXTENSION ACTIVITY

READY, SET, GOAL

OBJECTIVES

Students will be able to:

- Understand how the Magnus effect applies to sports.
- Experience the Magnus effect and apply it to sports and then vehicles.

OVERVIEW

Students will explore the role of the Magnus effect on football/soccer. First through the lens of professional athletes during set plays, then by playing with *Flying Cups*. Students will be able to take their understanding of the Magnus effect onto the football pitch and see how their feet connecting with the ball impacts its movement. Afterwards, students will be given an extension challenge to apply the Magnus effect to vehicles.

MATERIALS FOR ALL ACTIVITIES

- Phone, tablet, or computer
- Printer
- Two cups
- Tape
- Rubber bands
- Empty 20oz plastic bottle with cap
- 4 Additional plastic caps
- Matchbox
- Scissors
- Thumbtack
- Hot glue or super glue
- 2 Straws
- 2 Skewers (longer than the width of the matchbox)
- Wind source such as a vacuum cleaner with hose, shop vac, or a fan (can roll up a piece of paper or use a cardboard tube to focus the wind from the fan)

PROCEDURE

- First watch: https://www.youtube.com/watch?v=1B_7JxGsK7Y
    - Explain to students that although it's not realistic to expect direct corner kick goals, set pieces are an integral

part of scoring. Having control over where the ball goes on the pitch is essential to the success rate of a set piece. While Juninho's powerful knuckle shot has set him apart as one of the greatest free kick specialists ever, many players rely on control and placement for scoring opportunities. The question, however, is what is happening with the ball that allows for curvature and placement on those set pieces? This is known as the Magnus effect. The Magnus effect is when a force is put onto a spinning object, like a ball, moving through a fluid, like air, that results in the path of the spinning object following an angle on the axis of the spin. In other words, putting a strong spin on a soccer ball by kicking it off-center will make the ball curve in the air. Let's do a little experiment to see how we can manipulate the Magnus effect to control the object we use.

- Gather your materials for *Flying Cups*
    - Two cups (Plastic, Styrofoam, Paper, etc.)
    - Tape
    - Several rubber bands
- Directions
    1. Tape the two cups together, base to base.
    2. Interlock the rubber bands together to make one long rubber band.
    3. Using your thumb, hold down one end of the rubber band at the center of your flying cups, and using your other hand, start wrapping the rubber band around the center towards yourself. Make sure you finish your wrap with the rubber band at the bottom of the flying cups with the hand holding the end of the rubber bands facing away from you.
    4. Pull the flying cups straight back and release.
- Have students describe the motion of the flying cups. Why do they think the cups moved that way?
- This time, repeat steps 3 and 4, but wrap the rubber band *away* from the student.
    - Have students discuss the following:
        - Did the flying cups move the same way?
        - What do they think will happen if you change the starting orientation of the flying cups?
        - Instead of the cups being horizontal, what happens if the flying cups are vertical?

Try using different materials for your cups. Do the cups fly differently?

- Print out the targets for Target Practice
    - Place targets behind an object directly in front of students. The object should be about 1m away from the students, with the target behind that another 1m. For example, there is a tree/plant 1m in front of the students, the printed target should then be 1m behind the tree/plant (the students should not have a direct line of sight of the target). Manipulate the flying cups to hit the target by going around either side of the object or above it. Increase the challenge by moving the object and target further away from the students, or by making the obstructing object wider or taller (think a wall of players during a free kick).
- Have students discuss how they found success.
    - What did they notice about the power and speed of rotation needed to hit the target as distances changed?

  - Flying cups are pretty light, so how would they adjust for something with more mass; like a ball?
- Grab a football/soccer ball and find a place to do some free kicks.
  - While students may have observed penalty kicks apply the Magnus effect to score, ask students why do we place a curve on the ball in the air?
- Explain to students that there are two main reasons, one is to make the ball harder for the defense and goalie to follow the ball and know where it will land. The other reason is that it serves as a force multiplier when contact is made, assisting the attacking player in doing a stronger shot.
- Remind students of Newton's 3rd Law. For every action, there is an equal and opposite reaction. The more force the ball comes at you when contact is made, the more force is then applied back at the ball.
  - If you are on the pitch, use the goal post as the target. However, if you don't have a goal post, any object can serve as your target for this activity. Make sure the ball is approximately 20m away from the goal post/target. This is roughly the distance from the top of the arc on the penalty box to the goal line.
  - Place another object (ideally the obstacle has a little bit of height to it) that will serve as the student's obstacle approximately 10 meters away. Have the student attempt to hit the target by going around the object.

