Forces of Flight: The Magnus Effect

Impossible Flight - How can we make spinning objects fly?

For students in grades K through 6th

'Impossible Science' lessons aim to be 75-90 minutes long for grades 3 through 6, and 60-75 minutes long for grades K through 2. The final 15 minutes for K-2 will be filled with a 'wind down' drawing activity (see "Evaluate" section for details).

Objectives

By the end of this lesson, students will:

- **know** how air pressure is defined and some of the basic principles of how the Magnus Effect works
- **understand** how air molecules interact with moving objects to create pockets of different air pressures which affect the motion of the object
- **be able to** model, predict behaviors, and conduct experiments to observe the Magnus effect and air pressure phenomena

Big Ideas:

- Air is a powerful **force**. Air is not just empty space, but instead a collection of free moving molecules that are capable of **applying pressures** on objects to exert force.
- **Air pressure** is a measure of the amount of molecules contained within a volume of space and how fast those molecules are moving. More air molecules moving slowly in a tight space exert higher air pressure than less molecules moving really fast in a large space.
- Depending on the motion of objects as they travel through air, the air molecules can exert **forces that affect the motion** of the object.
- **The Magnus Effect** is a kind of force exerted by air on an object that is spinning. This force acts perpendicular to the object, pushing it in the direction that it is spinning. For

example, if you throw a ball with backspin, so that it rotates upwards, the Magnus Effect will push the ball up, seeming to counteract some of the force of gravity.
- **Fluid dynamics** is the field of study that deals with fluids, which are liquids and gasses like air, and how they move in relation to solid objects.

Essential Questions:

- What is air pressure?
- What causes air pressures to change?
- How does air pressure influence the movement of objects?
- How does air pressure influence the movement of spinning objects?
- How do differences in air pressure create lift?
- What real world examples can you think of that demonstrate the Magnus Effect?

Engage:

Warm Up Activity - [2 to 3 minutes]

Ask the group of students to call out examples of objects that fly. On the board or on a piece of chart paper, write down student responses. Then, ask students to share some of the characteristics or properties that these objects have in common.

Impossible Science Demo - Bernoulli's Principle and Lift [5 minutes]

Includes "Teach Like A Magician" progression of steps with recommended script.

- *[TLAM] "Today, we are going to defy gravity using nothing but air."*
- Take a piece of composition paper (or paper of equivalent weight), and tape it so that its length hangs over the edge of the table.

- *[TLAM]: "I have taped this piece of paper to the edge of the table. There is nothing else holding on to the paper, and the tape is in place just to prevent this piece of paper from flying away."*
- Make sure that students can see the full set up and details before proceeding.
- *[TLAM]: "As I said, air has the power to defy gravity. Let's use some air and help this paper reach for the stars!"*
- With the straw, blow a steady, strong burst of air across the top of the piece of paper. This will cause the end that is hanging off of the table to rise and flap like a wing.

- *[TLAM]: "Huh. Who knew blowing air on top of this paper would cause it to lift up like that!?"*

Think | Pair | Share [5 minutes]

- *Think [1-2 min]:* Individually, students should try to explain what they just observed in their journals under "Prompt #1"
- *Pair [1-2 min]:* Students pair up and take turns sharing their thoughts. They ask each other questions after sharing and formulate their combined responses to the question prompts.
- *Share [2-3 min]:* The larger group comes together and the pairs take turns summarizing their combined responses. Summarize their hypotheses into a couple of statements on the board.

Explore:

Activity 1 - Air Pressure and Stationary Objects [10 minutes]

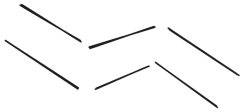
Students will work in pairs on this activity. Distribute the materials for "Activity 1" from the Materials page.

- Place a cup on the table
- Using the straw, blow a burst of air just to the left of the cup. Observe what happens.
- Using the straw, blow a burst of air just to the right of the cup. Observe what happens.
- Place a second cup next to the first cup, about two inches apart
- Make a prediction about what will happen when you blow air through the straw between the two cups. Draw your prediction, and explain your reasoning (older students) under Prompt #2 in your workbook.
- Using the straw, blow a burst of air between the two cups. Observe what happens.

Activity 2 - Air Pressure Obstacle Course [15-20 minutes]

Students will work in pairs on this activity. Distribute the materials for "Activity 2" from the Materials page.

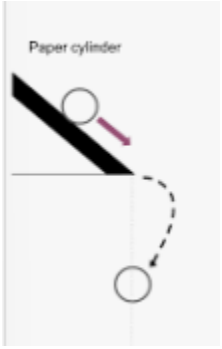
- Using pencils and markers, create the outline of an obstacle course track. Make sure that the track is wide enough for the cup to travel through it, and that it features at least three turns.



