Going With The *Flow*

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Field(s) of Interest: Fluid dynamics

Brief Overview (1-3 sentences):
Mentees will be learning about Bernoulli's principle and its application on planes and boats! Planes use this principle of fluid dynamics on their airfoil-shaped wing, creating lift. On the other hand, boats use it on their sails to maintain direction.

Agenda:

- Module 0: I'm under so much pressure!! 😰(5 mins)
- Module 1: The Better Bernoulli  (15 min)
- Module 2: Cabin Crew Ready For Takeoff 🛫 (15 min)
- Module 3: I Like Big Boats and I Cannot Lie 🛳️ (15 min)
- Conclusion (10 min)

Main Teaching Goals/Key Terms:	**Mentor Development Goals:** **Written by MD**
• Fluid • Pressure • Bernoulli's Principle • Velocity • Airfoils • Lift • Angle of attack • Upwind • Downwind • Keel	➔ **Connect to the Real World** 🌎 ➔ **Classroom Management & Safety** 🚨 ➔ **Teamwork Makes the Dream Work!**

Background for Mentors

Module 0 ● Fluid ● Flow ● Pressure	**Fluid** is something that can flow and take the shape of its container. Some examples of fluids include water, air, and liquids like oil and honey. For example, if you fill a glass with water, it will take the shape of the glass. There are several properties of fluids that distinguish them from solids: 1. Fluids can **flow**, which means that fluids can easily move from one place to another on their own. Unlike solids, which are rigid and do not move on their own. 2. Fluids can easily change shape depending on the container it is placed in or objects that cut through it. 3. Fluids exert **pressure** in all directions. To better understand pressure, it is similar to exerting all your energy into pushing a rock or pressing your fingers onto a surface. In those cases, you would be *applying* pressure onto other objects. Similarly, fluids can apply pressure onto other objects too. Essentially, pressure is a force exerted on an object's surface. To simplify it for younger sites, they can think of pressure as the way things push on each other. For example, if you push your right hand down with your left hand on the table, you are *applying pressure* onto your left hand.

Module 1

- Bernoulli's Principle
- Velocity
- Density

To build upon what we have already learned about fluids, we are going to introduce the idea of **Bernoulli's Principle**! We already know that fluids can move (flow) and can exert pressure. But just how much pressure can fluids exert? This is where Bernoulli's Principle comes in! This principle explains how the pressure of a fluid can change depending on its flow **velocity**. For younger sites, you do not have to mention velocity, just try to explain speed (how fast an object is) instead! In summary, pressure is dependent on speed (with direction).

It might not be too intuitive for mentees yet, but the idea is that:

1. Faster Flow, Lower Pressure: The faster a fluid flows, the lower the pressure the fluid exerts.
2. Slower Flow, Higher Pressure: The slower a fluid flows, the higher the pressure the fluid exerts.

Why does this happen? It has to do with **density**, which refers to how densely packed atoms are within a specific volume.

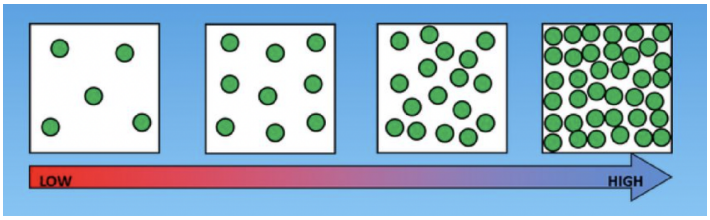

Figure 1. *Low to high density*

For younger sites, it might be easier to say how much space you give atoms to move around! Imagine you are playing tag in a small classroom vs. a large playground. Which is easier for you to move around? Probably the large playground because there is more space to run.

Similarly:

1. In lower-density areas (large playgrounds)
    a. Atoms move around more freely (faster flow)
    b. Exerts less pressure because there are fewer air molecules around each atom. Atoms can roam freely without having to push on each other.
2. In higher-density areas (small classrooms)
    a. Atoms can't move as freely (slower flow)
    b. Exerts more pressure to give leeway for atom movement. Atoms have to push hard against each other in order to move around.

Reminder: pressure is how hard one object is pushing against another object.

Module 2

- Airfoils
- Lift
- Angle of attack

Airfoil is the shape of an airplane's wing, more specifically, its cross-section. It helps control the flow of air around it and helps airplanes lift and fly.

