

## *Science of Diving: How Science Helps Navy Divers Stay Safe*

*Science Topic: Physiology and Physics*

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**Grades:** 9<sup>th</sup> – 12<sup>th</sup>

### **Essential Questions:**

- What conditions lead to perils facing divers including the bends, embolism and oxygen toxicity?
- How do the gas laws relate to safe diving practices?
- What are the principles of Boyle’s Law and Charles’ Law?
- How is the ideal gas law used to calculate changes in volume, pressure and temperature when one or the other variables is held constant?

### **Lesson Overview:**

Students will learn about how science helps divers avoid the physiological and physical conditions that lead to perils facing divers.

**A companion interactive whiteboard presentation that incorporates video and glossary terms used throughout this lesson is provided to use in classroom instruction (see Teacher’s Guide for directions).**

### **Learning Objectives:**

#### *Evaluation*

- Interpret data related to the physics and physiology of diving.
- Predict changes in gas volume, pressure and temperature when one or the other variables is held constant.
- Create a concept map that shows how each of the gas laws relates to specific risks faced by divers under different physical conditions.

#### *Synthesis*

- Evaluate the importance of different physical parameters including gas volume, pressure and temperature for their importance to divers.
- Model changes in different physical parameters including gas volume, pressure and temperature with changes in depth.
- Integrate knowledge from observations with theoretical knowledge of the gas laws to demonstrate understanding of the perils of diving.

### *Analysis*

- Analyze data from dive tables to determine patterns among time and depth variables.
- Calculate how gas volume, pressure and temperature vary, using Boyle's Law.

### *Application*

- Interpret effects on simple physical systems such as a Cartesian diver in terms of the gas laws.
- Interpret the abstract of a medical journal article to determine the consequences of misinterpreting a dive computer.

### *Comprehension*

- Explain how gas laws relate to the physics and physiology of diving.
- Identify specific physical and physiological conditions that lead to risks for divers.
- Demonstrate understanding of the gas laws and why they relate to risks for divers.

### *Knowledge*

- Recognize equations of the gas laws.
- Identify causes and symptoms of pressure-related diver conditions including the bends and embolisms.

## **National Science Education Standards**

### Disciplinary Core Idea PS3: Energy PS3.D: Energy in Chemical Processes and Everyday Life

- *A variety of multistage physical and chemical processes in living organisms, particularly within their cells, account for the transport and transfer (release or uptake) of energy needed for life functions.*

### Disciplinary Core Idea PS1: Matter and Its Interactions: PS1.A: Structure and Properties of Matter

- *Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. In a liquid, the molecules are constantly in contact with each other; in a gas, they are widely spaced except when they happen to collide.*
- *The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.*

### Disciplinary Core Idea PS1: Matter and Its Interactions: PS1.B: Chemical Reactions

- *The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.*
- *Chemical processes and properties of materials underlie many important biological and geophysical phenomena.*

### Disciplinary Core Idea LS1: From Molecules to Organisms: Structures and Processes LS1.A: Structure and Function

- *In multicellular organisms, the body is a system of multiple interacting sub- systems. These subsystems are groups of cells that work together to form tissues or organs that are specialized for particular body functions.*
- *Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Outside that range (e.g., at a too high or too low external temperature, with too little food or water available), the organism cannot survive.*

### Common Core State Standards: Math

Create equations that describe numbers or relationships: CCSS.Math.Content.HSA-CED.A.2

- *Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.*

Create equations that describe numbers or relationships: CCSS.Math.Content.HSA-CED.A.4

- *Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations*

### Time Frame:

This lesson is designed to be completed in three 90-minute blocks.

