LIGO Laser Interferometer Gravitational-Wave Observatory
Supported by the National Science Foundation
Operated by Caltech and MIT

Magnus Effect- Flying cups

Technically, on a cylinder, the Magnus effect is more properly called Kutta-Joukowski lift.

Anchoring Phenomenon https://www.youtube.com/watch?v=QtP_bh2lMXc

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Grade(s): Middle School

Topic: Physical Science

Standards:

Disciplinary Core Ideas

PS2.A: Forces and Motion

- For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law). (MS-PS2-1)
- The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. (MS-PS2-2)
- All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared. (MS-PS2-2)

Science and Engineering Practices:

1. Asking questions (for science) and defining problems (for engineering)
3. Planning and carrying out investigations
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Objectives:

Understand the effects of air flow on and around moving objects.

Describe Newton's 3rd law of motion and demonstrate using a ball or cups taped together.

Materials:

Cups of a variety of sizes, shapes, materials and masses.

Rubber bands (large)

Variety of tape

Advanced Preparation:
Build one set for demonstration.

Activity
After watching the anchoring phenomenon of the basketball dropped off a bridge ask:

What forces are acting on the basketball?

How could we investigate this phenomenon?

Building your Magnus Effect flier.
- Tape two cups together, base to base.
- Interlock several rubber bands.

Launching
Gripping your flier at the taped center, use your thumb to pin down one end of the rubber band and start wrapping it around the center of the cups, stretching your rubber band tightly as you wrap. Keep stretching until you have just enough rubber band to place your thumb. Pinch the free end of the rubber band with your thumb and index finger. Drop the rubber band off the underside of the flier, pull the flier back with your other hand.
Pull tight- as tight as you think the rubber band and cup can stand.
Aim and let go!

Describe the motion of the flier.

Can you draw the motion of the flier?

What forces are acting on the flier?

List variables that could cause a change in motion of the flier.
The amount of tension pulled on the rubber bands
The number of times the rubber band is wrapped around the cups.
The mass of cups
The size of cups
Type of tape
Ridges in the cups
Type of cup (plastic, paper or Styrofoam)
Putting fins on the cups
End caps on the cups

Underlying Science:
As you release the cups notice that the flier curves upward. The upward lift occurred because you put a spin on the cups as they were launched.
The rubber bands not only propel the cups forward, but also give them a rapid backspin.

As the backward-spinning cups fly through the air, a thin layer of air called the *boundary layer* gets dragged along for the ride and flung downward by the backspin. Newton's Third Law of Motion, every action has an equal and opposite reaction:
The downward force on the air results in the upward force on the cups.

Here's another way of looking at it. As the cups fly through the air, the rotation means the air flows smoothly over the top of the cups, and eventually curves around and down. In return, the air pushes upwards on the cups, making them fly higher.

Baseball pitchers vary the direction and rate of spin of a pitched ball to throw a variety of pitched balls: curveballs, fastballs, screwballs, and sliders.
Stitches on a baseball, golf ball, soccer ball, tennis ball, ping pong, etc. assist in deflecting air sideways, increasing the deflecting effect of the spin.

One more use for the Magnus effect is in transportation. In 1930, American inventors flew a plane with rotating cylinders instead of wings, but it was not very popular. A more modern use is for powering ships – a large cargo ship known as E-Ship 1 has four giant rotors sticking up like chimneys. When the wind blows and the cylinders are spinning, the Magnus effect pushes the ship forward!

History:
This cup glider's flight might seem surprising, but scientists have been studying the cause for hundreds of years. It's known as the Magnus effect, and it's named after Heinrich Gustav Magnus, a scientist who studied the phenomenon almost 170 years ago. He wasn't the first to look into it though – Isaac Newton noticed its effect on tennis balls 180 years earlier.

LIGO Connection:
LIGO's large quad suspension is a perfect model of Newton's 3rd Law. The front of the suspension is called the main chain and the back is called the reaction chain. Scientist use many different methods to push and pull on the optics suspended in the quad. The reaction chain is designed to remove motion away from the optics in the main chain.

Resources:
https://blog.doublehelix.csiro.au/flying-cups/
https://www.exploratorium.edu/snacks/curveball-demonstrator
https://www.ncsciencefestival.org/sites/default/files/documents/Magnus%20Gliders.pdf

Safety Considerations:
Caution when launching the fliers. Sometimes the rubber band of cups may come back and hit the face.

The hold and wrap!

The launch!