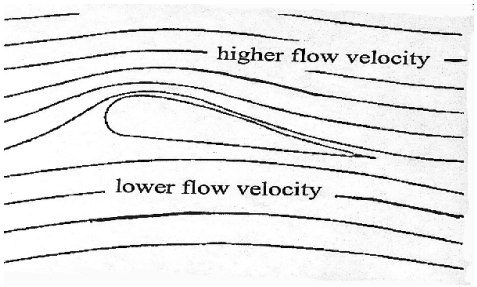

Figure 2: How airfoils create pressure difference based on shape

Lift is one of the four pillars of aerodynamics. The concept focuses on the force that makes things go up in the air.

The unique shape of the airfoil causes a difference in pressure between the top and bottom curves:

1. The air on top has a faster flow (lower pressure)
2. The air at the bottom has a slower flow (higher pressure)

Based on Bernoulli's principle, this concept would lift the wing (and the airplane) upward as the higher pressure from below generates lift.

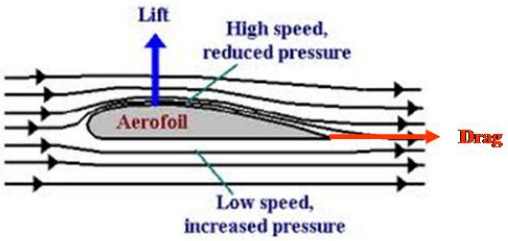

Figure 3: Diagram of how high/low pressure generates lift

For more advanced sites, optimal use of an airfoil also depends on an **angle of attack**, which refers to the angle at which the airfoil meets oncoming fluid. Changing the angle of attack can change the direction of an airplane. For example, tilting the airfoil down can make the plane face downwards, and vice versa. It may affect the plane in other ways too like the amount of lift, and the creation of more air resistance.

Module 3

- Upwind
- Downwind
- Keel

Similar to planes, sailboats also use a version of Bernoulli's principle in order to propel forward. A common misconception is that sailboats can only effectively travel when **downwind**, meaning when wind directly hits the back of the boat. However, with the aerodynamic shape of the sails, sailboats actually travel fastest when hitting the wind at an angle.

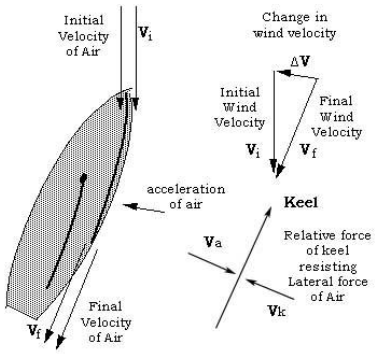

Figure 4: A vector map of air hitting a sail

When air hits the sail at an angle, the curved shape causes the final velocity of the wind in front of the sail to be faster than the velocity of the wind behind the sail. As stated earlier, the faster velocity results in less pressure, causing the ship to move towards that low pressure area. This works as long as the ship is not directly **upwind** (having the airflow hitting the direct front of the boat).

However, if the boat only relied on the sail, the resulting force would be at an angle. In order to resist this, a second "wing" is placed on the bottom of the boat, known as the **keel**. The keel's shape causes water on one side to move faster than the other. However, the resulting force resists the horizontal movement of the sail. This allows the boat to move in a straight line

Introduction

Bernoulli's principle is very applicable to any engineering field whether it is for boats or planes! It is important for kids to understand how fluid mechanics works if they are ever interested in engineering.

Concepts to Introduce	**Questions to Pique Interest**
● Fluids ○ What do water and air have in common? ○ How do they behave differently from solids? ○ What are other forms of fluids mentees can think of?	● Ever wondered how airplanes can fly? Or how you can change directions on a sailboat? ● Why do fluids flow?
Scientists, Current and Past Events	**Careers and Applications**
● Daniel Bernoulli was a Swiss mathematician and physicist. He is particularly remembered for his application of mathematics on fluid dynamics.	● Pilot ○ Someone who drives the plane. They too need to be knowledgeable about the plane's aerodynamics. ● Flight engineers ○ People who build the plane and/or do maintenance for planes.

Module 0: I'm Under So Much Pressure!! 😰

Fluid and pressure are the building blocks to understanding Bernoulli's Principle in simple terms. We would like mentees to have a clear understanding of what a fluid is and its mechanism (the exertion of pressure).

Teaching Goals (change this)

List and explain/define the 1-3 main concepts you want to focus on *for this specific module*. For example...

1. **Fluid:** something that can flow and take the shape of its container.
2. **Pressure:** How much "push" something exerts.

MD Goals

- **Connecting to the Real World 🌎:** This module heavily emphasizes terms that are present in our everyday lives. Especially for younger mentees, emphasize how blowing a balloon represents forces that are around us all the time!

- **Classroom Management & Safety 🚨:** Mentees will get excited to see and interact with balloons. Ensure to monitor all mentees to ensure they are safely interacting with the balloons and with others when participating in the module activity.