### Vocabulary:

- *Bends:* A condition arising when dissolved gases (mostly nitrogen) absorbed when air breathed under pressure is released as a gas back into the bloodstream.
- *Boyle's Law:* A mathematical description of the relationship between pressure and volume of a gas at a constant temperature.
- *Charles' Law:* A mathematical description of the relationship between temperature and volume of a gas at a constant pressure.
- *Decompression:* Decrease in ambient pressure due to ascent from depth.
- *Dissolved Gases:* Breathed gases dissolved in the bloodstream.
- *Embolism:* A condition arising when gases in the lung expand during ascent and rupture lung tissue, causing air bubbles to enter the bloodstream.
- *Hyperbaric Chamber:* A pressure-controlled structure used to treat divers suffering decompression sickness.
- *Oxygen Toxicity:* A condition arising when oxygen-enriched air is breathed under pressure at too great a depth.
- *Scuba:* An acronym for Self-Contained Underwater Breathing Apparatus.

### Media resources used in associated PowerPoint lesson plan:

#### Reading Passages

*The Physics of Diving*

<http://app.discoveryeducation.com/player/view/assetGuid/688D1B48-989C-42CD-B909-468D4F147CD5>

#### Video Segments

*Construction of the Brooklyn Bridge (0:00 to 1:50)*

<http://app.discoveryeducation.com/player/view/assetGuid/B93318CA-3E8E-45CC-8698-BDFBDE2047E3>

*Systems of Equations and Algebra – Scuba Diving*

<http://app.discoveryeducation.com/player/view/assetGuid/B7EAE86D-24F6-4C32-8D37-2AF20455FD0D>

### **Background for the Teacher:**

Since antiquity, the sea has remained a mysterious realm, out of reach beyond a few meters that we can see or swim down towards.

People's dream to swim with the fishes came true in the 1940s with the invention of scuba – a reliable, efficient mechanism that allowed breathing of air to several hundred feet below the ocean's surface.

To meet its mission of defending the nation, the US Navy adopted scuba technology, and created highly trained and equipped diver corps. US Navy divers undertake a wide variety of roles. Each of these jobs requires specialized skills so all Navy divers must undergo training.

Navy diver training includes learning the principles of physics and physiology that govern how the body responds to typical diving conditions. In particular, divers are expected to understand how gases we breathe behave under varying volume, pressure and temperature according to the gas laws.

To maintain maximum safety, divers need to know how the physics of gases relate to physiology. This knowledge allows divers to understand how dangerous diving conditions can lead to perils such as the bends, embolism and oxygen toxicity.

In this lesson, students are introduced to the importance of learning about gas laws and their relevance to diving physiology. Through a variety of interactive media and hands-on activities, students are introduced to the basic principles of the gas laws including Boyle's Law and Charles' Law. They extrapolate these principles to diving situations to learn how the gas laws can help divers adhere to safe diving practices.

Students use small group discussion and learning reinforcement activities to develop their understanding of how the physics of gases relates to diver physiology. Finally, students practice math skills by using the gas laws to calculate changes in volume, pressure and temperature when one or the other variables is held constant.

### **Common misconceptions:**

Here are some common misconceptions about diving, followed by the reality:

- Diving is just for looking at fish or spearfishing. – Numerous roles are possible as a diver such as search and rescue, underwater maintenance and construction, salvage and law enforcement.
- Diving is dangerous. – Diving is a high-risk activity (like hang-gliding or motorcycling) but generally safe within observed guidelines.
- Divers need weights to make them sink. – Scuba diving requires neutral buoyancy.
- The percent of oxygen inhaled increases with depth – The percent oxygen remains constant with depth.
- Dive computers are more accurate than dive tables. – Dive computers use algorithms based on dive table data.

- The pressure of gases inhaled at depth is the same as the pressure at the surface. – The scuba regulator ensures that pressure of gases at depth equals the water pressure at that depth.

## Classroom Activities:

### Materials

For the teacher:

- Power Point capabilities with computer and smart board
- Demonstration materials (optional)
  - Large bottle of diet cola
  - Packet of Mentos mints

For each group of/individual students:

- 1 quart clear plastic soda bottle
- 1 medicine droppers (or several condiment packets)
- Several empty aluminum soda cans
- Hot plate
- Large glass beaker
- Oven mitts and tongs
- Graph paper

## Session 1

### Session Summary

In this session, the instructor introduces the role of divers in the Navy and explains that divers face perils specific to their profession. In particular, such perils are related to the physics of gases and human physiology breathing gases under pressure using scuba equipment. This provides a context to review how physics of gases relates to physiology to determine the reaction of the body to breathing compressed gases, and the causes and consequences of decompression sickness.

