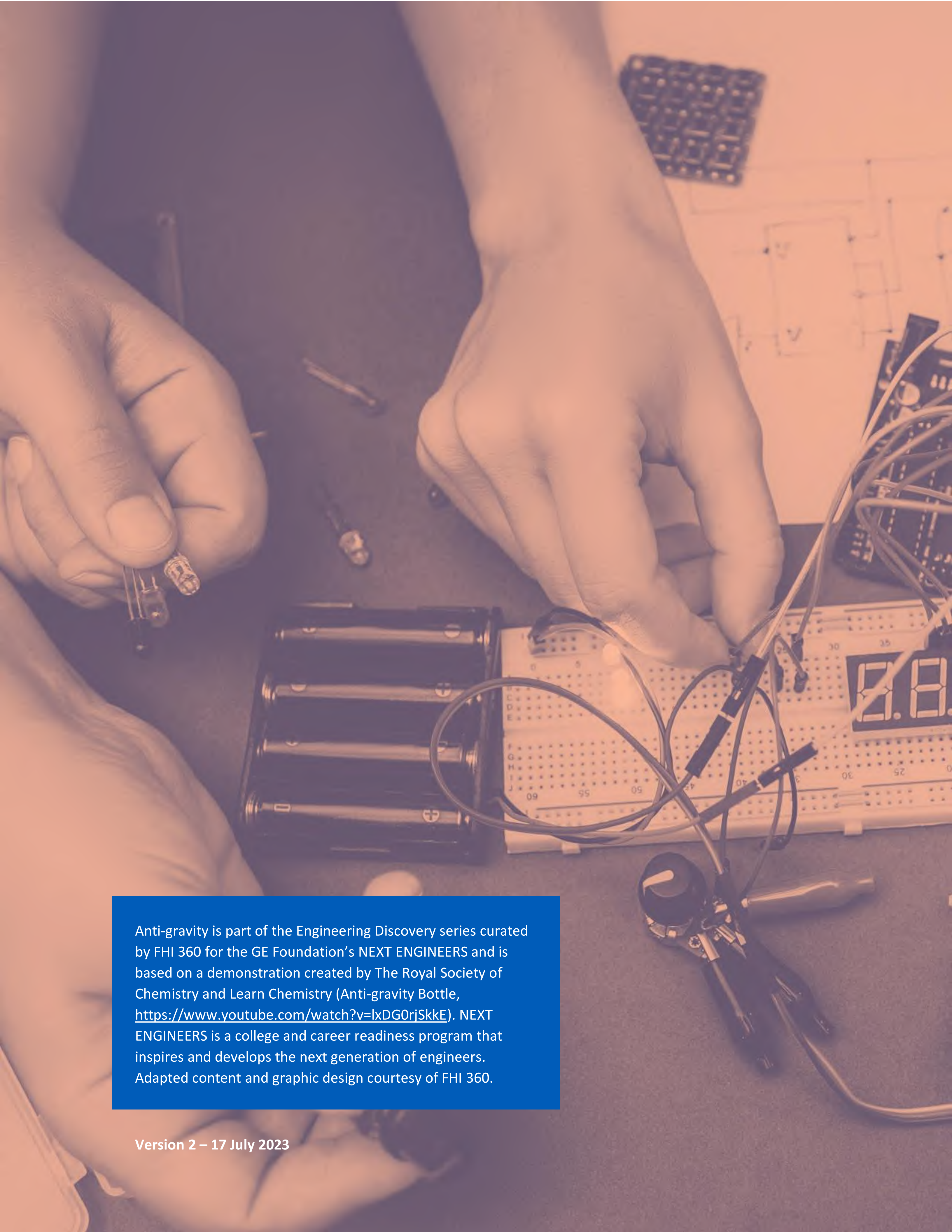
NEXT ENGINEERS

ENGINEERING DISCOVERY

Anti-gravity

Atmospheric Pressure

GE Foundation



Anti-gravity is part of the Engineering Discovery series curated by FHI 360 for the GE Foundation's NEXT ENGINEERS and is based on a demonstration created by The Royal Society of Chemistry and Learn Chemistry (Anti-gravity Bottle, https://www.youtube.com/watch?v=lxDG0rjSkkE). NEXT ENGINEERS is a college and career readiness program that inspires and develops the next generation of engineers. Adapted content and graphic design courtesy of FHI 360.

