

## **Week 2: Sea and Space Connections**

Astronauts routinely use underwater habitats to train for future space missions. There are many parallels to living under the water and living in outer space. The most common two are weightlessness and living in an environment with different air pressures. While living in underwater habitats the air pressure is higher than normal, living in space there is almost a complete absence of air pressure or a vacuum, each environments have special considerations for those living there. Astronauts use training in the water to get used to being weightless while they are working. This may seem silly until someone actually tries to do physical work and every time they push against an object, they start floating backwards! The last training mission was performed in Aquarius off the coast of Key Largo, Fl. Below is a picture of the NEEMO XVIII group of astronauts that trained in Aquarius. Let us look at the importance air pressure and what exactly does weightlessness mean.



Photo courtesy of NASA NEEMO

## **Exercise 1:**

### Potato Stabbing

#### **Materials:**

-potato

-plastic straw (preferably not the bendy straws)

If you use a bendy straw cut off the bendy part of the straw

First have the students hypothesize what will happen when they stab the potato. Have the students try to stab a hole in the potato with the straw ends open. (The straw should collapse and not penetrate the potato). Now have the students hypothesize what is going to happen if they hold one end of the straw and stab the potato again.

This time have the students stab the potato while sealing off the end of the potato with their thumb. This time the straw should penetrate much deeper into the potato.

#### **What is happening?**

When the straw is open, the straw is too weak to penetrate the potato. When we seal off the end of the straw the air on the inside, compresses because of the force exerted against the potato. When the air is compressed, the air presses against the inside of the straw giving support to the straw. With the help of the air, the straw is then strong enough to penetrate the potato.

#### **How this relates to Aquanaut Jess and Aquanaut Bruce:**

When people think about air pressures, they do not realize how strong these pressures can be. When divers descend the pressure of the water can cause a squeeze on the air spaces in a diver, such as the air space in the mask or the air space in the divers' ears. The diver has to add air to these air spaces in order to equalize the pressure. For example, as a diver descends the water pressure pushes against the diver's mask. The diver adds air into the mask by blowing air from their nose this increases the air pressure inside the mask. The pressure inside the mask is then equal to the pressure that is pushing on the outside of the mask. Since the pressure is equal on both sides of the mask it keeps the diver from experiencing an uncomfortable squeeze.

#### **Review Questions:**

1. What happened the first time the potato was stabbed with the straw?
2. What happened the second time the potato was stabbed?
3. Why was the straw able to penetrate the potato the second time?
4. Why did the air pressure not increase the first time?

#### **Definitions:**

-Pressure: The continuous physical force exerted on or against an object by something in contact with it.

-Force: A push or pull acting upon an object because of its interaction with another object.

-Squeeze: A condition that causes pain and discomfort when the pressure inside an air space of your body is less than the pressure outside an airspace.

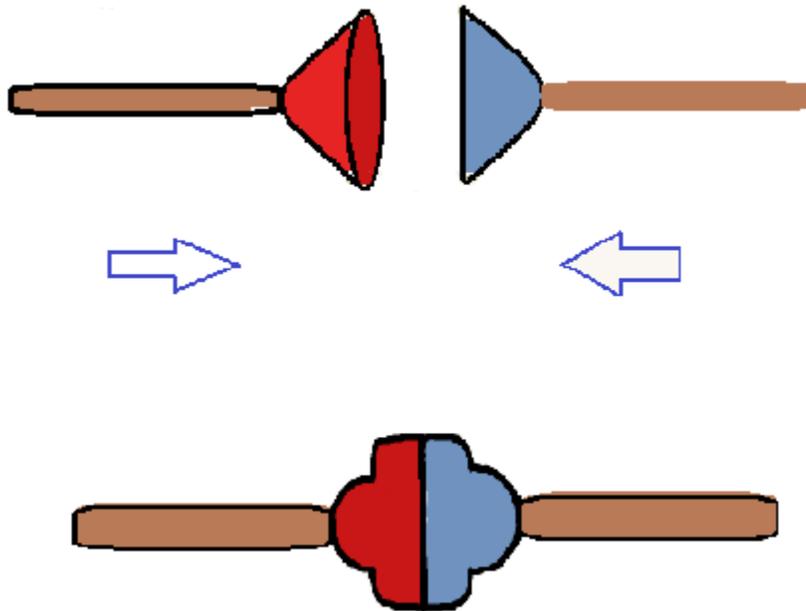
## Exercise 2:

### Two-Plunger Trick

#### **Materials:**

-Two old-fashioned toilet plungers

Pulling apart two toilet plungers may sound easy but I bet you cannot do it! Take two old-fashioned toilet plungers (clean) and wet the rims of the plunger. Now push the two rubber ends together hard enough that the air escapes. Now try to pull the plungers apart.



