It's Getting Harder to Breathe

Session Time: Two, 50-minute sessions

DESIRED RESULTS

ESSENTIAL UNDERSTANDINGS

Pilots must be aware of their physical and mental condition in order to conduct safe flights.

Atmospheric conditions and various gases can have a detrimental effect on a pilot's ability to fly safely.

ESSENTIAL QUESTIONS

1. How does a pilot recognize and prevent altitude-related health problems from affecting the safe conduct of a flight?

LEARNING GOALS

Students Will Know

- The definitions, symptoms, and treatments for hypoxia, hyperventilation, and decompression sickness.
- The definitions, symptoms, and treatments for carbon monoxide poisoning and over-exposure to carbon dioxide.

Students Will Be Able To

- *Distinguish* between the symptoms of hypoxia, hyperventilation, decompression sickness, carbon monoxide poisoning, and excessive exposure to carbon dioxide. [DOK L-2]
- *Describe* what a pilot should do to treat symptoms of hypoxia, hyperventilation, decompression sickness, carbon monoxide poisoning, or excessive exposure to carbon dioxide. [DOK L-2]

ASSESSMENT EVIDENCE

Warm-up
As a class or in small groups, students will demonstrate how a change in the amount of air available to a lit candle affects the flame. They will discuss how this concept may affect a pilot flying at altitude.

Formative Assessment
In pairs, students will analyze scenarios regarding oxygen, altitude, and flying, and apply those assessments to realistic flying scenarios.

Summative Assessment
Working in teams, students will participate in a *Jeopardy!*-style quiz game to demonstrate recall and understanding of the core concepts in this lesson.

LESSON PREPARATION

MATERIALS/RESOURCES

- It's Getting Harder to Breathe Presentation
- It's Getting Harder to Breathe Student Activity 1
- It's Getting Harder to Breathe Student Activity 2
- It's Getting Harder to Breathe Teacher Notes 1
- It's Getting Harder to Breathe Teacher Notes 2
- It's Getting Harder to Breathe Teaching Aid

- **It Depends on Oxygen: Student Activity 1 (per group)**
  - Freestanding candle
  - Two large drinking glasses, Mason jars, or similar
  - Matches or lighter
  - Dry ice and insulated gloves; or
  - Baking Soda (2 tablespoons)
  - Vinegar (1 cup)

LESSON SUMMARY

Lesson 1: It's Getting Harder to Breathe
Lesson 2: Your Eyes Are Deceiving You
Lesson 3: Disorientation and Motion Sickness

The lesson begins with a warm-up in which students will see the effect of changing or restricting the air available to a candle flame, and then they will apply those experiences to how a pilot's physiology might be affected at different altitudes. Students will then share personal experiences where they felt the effects of air pressure, which may include stories about diving underwater or flying at high altitudes.

This is followed by a discussion of the key concepts related to hypoxia, hyperventilation, and trapped gas. The students will complete an activity in which they create a trapped gas cavity and understand the effects of altitude changes on the body.

During the next session, students learn the sources, effects, and corrective actions related to carbon monoxide poisoning, carbon dioxide intoxication, and decompression sickness. Students will complete an activity in pairs to summarize the key concepts and enable them to apply those concepts to realistic scenarios.

Students will then review sample FAA Private Pilot Knowledge Test questions relating to atmospheric effects on pilot physiology. Finally, teachers will lead a *Jeopardy!*-style trivia game to summarize the main objectives and ensure common understanding.

BACKGROUND

In previous lessons, students learned about the characteristics of the atmosphere. This lesson focuses on the effects that changing air pressure can have on the human body. As altitude increases, the composition of the atmosphere is essentially the same, but the pressure decreases. Because of the lower pressure at higher altitudes, less oxygen enters the bloodstream through the lungs. This is something many people may experience as shortness of breath or lightheadedness when they visit a mountain in a national park for example. Long term exposure to a low-oxygen environment, whether from climbing a mountain or flying at high altitude, can result in oxygen deprivation, which can impair a person's cognitive ability.