A defender cannot be closer than 9.15m away during a free kick.

- Ask students how they found success.
  - Were they able to hit your target around the obstacle? Does moving the ball back 5m make is easier or harder?
  - Hint: If the students are having some trouble getting the Magnus effect to apply to the ball, think about how much spin and power were needed for the flying cups. They need to hit the ball off-center with a strong amount of force. They also need to think about where on our feet are they making contact with the ball. Make sure to hit the ball with the in-step part of their foot, the area between the toes and the inside arch, and have their toes pointing up on contact. Think about it as shooting the ball to a spot rather than passing the ball to a spot!
- Extension
  - Have students try to hit the goal post/target with an outward curve.

EXTENSION OVERVIEW

- While the Magnus effect has certainly made its impact felt in sports, where else has it made its impact in the real world? That would be in the air and sea! The Magnus effect is one of the core concepts that helped us understand how to use the wind as a source of power to move things. This is called a Flettner rotor. Remember our flying cups? Some early airplane designs used horizontal cylinders called Flettner rotor wings to assist in low elevation flight, but found it unsustainable. The Fletter rotor was used on ships and would allow control of the direction of the ship regardless of wind direction. They were essentially giant, smooth cylinders that would spin in place, and the wind blowing on them would allow for movement. While the Flettner rotors were found to be successful in the mid-1920s, they were short-lived due to fuel prices and diesel engines becoming more readily available and affordable. Today, Flettner rotors have seen a resurgence as a way of increasing fuel efficiency and sustainability. They operate as part of a hybrid ship to reduce the amount of fuel consumption.

If you have a tiny DC motor, you may replace the thumbtack and use the DC motor instead. This may require some adjustments in the materials, such as the matchbox, due to the weight of the motor.

- Have students gather their materials to build a Flettner Rotor Car
    - Empty 20oz soda bottle with cap
    - 4 additional plastic bottle caps (to serve as wheels)
    - Matchboxes
    - Scissors
    - Thumbtack
    - Hot glue or super glue
    - 2 Straws
    - 2 Wooden skewers (must be longer than the width of the matchbox)
    - Vacuum cleaner with hose attachment, shop vac, fan, etc. (anything that can provide continuous source of wind)
- Directions:

5. Cut the straws so that it is approximately the width of the matchbox.
6. Insert a wooden skewer into one straw and insert into a bottle cap on each end. This will create your axle and wheels.
    a. Once your have punched a hole, through the bottle cap with your skewer end, apply some glue into the hole and set the skewer end inside the hole. This will help keep your wheels attached to the axle.
    b. Repeat this process for the other skewer, straw, and two bottle caps.
7. Glue your straw onto the bottom of the matchbox, so that you now have the foundation for our Flettner Rotor Car.
8. Using a thumbtack and our empty 20oz. soda bottle with cap, punch a hole through the bottle cap.
9. Center the thumbtack under the top layer of the matchbox and punch through. Glue down the thumbtack to the matchbox.
10. Place the 20oz. bottle onto the thumbtack. The bottle should now be upside down on top of the matchbox. Test your Fletter Rotor by spinning the bottle. Make sure the thumbtack and bottle stay on the matchbox.
11. Test your Flettner Rotor Car by first pushing it along to see if the wheels move freely.
12. Take your wind source and apply it at the bottle. Try the left of the bottle, center, and right of the bottle.
13. Try spinning the bottle and then applying the wind source.

- What happened to your Flettner Rotor Car? What direction did it move when wind is applied to the car?
- Challenge students to make a boat using a Flettner Rotor.
    - How the Flettner Rotor is being used today: https://www.norsepower.com/technology/