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Anti-gravity

DEMONSTRATION

Time	Ages	Cost	Activity Type
15 minutes	12 - 14	Low	Demonstration
Engineering Areas			
• Atmospheric pressure • Forces	• Gases		

Demonstration Overview

This quick and simple demonstration powerfully illustrates what atmospheric pressure is and how large a force it applies to everything around us. It also helps students see that atmospheric pressure does not only act **downwards** but, like water pressure, it acts in **all directions**.

Materials

- A ping pong (table tennis) ball
- A glass or plastic bottle with a tapered neck. The ping pong ball should be able to just fit into the neck
- A jug of water
- A small basin

Demonstration Principles

Working with Youth: Facilitation Tips (https://www.nextengineers.org/resource/working-youth-facilitation-tips) is a handy summary of the key facilitation principles that volunteers need to keep in mind when demonstrating any activity with students.

Facilitator Preparation

1. Read the step-by-step instructions.
2. Collect the materials.
3. Practice doing the demonstration. Make sure that the neck of your bottle is correctly sized for your ball.
4. Plan when and how you will share your story and career journey in a relevant and personal way. Try to integrate your story into the demonstration as much as possible. You can find the following volunteer resources for how to tell your story on the Next Engineers website:
   a. **I'm an Engineer! Storytelling Worksheet** (https://www.nextengineers.org/resource/im-engineer-storytelling-worksheet)

DEMONSTRATION TIP

The ping pong ball should be able to just fit into the neck of the bottle. The more of the ball is inside the bottle, the more it will be subject to water pressure and the less it will be subject to atmospheric pressure.

b. **I Work with Great Engineers! Storytelling Worksheet** (https://www.nextengineers.org/resource/i-work-great-engineers-storytelling-worksheet)

5. Practice asking and answering questions students may ask. See **Frequently Asked Student Questions** (https://www.nextengineers.org/resource/frequently-asked-student-questions).

KEY WORDS

- Atmospheric pressure
- Force
- Pressure
- Surface area

Step-by-Step Instructions

Time	Instructions	Materials
3 min	**Welcome & Introductions** • Welcome students to the demonstration. • Tell the group a little about the kind of engineering you do and why you enjoy it. Describe briefly how you became an engineer and when you realized that this was the career for you. • Now ask the group whether they think air or water is heavier and whether they know what pressure and air pressure are. It is not important yet whether students give the correct answers.	
7 min	**Demonstration** • Perform the demonstration as follows. As you do each step, explain to the students what you are doing without giving too much away. 1. Place the ping pong ball onto the neck of the bottle and ask students to predict what they think will happen if you turn the bottle upside down. Most will correctly state that the ping pong ball will fall off. 2. Turn the bottle upside down to demonstrate that this is what happens. 3. Now ask the group what they think you can do to keep the ping pong ball from falling off but without using any glue or other adhesive materials. 4. Ask the group what they think about filling the bottle with water. Do they think this will keep the ping pong ball from falling off when you turn the bottle upside down? 5. Fill the bottle about ¼ with water and place the ping pong ball on top of the bottle.	Demonstration Materials