The FAA does not require the use of supplemental oxygen use by flight crew members below 12,500 feet, though pilots are free to use it below that altitude if they choose. Once above 12,500 feet, supplemental oxygen is required for flight crew members. Passengers are not required to use supplemental oxygen until the cabin altitude is 15,000 feet or higher. Supplemental oxygen systems can be as simple as small, portable tanks and masks, or they can be complex systems built into the aircraft.

Most aircraft designed to cruise at high altitudes account for lower atmospheric pressure, by pressurizing the aircraft cabin. Airliners, for example, maintain their cabin pressure such that a passenger feels like they are at about 6,000 to 8,000 feet, even if the airplane is at 35,000 feet or higher. Due to the size, power requirements, and complexity of pressurization systems, most small general aviation aircraft are not pressurized, so a pilot and their passengers experience the ambient pressure as they climb.

In addition to oxygen deprivation, other hazards pilots may face include hyperventilation, sinus and inner ear pain, and carbon monoxide poisoning. Hyperventilation, generally due to fear or anxiety, can cause a rapid reduction in carbon dioxide in the body and result in unconsciousness. Air trapped in the body, which might occur in the ears or sinuses when a pilot has a cold, can expand or compress with climbs and descents, causing discomfort or pain. Carbon monoxide, which is an invisible, odorless gas found in the exhaust of engines, can enter the cockpit and adversely affect anyone in the aircraft.

Finally, decompression sickness is a concern for those who may have been scuba diving prior to flying. In order to prevent decompression sickness, anyone who has been scuba diving should wait 12-24 hours depending on the type of diving and the cruising altitude.

Most of the symptoms associated with these physiological issues are preventable or occur gradually. With training and procedures, pilots can recognize and mitigate the hazards associated with these physiological issues.

MISCONCEPTIONS

Students may believe that it is safe for pilots to take medications to alleviate common conditions like sinus pressure prior to departing on a flight. In fact, the Federal Aviation Administration (FAA) has strict rules regarding all medications, even over-the-counter (OTC) medications for common illnesses and symptoms. All medications, even common OTC medications, have the potential to negatively impact a pilot's performance. For many medications, the FAA dictates a waiting time between the last dosage and operating an aircraft.

DIFFERENTIATION

Some students may benefit from using graphic organizers to keep track of information.

Ask students to record and review their notes in graphic organizers to be able to recall this information more easily.

LEARNING PLAN

ENGAGE

Teacher Materials: It's Getting Harder to Breathe Presentation, It's Getting Harder to Breathe Teacher Notes 1
Student Material: It's Getting Harder to Breathe Student Activity 1

Session 1

Slides 1-3: Introduce the topic and learning objectives of the lesson.

Slide 4: Conduct the **Warm-Up**.

Warm-Up

Note: This Warm-Up can be completed one of three ways: (1) A traditional Student Activity, using **It's Getting Harder to Breathe Student Activity 1**; (2) A teacher-led demonstration using **It's Getting Harder to Breathe Teacher Notes 1**; or, if time is limited or resources are not available, (3) a video demonstration using the links below.

Fire needs oxygen in order to burn, so a flame can be a useful stand-in for demonstrating the impacts of changing oxygen levels in a closed environment. Distribute **It's Getting Harder to Breathe Student Activity 1** and have students complete the two oxygen demonstration exercises, followed by the related questions. Potential responses are available in **It's Getting Harder to Breathe Teacher Notes 1**.

- "5 Weird Ways to Put Out a Candle" (Length 0:36) https://video.link/w/hOk1

For teachers unable to access Safe YouTube links, the video is also available here: https://www.youtube.com/embed/WainnKKtGZI?start=127&end=163

- "5 Weird Ways to Put Out a Candle" (Length 0:58) https://video.link/w/gdj1

For teachers unable to access Safe YouTube links, the video is also available here: https://www.youtube.com/embed/WainnKKtGZI?start=163&end=222

EXPLORE

Teacher Material: It's Getting Harder to Breathe Presentation

Slide 5:

Questions

Have you ever experienced reduced or lack of oxygen in your travels? For example, have you ever climbed a high mountain or visited a high-altitude city like Denver, CO?

Responses will vary based on student experiences. Students who traveled to high altitude cities (Denver, Colorado) or have been on high mountains (Pikes Peak, Colorado) may have experienced the effects of reduced oxygen like shortness of breath or lightheadedness.