### Engage: Soda and scuba – what is the connection? (30 min.)

*Presentation Slides 1 to 7*

1. Ask students “What happens when you shake a can of soda and open it?” They will know the answer.
2. Ask students “Why does the soda fizz up and come out of the can?”
3. Have small groups discuss the answer. To stimulate discussion have students consider why the soda does not get so fizzy if the can is not shaken.
4. Lead students to the conclusion that gases in the can are under pressure, and when that pressure is released, the bubbles expand, reducing the volume for the liquid and forcing it out of the can—sometimes with explosive results. The reason that a shaken can fizzes more than an unshaken one is that shaking causes formation of more bubbles so the gas can escape more easily.
5. Google “Mentos and Diet Coke Experiment” to find a video to demonstrate how this is a physical not a chemical reaction. If time allows, demo the experiment (outside!) and have

students consider why adding Mentos causes an even more violent reaction than just shaking a bottle of soda.

6. Now ask students individually to consider how the gases in soda are the same or different from the gases that they breathe.
7. Show the video concerning the Navy divers. Then ask students if they have ever wanted to go diving in the ocean? Explain that **scuba** technology makes that possible, but diving can be dangerous if the role of physics and physiology are not understood.
8. Ask them if they ever wanted to breathe underwater. Ask students how that might be possible. If some students have used scuba, have them share their experience with the class.
9. Define the acronym SCUBA and have students consider whether diving is safe or not.
10. Have students create a K-W-L chart to describe what they know about breathing, gases and diving. Explain to them that US Navy divers are among the best trained in the world. Hence, students will study divers and the perils they face.

### **Explore: Divers must understand how gas laws relate to physiology (60 min.)**

*Presentation Slides 8 to 11*

*Essential Question: “What conditions lead to perils facing divers including the bends and embolism?”*

1. Introduce students to the basic concept: Gas laws help us understand what is happening physically and biologically when people use scuba.
2. Show the video segment *Construction of the Brooklyn Bridge*. This video shows that decompression sickness can happen whenever people breathe compressed air, not just underwater.
3. Emphasize that air exerts pressure due to weight. At sea level, air weighs 14.7 pounds per square inch. A large textbook weighs around three pounds. Explain that because water is denser than air, pressure because of its weight increases rapidly with depth. Every 33 feet (10 meters) an additional 14.7 pounds per square inch of pressure is added. Hence, divers breathe air under pressure, which can cause problems when if a diver ascends too fast.
4. Divide the class into small groups to discuss what causes diver conditions including the bends and embolism.
5. Ensure that students grasp the basic mechanism causing the bends and embolism: when pressure is reduced, gases expand. The **bends** result when **dissolved gases** (mostly nitrogen) absorbed when air breathed under pressure is released as a gas back into the bloodstream. This happens most frequently if a diver ascends too quickly. **Embolism** results when gases in the lung expand during ascent and rupture lung tissue, causing air bubbles to enter the bloodstream.
6. Have students consider that if rapid **decompression** is the cause of the bends, how might a diver be treated? Introduce use of the **hyperbaric chamber** to treat the bends.

## **Session 2**

### **Session Summary**

In this session, students conduct lab activities to illustrate the principles of the gas laws that concern the physics of gases and physiology during scuba diving. Two sets of hands-on activities (HOAs) allow students to explore the principle of Boyle’s Law. Another HOA introduces students to the principle of Charles’ Law. Student’s complete two HOA activities that allow them to explore how the principles of gas laws can be interpreted from the way real objects respond to specific conditions. Once the HOAs are completed, students learn about the ideal gas law, which combines Charles’s Law and Boyle’s Law in an equation that relates the number of moles of a gas to its temperature, pressure, and volume.