Materials

- Balloon
- Balloon pump

Different Methods for Teaching

Give a couple of different teaching techniques that you think would be the most effective way for mentors to teach this module/the different teaching goals . For example...

1. **Pressure:** Ask mentees what is harder to move from, a single blanket or 100 blankets (or an object of your choice)? The more of something there is in a certain space, the more pressure it exerts.
2. **Fluid:** Although students will understand that liquids are a fluid, make sure to emphasize that gasses are also fluids

Procedure

1. Distribute balloons to all mentees in the room.
2. Ask mentees to blow balloons.
3. If mentees are unable to blow balloons, use the balloon pump.
4. The balloons expand uniformly throughout the surface based on the original shape.
5. Explanation: The balloon is able to expand because air molecules are pushing against the inner surface of the balloon.
6. Note: the main goal of this exercise is simply to demonstrate that fluids exert pressure.

Figure 5: *Balloon activity*

Module 1: The Better Bernoulli 

Mentees will learn about what boats and planes have in common– the use of Bernoulli's principle! In this activity, Bernoulli's principle will be demonstrated by flowing in between two balloons and mentees will see what happens!

Teaching Goals	**Materials**
List and explain/define the 1-3 main concepts you want to focus on *for this specific module*. For example... 3. **Bernoulli's Principle:** The idea that when a fluid moves faster, it exerts less pressure, and vice versa. 4. **Velocity:** how fast an object moves, with direction	• 1 Bernoulli Bag • 1 sheet of paper

Different Methods for Teaching

Give a couple of different teaching techniques that you think would be the most effective way for mentors to teach this module/the different teaching goals . For example...

3. **Bernoulli's principle:** This topic is probably the hardest to teach. Avoid using overly scientific when doing the initial explanation
4. **Pressure:** Ask mentees what is harder to move from, a single blanket or 100 blankets? (or an object of your choice) The more of something there is in a certain space, the more pressure it exerts.
5. **Fluid:** Although students will understand that liquids are a fluid, make sure to emphasize that gasses are also fluids
6. **Velocity:** Although this might be a complicated word, it is very similar to speed, just with its direction also being noted.

Procedure

Part 1:

1. Using the Bernoulli bag, have a mentor try blowing up the bag like a balloon. Although it might be possible, it takes a lot of air and can be exhausting
2. However, the bag can be blown up using a different method: bernoulli's principle! Have the mentor take a deep breath and blow into the bag, this times a little ways away
3. This time, the bag should fully inflate. Ask the students why they think this works?
4. Explanation: When blowing into the bag further back, the mentor creates a high velocity (and therefore low pressure) tunnel. Given Bernoulli's principle, the surrounding higher pressure air will follow this tunnel and fill up the bag much faster than blowing straight into it.

Part 2:

5. If mentees still do not understand, cut a standard piece of paper in half, then ask mentee volunteers to blow straight and over the piece of paper.
6. Explanation: The idea is similar to the balloon but horizontally. Higher pressure from below the paper pushes the paper upward as the top of the paper has lower pressure due to faster flow.

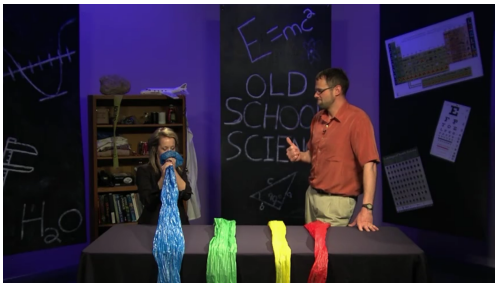

Figure 6: *When blowing directly into the bag, it should be difficult to inflate*

Figure 7: *Taking a breath away from the bag will inflate it much easier*

Figure 8. part 2 to the activity

Module 2: Cabin Crew Ready For Takeoff 🛫

In this module, mentees are going to build an airfoil to demonstrate Bernoulli's principle in an airplane. Mentees are going to see how an airfoil creates lift by blowing on it.

Teaching Goals

List and explain/define the 1-3 main concepts you want to focus on *for this specific module.* For example...

5. **Airfoil:** Shape of an airplane wing cross-section that controls the flow of air to help lift and fly.
6. **Lift:** Force that makes things go up in the air.
7. **Angle of attack:** The angle at which oncoming fluid meets the airfoil.

MD Goals

- **Classroom Management & Safety 🚨:** Watch the mentees carefully with the sticks so that they do not hurt themselves/others and so they are not misused.