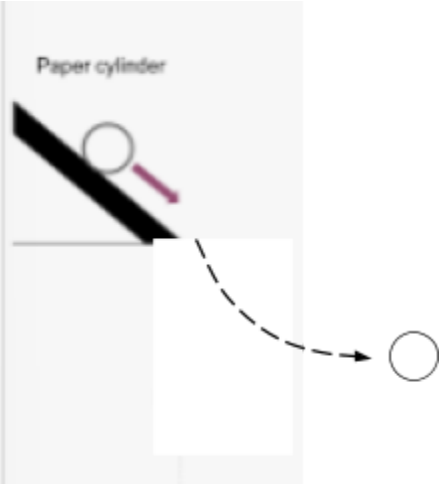
- Based on their observations from Activity #1, ask students to create a plan for successfully using the straw and bursts of air to guide a cup through the obstacle course without touching the boundary.
- Taking turns, students should implement their plan and try to race each other through their obstacle course.
    - *If their plan does not work, have students revisit it before trying again.*

Activity 3 - Air and Spinning Objects [10-15 minutes]
Students should work in pairs on this activity. Distribute the materials for "Activity 1" from the Materials Page.

- Roll the piece of paper up so that it forms a cylinder that is approximately 2 inches in diameter. Tape the paper so that it holds that shape.
- Stand up and hold the cylinder so that it is resting in your hands and away from your body.
- Drop the cylinder, and observe how it falls.
    - *Students should observe the cylinder falling straight down.*
- Stand up again and hold the cylinder away from your body.
- This time, drop the cylinder by letting it roll out of your hands. Again, observe how it falls.
    - *Students should see the cylinder curve as it falls, hooking toward the person who dropped it.*



- Stand again holding the cylinder, this time with two hands. To drop it this time, spin the cylinder towards you as you release it. Observe how it falls.
    - *Students should see the cylinder curve as it falls, this time hooking away from the person who dropped it.*



Explain:

Watch and Discuss [10-15 minutes]

Link: *Use The Magnus Effect To Make Your Plastic Cups Fly! | Impossible Science At Home*

After watching the video, guide the students though a brief reflection:

- What did they notice in the video?
- How was Jason able to make the illusion work?

Define and clarify the following terms while watching the above video. Pause video and elaborate on definitions as deemed necessary based on student engagement, using the "Big Ideas" and "Essential Questions" as a guide:

- Air pressure
- Low air pressure versus high air pressure
- Magnus Effect
- Lift

At this time, have students return to their journals and, under Prompt #3, explain with models and words how the three Activity experiments demonstrated air pressure, lift, and the Magnus Effect.

Elaborate:

Experiment - Magnus Effect Flyers [20 minutes]:

Separate students into groups of 2-3. Distribute the materials for 'Experiment' from the Materials Page.

Students will first work together to replicate the Magnus Effect flyers trick that they observed in the video. ***Make sure you are in a space (or outside) that provides students with plenty of space to test fly their Magnus Effect Flyers.***

- Take the two cups and tape them together, bottom to bottom
- Tie the rubber bands together to make a long rubber band
- Wrap the long rubber band tightly around the middle of the Magnus Effect Flyer
- Test fly the Magnus Effect Flyer.
    - Try launching the Flyer at different angles to see how it affects the flight
    - Try wrapping the rubber band in different ways to see how it affect the flight
    - Based on your observations, try launching your Magnus Effect Flyer to achieve the longest flight as measured in:
        - Distance (feet or meters)
        - Time (seconds)

If time allows, challenge students to modify their Magnus Effect Flyers in the following ways. They should make predictions about how the new Flyer will work based on their understanding of the Magnus Effect and lift, and then test their predictions with the modified Flyer.

- Instead of taping the two cups together bottom to bottom, tape them together opening to opening
- Add weight to the inside of both cups of the Magnus Effect Flyer
- Add weight to the inside of one cup of the Magnus Effect Flyer
- Partner with another team to create a Magnus Effect Flyer with three cups
- Partner with another team to create a Magnus Effect Flyer with four cups

Modify / Extend:

Modified Activity 3:

Younger learners may find it difficult to roll the paper cylinder with their hands and have it curve as intended. To help them, construct a small ramp that lets the students roll their paper cylinders off of the edge of an elevated position, such as a table or lab station.

Extension Activity 1 - Ping Pong Ball Trick Shots [15-20 minutes]

Students will work in pairs on this activity. Distribute the materials for “Extension 1” from the Materials Page.

Students will use their knowledge of the Magnus Effect to try and throw curving ping pong balls and make increasingly difficult trick shots.

- Taking turns, students will design a shot that requires a student to throw a curving ping pong ball and have it land in a target (cup, trash can, etc.).
- Each student gets two chances to make the trick shot
- First student to reach a score of ‘3’ wins!

Evaluate:

In their workbooks under “Prompt #4”, challenge students to create a model explaining how each of their Magnus Effect Flyers used the Magnus Effect to create lift. Encourage older students to label their models with appropriate terms and concepts.

Based on the results of their experimentation, have students draw what they think the best Magnus Effect Flyer looks like and explain their reasoning with a model.

Materials

Impossible Science Demo (per class)

- Piece of composition paper
- Tape
- Straw

Activity 1 (per student pair)

- Two plastic cups
- Straw

Activity 2 (per student pair)

- A plastic cup
- Straw
- Writing Utensils (to create obstacle course)

Activity 3 (per student pair)

- Paper
- Tape

Experiment (per group of 2-3 students)

- Tape
- Two plastic cups
- Rubber Bands
- Pennies (for adding weight to the insides of the cups)

Modified Activity 3 (per class)

- Materials to build a ramp (tray, stack of books, cardboard poster, etc.)

Extension 1 (per student pair)

- Ping pong ball

- A plastic cup