**Explore: Gas law principles explain the physics and physiology of divers breathing pressurized gases (60 min.)**

*Presentation Slides 12 to 14*

*Essential Question: What are the principles of Boyle's Law and Charles' Law?*

1. Introduce students to the basic concept: Gas laws help us understand what is happening physically and biologically when people use scuba.
2. Explain to the class that small groups will perform one of the HOAs to investigate Boyle's Law or Charles' Law. Explain to students that the activities they will conduct are to investigate Boyle's Law and Charles' Law.
3. Ensure students observe good practices for safety and for observing their activities.

*Hands-On Activity 1: Cartesian Diver – Boyle's Law*

1. Introduce students to the basic concept of Boyle's Law – When a gas is at constant temperature, there is an inverse relation between the volume and pressure of the gas. As the volume decreases, pressure increases and as the volume increases, pressure decreases.
2. In this activity, students create a Cartesian diver using simple tools and materials. The diver is made from a medicine dropper weighted to achieve neutral buoyancy. The dropper is placed in a tall soda bottle. The bottle is then sealed. Squeezing the bottle increases pressure in the dropper, so the volume decreases, increasing its density. The increase in density causes the dropper to become negatively buoyant so it sinks. Likewise, releasing pressure causes the diver to rise. If time allows, students can perform simple experiments such as timing the rate of descent of the diver when pressure is applied gently or more forcefully to the bottle, or adding salt to the water to see if this changes the rate of descent.

*Hands-On Activity 2: Pressure Can – Charles' Law*

1. Introduce students to the basic concept of Charles' Law – When an ideal gas is maintained at constant pressure, there is a direct relation between its temperature and volume. As temperature decreases, the volume of the gas decreases.
2. In this activity, students observe the effect of pressure on a can that has a lower pressure than the ambient pressure. A can containing a small amount of water is placed on a hot plate. When the water in the can is boiling, the can is removed and placed inverted in a bowl of water. As the can cools, the water vapor in the can condenses, reducing the volume of gases in the can. Since the volume is lower, the pressure is lower than the ambient pressure, so the can implodes.

After students have completed these activities, tell the groups that they will next work on understanding how each of the laws they learned about relates to the physics and physiology of diving.

NOTE: If time allows, allow students to perform additional experiments with their apparatus.

## **Explore: The ideal gas law states that the product of gas's pressure and volume is proportional to its temperature. (30 min.)**

*Presentation Slides 15 to 23*

1. Present the equations for Charles's Law and Boyle's Law on the board. Ask students what the equations have in common.
2. Explain that the ideal gas law combines Charles's Law and Boyle's Law in an equation that relates the number of moles of a gas to its temperature, pressure, and volume.
3. Present the equation for the ideal gas law that combines Charles's Law and Boyle's Law.
4. Ensure that students understand the basic concept that the product of gas's pressure and volume is proportional to its temperature.
5. Also, ensure that students can relate this concept to conditions experienced by divers.

*Essential Question: How do the gas laws relate to safe diving practices?*

1. Have students brainstorm why Boyle's Law is relevant to divers. For example, the bends and embolisms result when a diver ascends too quickly because decreased pressure results in increased volume of absorbed gases (since Boyle's Law states that  $PV = k$ ,  $V = k/P$  therefore if pressure decreases, volume increases).
2. Have students brainstorm why Charles' Law is relevant to divers. Remind them that gases in a scuba tank are under pressure. What happens if the tank is heated up? This could happen if the tank was left in a car on a sunny day. The tank could explode. If a diver ascends too quickly and is close to a bends or embolism condition, warming the diver could cause gases to expand enough to cause dissolved gases to form bubbles, resulting in a bends or embolism situation. Therefore, warming a diver too quickly could be dangerous. Another consideration is that, when a tank is filled, the pressurization of air causes it to heat slightly, increasing the pressure of air in the tank. Point out that when dive shops fill a tank, they must add extra air to compensate for the higher temperature of gases since the air heats up as it is compressed.
3. Have students brainstorm the question: "What can divers do to avoid the bends?" Lead students to realize that the body needs time to eliminate excess nitrogen that is under pressure in body tissues. Remind students that divers are trained to ascend slowly. Therefore, even on short dives, scuba divers routinely include a three-minute "safety stop" at about 15 feet below the surface, before continuing an ascent. This allows time for the lungs to eliminate excess nitrogen without it forming bubbles. A diver that is down for a long time must account for the possibility of decompression sickness (or DCS). This diver has to undertake decompression stops. These are timed waits at specific depths during the ascent, to allow safe elimination of dissolved respiratory gases.
4. Introduce students to the concept of dive tables. Explain that divers use these to avoid dangerous situations. They do not need to understand all the details, just that dive tables contain data that helps divers to dive safely.