Materials

Test Base

- 1 rectangular block of styrofoam
- 2 thin sticks

Airfoil

- ¼ of a sheet of paper
- 1 roll of tape
- Hole puncher
- Mini fan

Different Methods for Teaching

Give a couple of different teaching techniques that you think would be the most effective way for mentors to teach this module/the different teaching goals . For example...

7. **Airfoil:** Have mentees think about swimming. When moving your hand through water, is it easier for it to move when your palm is horizontal or vertical?
8. **Lift:** I don't think it's super intuitive, even for me, but just let the activity do its job. As long as the airfoil lifts and mentees can see it, it should be okay.

Procedure

Making the test base

1. Poke the styrofoam block with the two toothpicks, 3 inches apart from each other, don't remove the toothpicks.
2. Basically, you want the build to look somewhat like Figure 9 but with styrofoam.
3. Don't forget to stick it using masking tape onto the table to stabilize it.
4. Make sure the toothpicks are straight.

Making the airfoil

1. Hand each mentee a sheet of paper.
2. Take the longer edges and stick them together like figure 10 using tape.
3. Then gently fold it so it takes the shape of an airfoil like in figure 11.
4. The airfoil should look like figure 12.
5. Hole punch it the same distance as the two sticks.
6. Insert the airfoil through the two sticks.
7. Make sure the airfoil can go up and down.
8. Use a mini fan from the front of the airfoil (the curved part). You should see it lift.

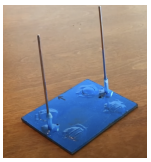

Figure 9: *Styrofoam and sticks should look something like this build*

Figure 10: *Paper is a rectangle, so tape the longer side's edges together*

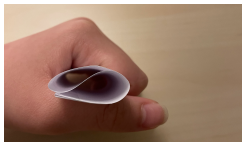

Figure 11: *Gently fold it like this*

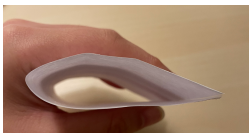

Figure 12: *The airfoil should somewhat take on this shape*

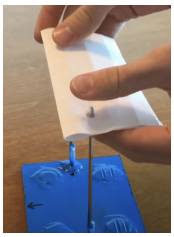

Figure 13: *Inserting airfoil through test base*

Classroom Notes

Careful with the scissors when making the hole on the airfoil.

Conclusion

Ask mentees what they observe, point towards the idea of lift and how it is generated.

References

- https://www.youtube.com/watch?v=wrouhCGg9ko

Module 3: I Like Big Boats and I Cannot Lie 🛳️

In this activity, mentees are going to build boats and race against each other. Mentees can learn how the different shapes and curves of the sail can affect the speed at which the boat is running.

Teaching Goals

List and explain/define the 1-3 main concepts you want to focus on *for this specific module*. For example...

8. **Downwind:** When the wind blows directly behind an object, pushing it forward
9. **Upwind:** When the wind blows directly in front of an object, making it difficult to move forward
10. **Keel:** The "tail" of a sailboat, acts similar to a sail but under the water

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MD Goals

- **Teamwork Makes the Dream Work!** Some mentees may get competitive or try to take over the build from their teammate. Remind them to have fun with the activity together and see what they can achieve!

Materials

- Jumbo Popsicle sticks (about 4 per pair)
- Straws (~1 per person)
- 1 roll of tape per site
- Toothpicks (4 per pair)
- Bottlecaps (4 per pair)
- Construction paper

Different Methods for Teaching

Give a couple of different teaching techniques that you think would be the most effective way for mentors to teach this module/the different teaching goals . For example...

9. **Downwind/Upwind:** Have students think about how they feel moving through the wind. How easy is it to walk when the wind is at your back? What about when you're moving against the wind?
10. **Keel:** Just like how an airplane has two wings, a sailboat has 2 "wings" of its own with the sail and the keel.
11. **Anything else?** Students might not be able to see how the same principle that moves a plane upwards moves a boat forward. However, sailboats are similar to airplanes turned on their side, with the front part of the sail causing the "lift" forward

Procedure

1. Each pair of students will have ~15 minutes to design and construct a sailboat car that can move using wind (their breaths)
2. The four popsicle sticks can make up the base of the boat, with the straw holding up the construction paper mast. The toothpicks and bottlecaps act as wheels
3. Once completed, students can race their cars by blowing against the mast and determining which car moves the fastest

Classroom Notes

Any additional tips for mentors to make their lives easier?

Conclusion

Bring back the definition of Bernoulli's principle, as well as how it applies to real life. Try to see if the mentees can think of any other applications of Bernoulli's principle!

Summary Materials Table

Material	Amount per Site	Expected $$	Vendor (or online link)
Extremely Specific Item Name	1 per student		Amazon