Have you ever experienced "ear popping"? When? Where? What did you do to alleviate discomfort you may have experienced?

Responses will vary based on student experiences. Examples may include large air pressure changes (opening or closing car windows at high speed) or during the climb or descent while traveling on a commercial airliner. The effects may have been magnified or more noticeable if they had a cold or sinus congestion at the time.

EXPLAIN

Teacher Material: It's Getting Harder to Breathe Presentation

Slide 6: Watch the following video, which reviews fundamental concepts of the atmosphere and physiology.

- "Aeromedical Factors" (Length 1:06)
  https://video.link/w/oGU4

For teachers unable to access Safe YouTube links, the video is also available here: https://www.youtube.com/embed/xK44nFczul0?start=0&end=66

Slide 7: Recall from prior lessons that the atmosphere has the same basic makeup of gases up to about 70,000 feet: 78% nitrogen, 21% oxygen, 1% CO_2 or other trace gases. However, the pressure and air density decrease with altitude, and not in a linear fashion. At 18,000 feet, air is half as dense as it is at sea level. At 34,000 feet, it is half as dense again. The reduced pressure at higher altitude means that oxygen is not forced into the bloodstream (via the lungs' alveoli) as it is at lower altitudes, and the reduced density means there is less oxygen for the same volume of air. Thus, as pilots fly higher in altitude, they reach points where supplemental oxygen is either recommended or required.

Slide 8: The FAA defines hypoxia as "reduced" or "not enough" oxygen. The threat that hypoxia poses to aviators is reduced oxygen to the brain, which impairs mental function. There are four forms of hypoxia, and the form of hypoxia that a pilot is most likely to encounter is hypoxic hypoxia, which is a result of insufficient available oxygen. Hypoxic hypoxia is generally experienced with increasing altitude, where the reduced oxygen pressure in the atmosphere prevents the body from taking in enough oxygen. The FAA's Aeromedical Division highlights that "all pilots are susceptible to the effects of oxygen starvation, regardless of physical endurance or acclimatization."

Slide 9: The following video describes what causes hypoxic hypoxia and how pilots are trained and equipped to prevent it.

- "Hypoxia: How to Stay Alive above 12,500" (Length 3:07)
  https://video.link/w/oUN1

For teachers unable to access Safe YouTube links, the video is also available here: https://youtu.be/Ork1mjsY810

Slide 10: Certain conditions can make pilots more vulnerable to hypoxia:

- Blocked airways
- Anemia
- Severe bleeding
- Carbon monoxide poisoning
- Blood donation
- High G-forces
- Extreme cold
- Constricted blood vessels (An arm or leg "goes to sleep" is an example.)
- Alcohol or drugs

Symptoms of hypoxia vary with every individual, but common symptoms include:

- Cyanosis (blue fingernails and lips)
- Headache
- Decreased response to stimuli and increased reaction time
- Impaired judgment
- Euphoria
- Visual impairment
- Drowsiness
- Lightheaded or dizzy sensation
- Tingling in fingers and toes
- Numbness

Slide 11: Generally, the symptoms of hypoxia develop slowly, and because of their nature (a sense of euphoria is the most common early symptom), pilots who begin to experience hypoxia may not be concerned or worried, which further complicates attempts at recovery. Hypoxia left untreated could progress to a point in which the pilot no longer has the desire or ability to take life-preserving steps. At this point, even though the pilot is still awake, the pilot is said to have exceeded the "time of useful consciousness" (TUC). The PHAK defines TUC as the maximum time that a pilot has to make and execute rational, life-saving decisions without supplemental oxygen.

Reference the TUC chart from the Pilot Handbook of Aeronautical Knowledge. The TUC can be as long as 30 minutes or more at 20,000 feet pressure altitude, but can be as short as 9 seconds at 45,000 feet. These numbers assume a "normal climb" to those pressure altitudes. In cases of rapid decompression (for example, a sudden loss of cabin pressure due to a window blowing out), the TUC is about half these values. For this reason, pilots who experience major pressure system or oxygen system malfunctions at high altitudes have a very short time to respond.