## **Session 3**

### **Session Summary**

In this session, students integrate the knowledge they gained during the hands-on activities to demonstrate their understanding of the perils of diving. First, students create a concept map to show how each of the gas laws relates to specific diver conditions. They use their concept map to create a table that compares each of the gas laws and how they apply to diving physics and physiology. Finally, students are challenged to create a simple demonstration that illustrates one or more principles from the gas laws. This may include an outline for a webpage or PowerPoint presentation, or a sketch for a smart phone app. (See Additional Activities for suggestions for Web 2.0 extensions to the lesson.)

In the Elaborate part of the session, students apply the knowledge gained earlier in the lesson to extrapolate to situations that are more complex for divers. Students calculate the change in volume of air as a diver ascends to assess the risk of embolism. They then consider how breathing enriched air (nitrox) reduces the chances of DCS but increases the chances of oxygen toxicity due to exceeding safety parameters for breathing enriched air mixtures under pressure (nitrox).

**Explain: Perils to divers can be explained by principles from the gas laws. (30 min.)**

*Presentation Slides 24 to 27*

1. Have students create a concept map to show how each of the perils facing divers relates to the gas laws, i.e., how the gas laws relate to specific diver conditions.
2. Have students use their concept map to formalize their knowledge by creating a table that compares each of the gas laws and how they apply to diving physics and physiology.
3. Challenge students to create a simple demonstration or presentation that illustrates one or more principles from the gas laws. This may include a PowerPoint, a skit, or specifications for a smart phone app.
4. Have students review the data in the U.S. Navy Standard Air Decompression Table (40-70 feet) and chart the data from the section representing a depth of 70 feet. Have them create a graph from the data in the column labeled “Bottom time” and the column labeled “Total decompression time.” They can just use the minutes to simplify their chart.
5. Ask students to explain any patterns they notice in their charted data. Have students interpret the chart. For example, if a diver spends one hour at 70 feet, he or she will need to spend more than two hours on decompression stops. Ensure that students understand that decompression time is added over successively shallower depths.
6. Explain that since dive tables can be misunderstood, divers are increasingly using dive computers to guide their diving activities including bottom time and estimating decompression. Have students read an abstract of the medical journal article on the consequences of misinterpreting dive computers (Sayer *et al.*, 2008) and explain such consequences using knowledge acquired during the lesson.

**Elaborate: The ideal gas law can be used to calculate changes in volume, pressure and temperature. (45 min.)**

*Presentation Slides 28 to 34*

*Essential Question: How is the ideal gas law used to calculate changes in volume, pressure and temperature when one or the other variables are held constant?*

1. Have students use Boyle’s Law to calculate the volume of 1000 liters of air in a scuba tank as pressure increases at successive depths below sea level, simulating the volume of air with depth. (Assume a pressure increase of 1.0 atmosphere for every 10.0 m of depth below the surface.) If time allows, have students chart their results on graph paper.
2. Provide students with an example problem. For example, if a diver runs out of air at 15 meters underwater, and immediately ascends to the surface, what are the risks of an embolism? How might the diver avoid embolism? Assume a constant temperature and that the lung capacity is 6 liters, and a pressure increase of 1.0 atmosphere for every 10.0 m of depth below the surface.
  - 1) Lead students through a potential solution by calculating parameters of the situation.