#### **What is happening?**

When the air escaped out of the ends of the plungers, the air pressure was reduced.

Now the air pressure on the outside of the plungers is greater than that on the inside.

The atmospheric air pressure is about 14.1 pounds/square inch (PSI) which is pushing on the ends of the plungers keeping them stuck together.

#### **How does this relate to Aquanaut Jess and Aquanaut Bruce?**

All of the supplies that Jessica and Bruce need are brought into the habitat via dry boxes from the surface. When the support diver brings down the sealed box the pressure from the water squeezes the box causing the air to compress. When the box

is put into the habitat, the air pressure inside the habitat is at about 26 psi, which is almost double the air pressure inside the dry box. This means we cannot open the dry box as soon as it comes into the habitat. We must first break the seal and slowly let the air pressure equalize before we can open the box.

So what happens when Jessica brings stuff like a Go Pro camera, inside an airtight case, into the habitat? Well, at first it works the same as the dry boxes the pressure on the inside of the case is less than the pressure inside the habitat so she would not be able to open the case. If she were able to break the seal and let the pressures equalize the case would easily open. If she closed the case and swam the camera back to the surface what would happen? Think back to last week's Cartesian Diver. When the pressure was lessened, the air volume expanded. Therefore, the pressurized air inside the camera case would expand when she swam it to the surface. If the air expanded enough, it could rupture the camera case!

### **Definitions:**

-Pressure: The continuous physical force exerted on or against an object by something in contact with it

-Air pressure: Force exerted by the weight of the air

### **Questions:**

1. What was pushed out of the plungers when you pushed them together?
2. Where was the lower air pressure located?
3. Where was the higher air pressure located?
4. What happened when you tried to pull apart the two ends of the plungers?
5. What would happen if the air pressures were the same on the inside and the outside of the plungers?

### **Related topics:**

What are vacuums?

### **Exercise 3:**

Gravity Free Water:

#### **Materials:**

- class of water
- piece of cardboard

Take the glass and fill it to the brim with water. Now take the piece of cardboard and slide it over the top of glass. Try not to get many air bubbles in the water. While holding the cardboard onto the glass turn the glass of water upside down. Now let go of the cardboard.

#### **What is happening?**

When the cardboard is let go, it should still be on the bottom of the glass along with all the water. So why is the water not falling out of the glass? Since there is no air pressure inside the glass the air pressure on the outside is greater causing the cardboard to stay put holding the water in, making it appear that the water is defying gravity.

#### **How does this relate to Aquanaut Jess and Aquanaut Bruce**

While the water is not actually gravity free, it does seem to be defying gravity. Bruce and Jessica are also able to experience neutral buoyancy, which is close to being weightless. This is partly why the astronauts practice taking space walks while they are underwater.

When the Aquanauts have to do physical tasks in the water they have to adjust to being weightless. When Bruce and Jessica clean the habitat windows and are trying to push against the windows, their bodies just float away from the windows instead of giving them the extra force needed to scrub off the barnacles. Some of the tools also float so if they drop them they have to catch them before they make it to the surface. Which is not a normal reaction to dropping an object.

#### **Definitions:**

-Gravity: the force that attracts a body towards the center of the earth or toward any other physical body having mass.

-weightless: being without apparent weight as a freely falling body or a body acted upon by a force that neutralizes gravitation.

-Newton's law:

1. Every object in a state of uniform motion tends to remain in that state of motion unless an external force is applied to it.
2. The relationship between an object's mass  $m$ , its acceleration  $a$  and the applied force is  $F=ma$ .
3. For every action there is an equal and opposite reaction.