Slide 12: The following two videos show the effects of high altitude on the brain. The first is in the controlled environment of a hyperbaric or "altitude" chamber. Have the students observe the subject's time of useful consciousness, beginning when he drops his oxygen mask and ending no later than when he can no longer obey a simple command. He states, "The overriding sensation I was feeling was one of euphoria and well-being."

The second video is about an incident that occurred on a Learjet, when the pilot and co-pilot experienced hypoxia in flight.

- "Effects of Hypoxia on the Brain" (Length 4:56)
  https://video.link/w/vVN1

For teachers unable to access Safe YouTube links, the video is also available here: https://youtu.be/n_MI9UiYwJA

- "Pilot Declares Emergency Because Of Extreme Hypoxia" (Length 4:34)
  https://video.link/w/34S1

For teachers unable to access Safe YouTube links, the video is also available here: https://youtu.be/_IqWal_EmBg

In the second video, the pilot who sounds "drunk" and seems to think it's funny that they are unable to control their aircraft is suffering from hypoxia. When the controller is finally able to get the pilot to descend to 11,000 feet toward the end of the video, you can hear their voices change and their communications return to normal.

Slide 13: Hypoxic hypoxia is primarily prevented by avoiding the situations in which it occurs. That is, by following FAA regulations regarding altitudes, supplemental oxygen, and other equipment, pilots should be able to prevent hypoxic hypoxia even in most emergency situations.

Federal regulations (14 CFR 91.211) require that pilots (and flight crews) use supplemental oxygen after 30 minutes of exposure to pressure altitudes between 12,500 and 14,000 feet. Once above 14,000 feet pressure altitude, supplemental oxygen is required immediately for pilots. All persons on an aircraft must have oxygen above 15,000 feet pressure altitude. While these are the regulatory requirements, because the effects of reduced oxygen can be felt at lower altitudes, the FAA recommends supplemental oxygen above 10,000 feet pressure altitude during the day, and above 5,000 feet at night, since deterioration of night vision due to reduced oxygen can occur as low as 5,000 feet. These pressure altitudes are cabin pressure altitudes; that is, the pressure inside the airplane. Most small general aviation aircraft are unpressurized, so their cabin pressure is the same as the ambient pressure. Larger aircraft, airliners, and many jets are often pressurized so pilots and passengers experience a lower pressure altitude inside the fuselage than what exists outside at cruising altitude.

Slide 14: Preventing hypoxia begins with education. Pilots learn about the types of hypoxia and how to recognize their symptoms. To understand how their bodies react to conditions conducive to hypoxia, pilots may enroll in programs where they can experience the effects of high altitudes in chambers designed for this purpose (as seen in the video from slide 12).

Prevention can also include the aircraft. Supplemental oxygen can be carried aboard (whether portable or built-in), or a pilot flying at high altitudes may choose to operate a pressurized aircraft.

If a pilot senses the onset of hypoxia, treatment involves either the use of supplemental oxygen or descending to an altitude where supplemental oxygen is unnecessary.

Slide 15: Hyperventilation is a related physiological issue that pilots and passengers sometimes face. Watch the following video for a short explanation of hyperventilation and its treatment:

- "Aeromedical Factors" (Length 1:30)
  https://video.link/w/O7P1

For teachers unable to access Safe YouTube links, the video is also available here: https://www.youtube.com/embed/xK44nFczul0?start=324&end=413

Hyperventilation is an excessive rate and depth of breathing that leads to low carbon dioxide levels in the blood. While most people understand the importance of oxygen, carbon dioxide is a critical part of the respiratory process as well.

The breathing cycle is normally initiated by a chemical reaction: the lungs react to an increase in the blood's alkaline pH caused by increased carbon dioxide in the blood. If another cause initiates the breathing cycle when the pH does not require it (for example: blowing up a balloon, fear), the amount of CO_2 in the blood could get dangerously low. Low oxygen environments (e.g., higher altitude), stressful situations, and anxiety can often contribute to the excessive breathing rate of hyperventilation. Common symptoms of hyperventilation include:

- Visual impairment
- Lightheaded or dizzy sensation
- Tingling sensations
- Hot and cold sensations
- Muscle spasms
- Unconsciousness

Slide 16: The chances of experiencing hyperventilation can be reduced by minimizing external stresses. Breathing normally and flying at altitudes that do not require supplemental oxygen also help to prevent the onset of hyperventilation.