- 2) Let  $P_1$ ,  $V_1$  and  $T_1$  = pressure, volume, and temperature respectively of the air in the diver's lungs when the last underwater breath is taken.
  - 3) Let  $P_2$ ,  $V_2$  and  $T_2$  = pressure, volume, and temperature respectively of the air in the diver's lungs at the surface.
  - 4) Since temperature is constant, we can use Boyle's Law to calculate the increase in volume of the air in the diver's lungs:  $P_1 \times V_1 = P_2 \times V_2$
  - 5) Rearranging,  $V_2 = (P_1 \times V_1)/P_2$
  - 6)  $P_1$  (pressure at depth) = 2.5 atmospheres, since  $= 15/10 \times 1 = 1.5 + 1 = 2.5$  (Note that 1 is added for the 1 atmosphere of pressure at the surface.)
  - 7)  $V_1$  (initial breath underwater) = 6 L
  - 8)  $P_2$  (pressure at surface) = 1 atm
  - 9) Therefore,  $V_2 = (6 \times 2.5)/1 = 15$  L
  - 10) The volume of air increases to 15 liters as the diver ascends. Since lung capacity is 6 liters, there is no way that 15 liters of air could be accommodated. If the diver retains air during ascent, an embolism would be inevitable.
  - 11) To avoid embolism, the diver must ascend more slowly to avoid a rapid increase in the volume of air in the lungs. In fact, divers are trained to release air gradually to avoid embolisms during emergency ascents.
3. Ask students: "How might divers overcome the problem of absorbing nitrogen which then turns to bubbles if the ascent is too fast?" Lead them to consider if the diver breathed 100 percent oxygen, then they would breathe zero nitrogen, so the bends would not be a problem.
  4. Explain that this sounds like a good solution but breathing pure oxygen under pressure carries a significant risk of **oxygen toxicity**. Instead, divers who want to less the risk of the bends breathe enriched air mixtures, or nitrox, that has a higher percentage of oxygen than air, but with a lower risk of oxygen toxicity. If time allows, show the video segment *Systems of Equations and Algebra – Scuba Diving*, which illustrates the principle of mixing respiratory gases.

### Evaluate (15 min.)

#### Presentation Slide 35

1. If students are challenged about the nature of gases, reteach basic physics about the nature of gases.
2. Have students consider their K-W-L charts and concept maps. Students should be able to answer each of the Essential (Guiding) Questions:
  - What conditions lead to perils facing divers including the bends, embolism and oxygen toxicity?
  - How do the gas laws relate to safe diving practices?
  - What are the principles of Boyle's Law and Charles' Law?
  - How is the ideal gas law used to calculate changes in volume, pressure and temperature when one or the other variables are held constant?
3. Students should also be able to define each of the key words.
4. For struggling students, emphasize the key principle that gases expand when pressure is decreased or temperature is increased. This principle explains two of the main perils faced by divers, the bends and embolisms. Emphasize that if temperature is constant, gases expand when pressure is decreased. Thus, when a diver ascends too fast, nitrogen dissolved in the blood forms bubbles. These bubbles cause the bends. Embolism results when air expands in the lungs, rupturing lung tissue and forcing air bubbles into the bloodstream.
5. For advanced students have them calculate the length of time a standard Aluminum 80 tank would last at the surface and at 100 feet deep. At its operating pressure, an "Aluminum 80"

tank holds 80 cubic feet of air. Assume an average person inhales around 500 milliliters of air per breath and takes 15 breaths per minute.

### Evaluate Problem Answer

*At the surface:*

1. 80 cubic feet = 2265 liters
2. 500 ml = 0.5 liter
3.  $2265/0.5 = 4530$
4. Therefore, the tank holds enough air for 4530 breaths.
5.  $4530/15 = 302$
6. Therefore, at the surface, the tank holds enough air for 302 minutes of breathing.