**Questions:**

1. What causes things to fall to the ground when dropped?
2. Why does the water and the cardboard not fall to the ground?
3. If there were air in the glass would the results be the same?
4. Will gravity change on different planets?

**Related topics:**

Effects of weightlessness on astronauts

Gravity on different planets

#### **Exercise 4:**

Floating Eggs

#### **Materials:**

- Two eggs
- Two small containers
- water
- salt

First, take two containers and fill them halfway full with tap water. Now add about 6 tablespoons of salt to one of the containers. Gently place an egg into each of the two containers.

#### **What is happening?**

Different densities! First, let us define what density is. Density is the amount of matter contained in a given space or volume. The denser something is, the more matter it has in the given space. For the experiment, the salt water is denser because it has more salt particles in the given volume of water compared to the tap water. The egg will sink in the tap water because the egg is denser than the water. The salt water is denser than the egg so it is able to "hold up" the egg.

#### **How does this relate to Jessica and Bruce?**

Divers are always concerned with buoyancy for a number of reasons but most importantly, they do not want to sink and possibly hit and damage coral or wildlife.

Divers strive to become neutrally buoyant which means they neither sink nor float. This is also known as being weightless. In order to maintain the neutral buoyancy divers have to adjust the amount of weight they use depending on where they are diving. If they are diving in fresh water systems, they need less weight for them to sink. If they are in ocean water, they will need more weight because of the different densities.

#### **Definitions:**

-Density: the amount of matter contained in a given space or volume

-Weightlessness: being without apparent weight as a freely falling body or a body acted upon by a force that neutralizes gravitation.

-Buoyancy: an upward force exerted by a fluid that opposes the weight of an immersed object.

**Questions:**

1. Which solution did the egg float in?
2. Why did the egg not float in the fresh water?
3. Why did the egg float in the salt water?
4. If you wanted the easiest place to practice floating where it would be?
  - a. the pool
  - b. the lake
  - c. the ocean
  - d. the pond

**Related topics:**

Densities of different bodies of water

Different densities of objects

**Links:**

Stab a potato:

<http://www.sciencekids.co.nz/experiments/stabapotato.html>

<http://www.planet-science.com/categories/experiments/magic-tricks/2012/02/poke-a-potato!.aspx>

<https://www.youtube.com/watch?v=mY-3fOh9wtA>

<http://www.sciencefriday.com/blogs/12/02/2011/stab-a-potato.html?interest=5&series=7>

Plungers:

[https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=0CCgQFjAB&url=http%3A%2F%2Fwww.wfyi.org%2FIndianaExpeditions%2FIDEXSeason2\\_2009%2FIDEX205%2FIDEX205AirPressureLesson.doc&ei=NG3uU7nyFYHC8QH35YDwDA&usg=AFQjCNFihC7WFd5Q9TvTxCzhNWGENmbuVA&sig2=DwiYkZAGa2LRa\\_QXBrgl7Q](https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=0CCgQFjAB&url=http%3A%2F%2Fwww.wfyi.org%2FIndianaExpeditions%2FIDEXSeason2_2009%2FIDEX205%2FIDEX205AirPressureLesson.doc&ei=NG3uU7nyFYHC8QH35YDwDA&usg=AFQjCNFihC7WFd5Q9TvTxCzhNWGENmbuVA&sig2=DwiYkZAGa2LRa_QXBrgl7Q)

Gravity Free Water:

<http://www.superchargedscience.com/documents/Top%20Ten%20Air%20Pressure%20Experiments%20to%20Mystify%20Your%20Kids.pdf>

Eggs:

<https://explorable.com/salt-water-egg-experiment>

Answers:

1. What happened the first time the potato was stabbed with the straw?
  - a. The straw was not strong enough to penetrate the potato
2. What happened the second time the potato was stabbed?
  - a. The straw was strong enough to penetrate the potato
3. Why was the straw able to penetrate the potato the second time?
  - a. The air on the inside of the straw compressed and the increase in pressure pushed against the inside of the straw.
4. Why did the air pressure not increase the first time?
  - a. The end of the straw was not sealed
1. What was pushed out of the plungers when you pushed them together?
  - a. Air
2. Where was the lower air pressure located?
  - a. Inside the two plungers
3. Where was the higher air pressure located?
  - a. Outside the two plungers
4. What happened when you tried to pull apart the two ends of the plungers?
  - a. They did not come apart, because of the pressure differences.
5. What would happen if the air pressures were the same on the inside and the outside of the plungers?
  - a. They would not suction together and they would come apart easily.
1. What causes things to fall to the ground when dropped?
  - a. Gravity
2. Why does the water and the cardboard not fall to the ground?
  - a. The higher air pressure pushing against the cardboard.
3. If there was air in the glass, would the results be the same?
  - a. No. Most likely the cardboard would have fallen and the water spilt
4. Will gravity change on different planets?
  - a. Yes
1. Which solution did the egg float in?
  - a. The salt solution
2. Why did the egg not float in the fresh water?
  - a. The egg was more dense than the fresh water
3. Why did the egg float in the salt water?
  - a. The egg was less dense than the salt water
4. If you wanted the easiest place to practice floating, where it would be?
  - c. The ocean

## **Tennessee State Standards:**

### **Grade 6 :Embedded Inquiry**

#### Conceptual Strand

*Understandings about scientific inquiry and the ability to conduct inquiry are essential for living in the 21st century.*

#### Guiding Question

*What tools, skills, knowledge, and dispositions are needed to conduct scientific inquiry?*

### **Grade Level Expectations**

GLE 0607.Inq.1 Design and conduct open- ended scientific investigations.

GLE 0607.Inq.2 Use appropriate tools and techniques to gather, organize, analyze, and interpret data.

GLE 0607.Inq.3 Synthesize information to determine cause and effect relationships between evidence and explanations.

GLE 0607.Inq.4 Recognize possible sources of bias and error, alternative explanations, and questions for further exploration.

GLE 0607.Inq.5 Communicate scientific understanding using descriptions, explanations, and models.

### **Checks for Understanding**

0607.Inq.1 Design and conduct an open-ended scientific investigation to answer a question that includes a control and appropriate variables.

0607.Inq.2 Identify tools and techniques needed to gather, organize, analyze, and interpret data collected from a moderately complex scientific investigation.

0607.Inq.3 Use evidence from a dataset to determine cause and effect relationships that explain a phenomenon.

0607.Inq.4 Review an experimental design to determine possible sources of bias or error, state alternative explanations, and identify Questions for further investigations.

0607.Inq.S Design a method to explain the results of an investigation using descriptions, explanations, or models.

### **State Performance Indicators**

SPI 0607.Inq.1 Design a simple experimental procedure with an identified control and appropriate variables.

SPI 0607.Inq.2 Select tools and procedures needed to conduct a moderately complex experiment.

SPI 0607.Inq.3 Interpret and translate data in a table, graph, or diagram.

SPI 0607.Inq.4 Draw a conclusion that establishes a cause and effect

relationship supported by evidence.

SPI 0607.Inq.5 Identify a faulty interpretation of data that is due to bias or experimental error.

## **Grade 6: Embedded Technology & Engineering**

Conceptual Strand

*Society benefits when engineers apply scientific discoveries to design materials and processes that develop into enabling technologies.*

Guiding Question

*How do science concepts, engineering skills, and applications of technology improve the quality of life?*

### **Grade Level Expectations**

GLE 0607.T/E.1 Explore how technology responds to social, political, and economic needs.

GLE 0607.T/E.2 Know that the engineering design process involves an ongoing series of events that incorporate design constraints, model building, testing, evaluating, modifying, and retesting.

GLE 0607.T/E.3 Compare the intended benefits with the unintended consequences of a new

GLE 0607.T/E.4 Describe and explain adaptive and assistive bioengineered products.

### **Checks for Understanding**

0607.T/E.1 Use appropriate tools to test for strength, hardness, and flexibility of materials.

0607.T/E.2 Apply the engineering design process to construct a prototype that meets certain specifications.

0607.T/E.3 Explore how the unintended consequences of new technologies can impact society.

0607.T/E.4 Research bioengineering technologies that advance health and contribute to improvements in our daily lives.

0607.T/E.5 Develop an adaptive design and test its effectiveness.