Some symptoms of hyperventilation are similar to those of hypoxia, so pilots should attempt to correctly diagnose their condition before beginning a corrective action. Pilots can look at the altitude (and cabin pressure altitude) and status of the supplemental oxygen system first to minimize the possibility the symptoms are hypoxia related. However, if a pilot is unsure if the condition is hypoxia or hyperventilation, pilots should treat them the same: Use supplemental oxygen and control breathing.

The best treatment for hyperventilation is to slow the rate of breathing. Breathing normally is the best cure for hyperventilation. Breathing into a paper bag or talking out loud tends to foster a steady breathing rate, which increases CO_2 levels and prevents or alleviates hyperventilation. The act of breathing into a paper bag allows a person to re-breathe their own CO_2 thus increasing the volume of CO_2 in their lungs.

If hyperventilation continues uncontrolled, unconsciousness could result, at which point the body will restore its normal breathing rate.

Slide 17: Ear and sinus pain are other physiological issues a pilot can experience related to altitude. Watch the following video for an overview of the effects of trapped gas on the ear and sinuses:

- "Aeromedical Factors" (Length 1:28)
  https://video.link/w/IuP1

For teachers unable to access Safe YouTube links, the video is also available here: https://youtu.be/xK44nFczul0?t=526

Slides 18-19: The eardrum membrane acts as a seal, with air pressure normally equalizing through the eustachian tube. If the eustachian tube is impeded or blocked (for example, due to the mucus build up during a cold or swelling during a sinus infection), the body will be unable to relieve the pressure in the middle ear. This is not normally an issue on the ground, since pressure isn't changing substantially. However, during a climb to altitude in an aircraft, the trapped air in the middle ear expands, causing discomfort initially and pain as it proceeds. If a pilot experiences ear discomfort while climbing, the climb should be terminated and the pilot should consider ending the flight. Frequently, the trapped air in the middle ear is able to escape slowly during the climb to altitude, which creates a false sense of relief. The problem then becomes the descent, in which it is nearly impossible to equalize the middle ear through a blocked eustachian tube, resulting in a painful or physically harmful descent.

Similarly, if the sinus cavities are impeded or blocked due to swelling or mucus, air can be trapped in the sinus cavity and can exert immense pressure that is felt as discomfort or pain behind the eyes and nose.

Ear and sinus pain brought about by an aircraft's descent can be excruciating, and it is not simply an issue of discomfort. If the descent continues without relief, a pilot with a blockage may rupture an eardrum, which may require significant recovery time and could be medically disqualifying for pilots.

Slide 20: To attempt to alleviate sinus or ear pain in a descent, pilots should consider slowing the rate of descent or holding an altitude. Another option is to climb back to an altitude where the pilot or passenger did not experience any pain then resume a descent slowly.

Pilots can use a chewing motion or manipulate their jaw to attempt to massage the eustachian tube. Application of some medications (for example, inhaled nasal decongestants) may provide some relief. Slower-acting decongestants may be taken to prevent congestion while flying; however, pilots must consult the FAA's go/no-go medications document. An excerpt from this document (officially titled "What Over-the-Counter (OTC) medications can I take and still be safe to fly?") appears on the slide.

Some medications are considered unacceptable for use before or during flight by the FAA. Because medications can affect a pilot's resistance to hypoxia or even the ability to safely fly the aircraft, the FAA closely controls medications that are or are not approved for flight.

Session 2

Slide 21: This slide reviews key concepts from the prior session. You may instruct students to answer each question individually, or you may discuss each question as a class.

Questions

What happens to the percentage of oxygen in the atmosphere as altitude increases?

The percentage remains constant. (The pressure decreases.)

Between 12,500 feet and 14,000 feet, pilots are required to use supplemental oxygen after how long?

30 minutes

Name at least two common symptoms of hypoxic hypoxia.