*At 100 feet:*

1. Pressure at 100 feet  $\approx 4$  atmospheres, since 100 feet = 30.5 meters,  $30.5/10 \times 1 = 3.0 + 1 = 4.0$
2. Using Boyle's Law,  $V_2 = (P_1 \times V_1)/P_2$ ,  $V_2 = (1 \times 2265)/4 = 566.25$
3.  $566.25/0.5 = 1132.5$
4. Therefore, the tank holds enough air for 1132 breaths.
5.  $1132/15 = 75.5$
6. Therefore, at 100 feet the tank holds enough air for 75.5 minutes of breathing.

### Additional activities

To further stimulate interest in this topic have student use Web 2.0 tools as an extension to this lesson. Possible approaches include:

- Have students use the CalcTool pressure/depth calculator to calculate pressure with depth, and then to plot the results on graph paper. Students can perform calculations with various units to practice using metric or U.S. units.
- Have students run the Ideal Gas Law Simulation model in their browser. They can vary pressure, volume, temperature, or number of moles of gas to observe how these variables change when one or the other is kept constant. They will also see that gas laws apply to gases other than air.
- Have students use an online visual tool such as Glogster to develop their concept maps with photos and videos and to share ideas and thoughts.
- Students can create slide presentations to summarize their learning and share their presentations online through Slideshare.
- Students can review and edit or create wiki articles (e.g., [simple.wikipedia.org](http://simple.wikipedia.org)) related to the gas laws and scuba diving.

### Additional resources and further reading

CalcTool

[http://www.calctool.org/CALC/other/games/depth\\_press](http://www.calctool.org/CALC/other/games/depth_press)

Diving Physiology

<http://faculty.wvu.edu/schwarn/Training-Materials/PowerPointFormats/DivingPhysiology.ppt>

Ideal Gas Law Simulation

[http://www.chem.ufl.edu/~itl/2045/MH\\_sims/gas\\_sim.html](http://www.chem.ufl.edu/~itl/2045/MH_sims/gas_sim.html)

NOAA – Diving

<http://oceanexplorer.noaa.gov/technology/diving/diving.html>

Sayer MD, Wilson CM, Laden G, Lonsdale P (2008) The consequences of misinterpreting dive computers: three case studies. *Diving Hyperb Med* 38(1): 33-9. <http://www.ncbi.nlm.nih.gov/pubmed/22692658>

U.S. Navy Standard Air Decompression Table (40-70 feet)

[http://www.ndc.noaa.gov/graphics/USNDeco40\\_70.jpg](http://www.ndc.noaa.gov/graphics/USNDeco40_70.jpg)

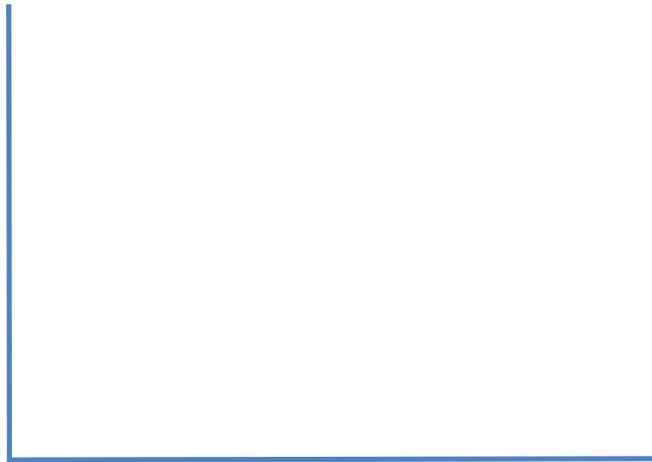
*Science of Diving: How Science Helps  
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*Science Topic: Physiology and Physics*

*STUDENT WORKSHEET*

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1. Sketch a graph that shows the relationship between depth and pressure in the ocean. Which is the dependent variable and independent variable?



2. What can divers do to avoid the bends? Write your thoughts below.