### **State Performance Indicators**

SPI 0607.T/E.1 Identify the tools and procedures needed to test the design features of a prototype.

SPI 0607.T/E.2 Evaluate a protocol to determine if the engineering design process was successfully applied.

SPI 0607.T/E.3 Distinguish between the intended benefits and the unintended consequences of a new technology.

SPI 0607.T/E.4 Differentiate between adaptive and assistive engineered

products (e.g., food, biofuels, medicines, integrated pest management).

## **Grade 7 : Embedded Inquiry**

Conceptual Strand

Understandings about scientific inquiry and the ability to conduct inquiry are essential for living in the 21st century.

Guiding Question

What tools, skills, knowledge, and dispositions are needed to conduct scientific inquiry?

### **Grade Level Expectations**

GLE 0707.Inq.1 Design and conduct open- ended scientific investigations.

GLE 0707.Inq.2 Use appropriate tools and techniques to gather, organize, analyze, and interpret data.

GLE 0707.Inq.3 Synthesize information to determine cause and effect relationships between evidence and explanations.

GLE 0707.Inq.4 Recognize possible sources of bias and error, alternative explanations, and questions for further exploration.

GLE 0707.Inq.5 Communicate scientific understanding using descriptions, explanations, and models.

### **Checks for Understanding**

0707.Inq.1 Design and conduct an open-ended scientific investigation to answer a question that includes a control and appropriate variables.

0707.Inq.2 Identify tools and techniques needed to gather, organize, analyze, and interpret data collected from a moderately complex scientific investigation.

0707.Inq.3 Use evidence from a dataset to determine cause and effect relationships that explain a phenomenon.

0707.Inq.4 Review an experimental design to determine possible sources of bias or error, state alternative explanations, and identify questions for further investigation.

0707.Inq.5 Design a method to explain the results of an investigation using descriptions, explanations, or models.

### **State Performance Indicators**

SPI 0707.Inq.1 Design a simple experimental procedure with an identified control and appropriate variables.

SPI 0707.Inq.2 Select tools and procedures needed to conduct a moderately complex experiment.

SPI 0707.Inq.3 Interpret and translate data in a table, graph, or diagram.

SPI 0707.Inq.4 Draw a conclusion that establishes a cause and effect relationship supported by evidence.

SPI 0707.Inq.5 Identify a faulty interpretation of data that is due to bias or experimental error.

## **Grade 7 : Embedded Technology & Engineering**

Conceptual Strand

Society benefits when engineers apply scientific discoveries to design materials and processes that develop into enabling technologies.

Guiding Question

How do science concepts, engineering skills, and applications of technology improve the quality of life?

### **Grade Level Expectations**

GLE 0707.T/E.1 Explore how technology responds to social, political, and economic needs.

GLE 0707.T/E.2 Know that the engineering design process involves an ongoing series of events that incorporate design constraints, model building, testing, evaluating, modifying, and retesting.

GLE 0707.T/E.3 Compare the intended benefits with the unintended consequences of a new technology.

GLE 0707.T/E.4 Describe and explain adaptive and assistive bioengineered products.

### **Checks for Understanding**

0707.T/E.1 Use appropriate tools to test for strength, hardness, and flexibility of materials.

0707.T/E.2 Apply the engineering design process to construct a prototype that meets certain specifications.

0707.T/E.3 Explore how the unintended consequences of new technologies can impact society.

0707.T/E.4 Research bioengineering technologies that advance health and contribute to improvements in our daily lives.

0707.T/E.5 Develop an adaptive design and test its effectiveness.

### **State Performance Indicators**

SPI 0707.T/E.1 Identify the tools and procedures needed to test the design features of a prototype.

SPI 0707.T/E.2 Evaluate a protocol to determine if the engineering design process was successfully applied.

SPI 0707.T/E.3 Distinguish between the intended benefits and the unintended consequences of a new technology.

SPI 0707.T/E.4 Differentiate between adaptive and assistive engineered products (e.g., food, biofuels, medicines, integrated pest management).

## **Grade 8 : Embedded Inquiry**

Conceptual Strand

Understandings about scientific inquiry and the ability to conduct inquiry are essential for living in the 21st century.