- *Cyanosis (blue fingernails and lips)*
- *Headache*
- *Decreased response to stimuli and increased reaction time*
- *Impaired judgment*
- *Euphoria*
- *Visual impairment*
- *Drowsiness*

- *Lightheaded or dizzy sensation*
- *Tingling in fingers and toes*
- *Numbness*

True or False: A pilot can fly with a seasonal allergy if they take an antihistamine that has drowsiness as a side effect to prevent ear or sinus blockages.

False. The FAA considers "sedating" over-the-counter medications to be "no-go" for flight. Further, the pilot cannot always anticipate how long the medication will remain effective or what other effects it may have. In general, if a pilot requires medication to feel well enough to fly, the pilot probably isn't well enough to fly.

Slide 22: Other gases can be present in the aircraft cabin besides oxygen. For example, carbon monoxide (CO) is a product of combustion. CO is found in cigarette and cigar smoke as well as in engine exhaust; it can enter an aircraft cabin through an exhaust leak.

Watch the following video for a quick discussion on the sources and detection of carbon monoxide:

- "Aeromedical Factors" (Length 0:46)
  https://video.link/w/l8P1

For teachers unable to access Safe YouTube links, the video is also available here: https://youtu.be/xK44nFczul0?t=202

Slide 23: Unlike the example of carbon dioxide and the candle, carbon monoxide does not displace oxygen in the aircraft cabin. Instead, CO attaches to the hemoglobin in the blood more easily than oxygen, preventing oxygen from entering the bloodstream. As a result, exposure to CO will eventually starve the body of its needed oxygen. This is known as hypemic hypoxia. Pilots should not rely on smell or sight to detect carbon monoxide, which is odorless and colorless. However, if a pilot smells exhaust in the cabin, they should be aware that this might indicate that CO is present. Fairly inexpensive CO detectors are available specifically for aircraft applications. They are often simple paper cards with spots that change color in the presence of CO. Other more expensive electronic detectors can also be purchased.

Slide 24: The symptoms of CO poisoning include headache, blurred vision, dizziness, drowsiness, and/or loss of muscle power. While somewhat similar to hypoxic hypoxia, CO poisoning generally results in discomfort and irritability as opposed to the euphoria of hypoxia.

Slide 25: When pilots suspect CO poisoning, immediate action is required to block the source of the CO and allow fresh air to enter the cabin. Generally, this may mean turning off any aircraft cabin heater, opening fresh air vents (or a window, if possible), and using supplemental oxygen.

The possibility of CO poisoning can be reduced through regular maintenance to prevent, detect, or repair issues with the aircraft engine exhaust and cabin ventilation system. Failure to properly maintain the aircraft can increase the risk of exposure to carbon monoxide. Also, smoking cigarettes and cigars is essentially self-induced carbon monoxide poisoning. Pilots who smoke substantially increase their risk for physiological incidents, as well as increase the risk for health ailments that may be medically disqualifying for pilots under FAA regulations.

Slide 26: Carbon dioxide (CO2) is another gas that can be harmful to a pilot in flight. As noted in the discussion about hyperventilation, a certain level of CO2 in the body is normal and necessary to maintain the proper pH of the blood (which then controls breathing). However, too much CO2 in the air can deprive the body of oxygen. While CO interferes with the ability of the blood to transport oxygen, CO2 simply displaces the oxygen available. In confined spaces, such as an airplane cabin, excessive CO2 can prevent a pilot from receiving enough oxygen, leading to hypoxic hypoxia, just as if they had climbed in altitude.

Where might excessive CO_2 come from? Carbon dioxide is not normally produced in large quantities in most circumstances, except from the sublimation of dry ice, which is frozen CO_2.

Dry ice is commonly used to transport frozen foods or other perishable items. Airliners and commercial cargo aircraft have special handling rules and limits on how much dry ice they (or their passengers) can carry. For most general aviation operations, there is no restriction on carrying dry ice, though pilots are generally advised not to do so. The relatively small cabin space in a GA aircraft could quickly fill with CO_2 from even a small quantity of dry ice. As the dry ice sublimates, the CO_2 would begin to displace the oxygen in the aircraft cabin, leading to oxygen deprivation for the occupants, much like the flame of the candle that was extinguished by CO_2.