	6. Hold the bottle over the small basin and ask students to predict what is going to happen if you turn it upside down. They will probably say that the ball will fall off and the water will pour out of the bottle. Demonstrate that this is the case and ask students to explain why they think this happened. 7. Now ask the group whether they think pouring more water into the bottle will stop the ping pong ball from falling off when turn it upside down. Most students will probably say 'no'. 8. Fill the bottle until it is completely full and place the ping pong ball on top of the bottle. There should be little to no air inside the bottle. 9. Hold the bottle over the jug and ask students to predict what is going to happen if you turn it upside down now. 10. Turn the bottle upside down to demonstrate that the water does not come pouring out. Instead, the ping pong ball stays in place and holds back all the water inside the bottle. 11. Ask students to try to explain what is going on.	
5 min	**Review and Closing** • Explain that the ping pong ball is not stuck to the bottle with glue. Rather, another force is pushing up on the ping pong ball with more force than gravity and the pressure of the water. • This force is the force exerted by the air around us. This is called **atmospheric pressure**. It acts in all directions and is usually about 100,000 Pa (Pa = Pascal) or 100 kPa. This is equivalent to about 1 kg of mass pushing on each square centimeter of the ping pong ball (or 14.7 pounds per square inch). • The exposed surface area of the ping pong is about 35 cm^2 (5.4 in^2) so this is quite a big force holding the water inside the bottle. • Ask students to try to explain why the water poured out of the partially filled bottle. (The air inside the bottle was at the same atmospheric pressure and push down on the water and the ping pong ball) cancelling the pressure pushing the ball up.	

DEMONSTRATION TIP

Turn the full bottle upside down slowly and carefully. Occasionally, air enters the bottle causing water to rush out and make a great mess!

Screenshot from available at https://www.youtube.com/watch?v=lxDG0rjSkkE

	• Ask students whether they think atmospheric pressure is higher or lower where you are or on a very high mountain. Have them explain their reasoning. Ask how such changes in atmospheric pressure could be used. One answer is that they are used to tell pilots how high they are flying (an altimeter). • Close the demonstration by noting that differences in atmospheric pressure are crucial drivers of climate and local weather. By noting areas of high or low pressure, we are able to predict the weather with reasonable accuracy.	

Extension

One way to extend this demonstration is to use balls and bottles of different sizes to link the total force exerted on the ball by atmospheric pressure with the surface area of the ball.

Alternatively, you can experiment with filling the bottle with different amounts of water to find the least amount of water needed to produce the effect (i.e., the amount of water where the atmospheric pressure pushing up on the ball is just greater than the water pressure inside the bottle and the atmospheric pressure of the air pocket inside the bottle).

Key Words

- **Atmospheric pressure:** Also known as barometric pressure. The pressure exerted by the atmosphere of Earth.
- **Force:** Any influence that, when unopposed, will change the motion of an object. A force can cause an object with mass to change its speed (i.e., to accelerate or decelerate). Force can also be described intuitively as a push or a pull. A force has both magnitude (size) and direction.
- **Pressure:** The force applied perpendicular to the surface of an object per unit area over which that force is distributed.
- **Surface area:** A measure of the total surface covering an object. It is measured in square units like cm^2, m^2 or km^2.

Demonstration Background

This is a simple demonstration that shows that the air around us exerts a force. We call this force atmospheric pressure, and it is usually taken to be about 100,000 Pa or 100 kPa (Pascal). 1 Pa is defined as a force of 1 N applied over an area of 1 m^2. Therefore 100 kPa is 100,000 N of force per m^2 or 10 N of force per cm^2.

10 N is about the same force with which a 1 kg object pushes down on your hand! You can feel this force on your hand by placing a 1 kg object on it.

First, a ping pong ball is placed on top of a partially filled bottle of water. When turned upside down, the water pours out, as expected.
Then, a ping pong ball is placed on top of a completely filled bottle of water. When turned upside down, the water stays in the bottle. The relatively large surface area

of the ping pong ball means that the force acting on it by atmospheric pressure is greater than the pressure of the water pushing down. This pressure is a direct result of the force due to gravity acting on the water.

Remember that the air is a fluid like water. If you are underwater, the water pressure exerts a force in every direction on your whole body, not just downwards. The same is true of atmospheric pressure. It exerts a force in all directions on objects in the air.

This demonstration is designed to help students understand that atmospheric pressure (normal air pressure) applies a constant force in all directions.

You can watch a video of this demonstration at https://www.youtube.com/watch?v=lxDG0rjSkkE.

References

This demonstration is based on **Anti-gravity Bottle** originally created by **The Royal Society of Chemistry** and **Learn Chemistry** and available at: https://www.youtube.com/watch?v=lxDG0rjSkkE.