Guiding Question

What tools, skills, knowledge, and dispositions are needed to conduct scientific inquiry?

### **Grade Level Expectations**

GLE 0807.Inq.1 Design and conduct open- ended scientific investigations.

GLE 0807.Inq.2 Use appropriate tools and techniques to gather, organize, analyze, and interpret data.

GLE 0807.Inq.3 Synthesize information to determine cause and effect relationships between evidence and explanations.

GLE 0807.Inq.4 Recognize possible sources of bias and error, alternative explanations, and questions for further exploration.

GLE 0807.Inq.5 Communicate scientific understanding using descriptions, explanations, and models.

### **Checks for Understanding**

0807.Inq.1 Design and conduct an open-ended scientific investigation to answer a question that includes a control and appropriate variables.

0807.Inq.2 Identify tools and techniques needed to gather, organize, analyze, and interpret data collected from a moderately complex scientific investigation.

0807.Inq.3 Use evidence from a dataset to determine cause and effect relationships that explain a phenomenon.

0807.Inq.4 Review an experimental design to determine possible sources of bias or error, state alternative explanations, and identify questions for further investigation.

0807.Inq.5 Design a method to explain the results of an investigation using descriptions, explanations, or models.

### **State Performance Indicators**

SPI 0807.Inq.1 Design a simple experimental procedure with an identified control and appropriate variables.

SPI 0807.Inq.2 Select tools and procedures needed to conduct a moderately complex experiment.

SPI 0807.Inq.3 Interpret and translate data into a table, graph, or diagram.

SPI 0807.Inq.4 Draw a conclusion that establishes a cause and effect relationship supported by evidence.

SPI 0807.Inq.5 Identify a faulty interpretation of data that is due to bias or experimental error.

## **Grade 8 : Embedded Technology & Engineering**

Conceptual Strand

Society benefits when engineers apply scientific discoveries to design materials and processes that develop into enabling technologies.

Guiding Question

How do science concepts, engineering skills, and applications of technology improve the quality of life?

### **Grade Level Expectations**

GLE 0807.T/E.1 Explore how technology responds to social, political, and economic needs.

GLE 0807.T/E.2 Know that the engineering design process involves an ongoing series of events that incorporate design constraints, model building, testing, evaluating, modifying, and retesting.

GLE 0807.T/E.3 Compare the intended benefits with the unintended consequences of a new technology.

GLE 0807.T/E.4 Describe and explain adaptive and assistive bioengineered products.

### **Checks for Understanding**

0807.T/E.1 Use appropriate tools to test for strength, hardness, and flexibility of materials.

0807.T/E.2 Apply the engineering design process to construct a prototype that meets certain specifications.

0807.T/E.3 Explore how the unintended consequences of new technologies can impact society.

0807.T/E.4 Research bioengineering technologies that advance health and contribute to improvements in our daily lives.

0807.T/E.5 Develop an adaptive design and test its effectiveness.

**State Performance Indicators**

SPI 0807.T/E.1 Identify the tools and procedures needed to test the design features of a prototype.

SPI 0807.T/E.2 Evaluate a protocol to determine if the engineering design process was successfully applied.

SPI 0807.T/E.3 Distinguish between the intended benefits and the unintended consequences of a new technology.

SPI 0807.T/E.4 Differentiate between adaptive and assistive engineered products (e.g., food, biofuels, medicines, integrated pest management).

**Grade 8: Standard 12- Forces in Nature**

Guiding Question 12

What are the scientific principles that explain gravity and electromagnetism?

**Grade Level Expectations**

GLE 0807.12.4 Identify factors that influence the amount of gravitational force between objects.

GLE 0807.12.5 Recognize that gravity is the force that controls the motion of objects in the solar system.

**Checks for Understanding**

0807.12.5 Explain the difference between mass and weight.

0807.12.6 Identify factors that influence the amount of gravitational force between objects.

0807.12.7 Explain how the motion of objects in the solar system is affected by gravity.

**State Performance Indicators**

SPI 0807.12.4 Distinguish between mass and weight using appropriate measuring instruments and units.

SPI 0807.12.5 Determine the relationship among the mass of objects, the distance between these objects, and the amount of gravitational attraction.