It might seem logical to place the dry ice in a sealed container to prevent CO_2 from interfering with the pilot. However, if dry ice sublimates in a sealed container, it produces immense pressure—many times more than the CO_2 pressure from a shaken can of soda—and can even cause the container it is in to explode.

Slide 27: Prior to oxygen deprivation, occupants would experience the effects of carbon dioxide intoxication: increased breathing rate, faster heart rate, and impaired mental function. Recognition of these symptoms should prompt pilots to obtain fresh air or supplemental oxygen and mitigate the danger.

Slide 28: Normally, a person has a certain amount of nitrogen gas dissolved within their body tissues. The pressure around the human body affects how much nitrogen is in a person's body, and the speed at which this pressure changes can affect how quickly the gas enters or exits the body's tissues.

For example, if a pilot goes scuba diving, their body is subjected to increased pressure because of the weight of the water above them. In order to balance this pressure, air from the scuba diver's tanks is delivered through regulators at a pressure equivalent to that at the diver's depth. This allows oxygen and nitrogen to enter the body normally. As the diver moves toward the surface of the water, nitrogen escapes the body's tissues. Scuba divers know that rising slowly is important to alleviate decompression sickness (DCS), which is caused if the dissolved nitrogen gas escapes the body' s tissues too quickly and forms bubbles.

Slide 29: Watch the following two videos for explanations and demonstrations of how a gas can be dissolved in and leave a liquid, like the nitrogen in the bloodstream:

- "3 Perplexing Physics Problems" (Length 1:37)

Part 1:
https://video.link/w/GRR1

For teachers unable to access Safe YouTube links, the video is also available here: https://www.youtube.com/embed/K-Fc08X56R0?start=0&end=97

- "3 Perplexing Physics Problems" (Length 3:11)

Part 2:
https://video.link/w/1RR1

For teachers unable to access Safe YouTube links, the video is also available here: https://www.youtube.com/embed/K-Fc08X56R0?start=468&end=659

Slide 30: As the diver ascends, and for up to 24 hours thereafter, the process reverses and the nitrogen tries to return to equilibrium with the atmosphere by coming out of the tissues. Depending on the conditions and severity, this process can lead to nitrogen bubbles migrating to various parts of the body (including the lungs or brain), causing discomfort, nausea, unconsciousness, or even death, in a condition known as "decompression sickness" (DCS). Nitrogen bubbles can occur in the muscles, under the skin, in joints, or in the bloodstream. Bubbles in the musculoskeletal system can cause discomfort or pain, generally called the "bends" because the skin can appear to "bend" as the bubbles accumulate underneath. Bubbles that progress to the brain can cause neurological issues, while bubbles that block the capillaries in the lungs can cause the "chokes."

Slide 31: Decompression sickness can be prevented by following proper procedures. People who scuba dive are advised to allow enough time for the body to dispel the excess nitrogen prior to flying. The symptoms of decompression sickness could be incapacitating for a pilot trying to safely fly an airplane. More importantly, a rapid increase in altitude will only exacerbate the decompression that typically occurs at normal atmospheric pressure on the ground.

The recommended time between completing a dive and flying is 24 hours (though that time can be reduced in some circumstances). Failure to do so could result in DCS during flight. If a pilot experiences DCS symptoms during flight, they should use supplemental oxygen immediately and conduct an emergency descent to land as soon as possible where appropriate medical attention can be obtained. If experiencing DCS joint pain, the joint should be moved as little as possible to prevent nitrogen bubbles from migrating through the body. After landing, medical attention should be sought from an FAA medical officer, AME, military flight surgeon, hyperbaric specialist, or other doctors who specialize in dive medicine. Treatment may include spending time in a hyperbaric chamber.

EXTEND

Teacher Materials: It's Getting Harder to Breathe Presentation, It's Getting Harder to Breathe Teacher Notes 2
Student Material: It's Getting Harder to Breathe Student Activity 2

Slide 32: Complete the **Formative Assessment**.

Formative Assessment

Divide the class into pairs and distribute **It's Getting Harder to Breathe Student Activity 2**. Students will work in pairs to analyze the scenarios regarding oxygen, altitude, and flying. Potential responses are available in **It's Getting Harder to Breathe Teacher Notes 2**.

[DOK-L2; *describe*]

EVALUATE

Teacher Materials: It's Getting Harder to Breathe Presentation, It's Getting Harder to Breathe Teaching Aid

Slides 33-58: Review the Private Pilot Knowledge Test questions. These questions are preparing students to pass the FAA Private Pilot Knowledge Test, and they resemble what is on that test.

Slide 59: Conduct the **Summative Assessment**.

Summative Assessment

Conduct the *Jeopardy!*-style quiz game described in **It's Getting Harder to Breathe Teaching Aid**.

[DOK-L2; *distinguish*]

Summative Assessment Scoring Rubric

- Follows assignment instructions
- Responses show evidence of one or more of the following:
  - Correct recall of altitude and pilot physiological issues
  - Reasonable application of corrective actions to scenarios
  - Evidence and explanation of the above that demonstrate understanding of the material

- Contributions show understanding of the concepts covered in the lesson
- Contributions show in-depth thinking including analysis or synthesis of lesson objectives

Points **Performance Levels**

9-10 Correctly understands all altitude, atmosphere, and pilot physiological issues, and makes a reasonable analysis of scenarios to apply corrective actions, with appropriate explanations.
7-8 Correctly understands most altitude, atmosphere, and pilot physiological issues, with some errors, and makes generally reasonable analysis of scenarios to apply corrective actions to scenarios, with some incomplete analysis or errors.
5-6 Correctly understands some altitude, atmosphere, and pilot physiological issues, with errors, or makes generally reasonable analysis of scenarios to apply corrective actions to scenarios but lacks adequate explanation.
0-4 Provides few, if any, correct ideas about altitude, atmosphere, and pilot physiological issues, and/or makes poor analysis of scenarios to apply corrective actions to scenarios with inadequate explanation.

STANDARDS ALIGNMENT

COMMON CORE STATE STANDARDS

- **RST.11-12.2** - Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
- **RST.11-12.4** - Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 11-12 texts and topics*.
- **WHST.11-12.6** - Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information.
- **WHST.11-12.8** - Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.
- **WHST.11-12.9** - Draw evidence from informational texts to support analysis, reflection, and research

FAA AIRMAN CERTIFICATION STANDARDS

PRIVATE PILOT
I. Preflight Preparation
Task H. Human Factors

- Knowledge The applicant demonstrates understanding of:
  - **PA.I.H.K1** The symptoms (as applicable), recognition, causes, effects, and corrective actions associated with aeromedical and physiological issues including:
    - **PA.I.H.K1a** Hypoxia
      PA.I.H.K1b Hyperventilation
    - **PA.I.H.K1c** Middle ear and sinus problems
    - **PA.I.H.K1d** Spatial disorientation
    - **PA.I.H.K1e** Motion sickness

        - **PA.I.H.K1f** Carbon monoxide poisoning
        - **PA.I.H.K1g** Stress
        - **PA.I.H.K1h** Fatigue
        - **PA.I.H.K1i** Dehydration and nutrition
        - **PA.I.H.K1j** Hypothermia
        - **PA.I.H.K1k** Optical illusions
        - **PA.I.H.K1l** Dissolved nitrogen in the bloodstream after scuba dives
    - **PA.I.H.K2** Regulations regarding use of alcohol and drugs.
    - **PA.I.H.K3** Effects of alcohol, drugs, and over-the-counter medications.
    - **PA.I.H.K4** Aeronautical Decision-Making (ADM).
- Risk Management The applicant demonstrates the ability to identify, assess and mitigate risks encompassing:
    - **PA.I.H.R1** Aeromedical and physiological issues.
    - **PA.I.H.R2** Hazardous attitudes.
    - **PA.I.H.R3** Distractions, loss of situational awareness, or improper task management.
- Skills The applicant demonstrates the ability to:
    - **PA.I.H.S1** Associate the symptoms and effects for at least three of the conditions listed in K1a through K1l above with the cause(s) and corrective action(s).
    - **PA.I.H.S2** Perform self-assessment, including fitness for flight and personal minimums, for actual flight or a scenario given by the evaluator.

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"Pilot Declares Emergency Because Of Extreme Hypoxia" (Length 4:34)

https://youtu.be/_IqWal_EmBg