Altimeter and VSI

Session Time: Three, 50-minute sessions

DESIRED RESULTS

ESSENTIAL UNDERSTANDINGS

Innovations in aviation are driven by the desire to make aircraft safer, more capable, and more efficient. (EU2)

Safe and efficient aviation operations require that pilots use math, science, and technology. (EU3)

A deep understanding of how an aircraft operates enables a pilot to fly the aircraft to its maximum capabilities in both normal and abnormal situations. (EU4)

ESSENTIAL QUESTIONS

1. How do pilots know how high they are flying?
2. What affects a pilot's altitude?
3. Why is it important for pilots to understand all the factors that affect an aircraft's altitude?

LEARNING GOALS

Students Will Know

- What the pitot-static system is and which instruments it powers
- How an altimeter works and the different types of altitudes that concern pilots
- What a vertical speed indicator is and how it works

Students Will Be Able To

- *Differentiate* between instruments that require static air and those that require ram air to operate. (DOK-L3)
- *Explain* the operation of the altimeter in terms of what they have learned about air density and pressure. (DOK-L3)
- *Analyze* the settings and readings of pitot static instruments to determine altitude and calculate altitude changes. (DOK-L4)

ASSESSMENT EVIDENCE

Warm-up
Students split into two groups and discuss everyday experiences with atmospheric pressure and then relate those experiences to aircraft in flight.

Formative Assessment
Students will demonstrate that they can correctly read an altimeter correctly. They will also draw an altimeter with a specific altitude shown.

Summative Assessment

Students will recall important details related to the different types of altitude. Then, they will analyze flight scenarios to apply what they learned in this lesson.

LESSON PREPARATION

MATERIALS/RESOURCES

- Altimeter and VSI Presentation
- Altimeter and VSI Student Activity 1
- Altimeter and VSI Student Activity 2
- Altimeter and VSI Student Activity 3
- Altimeter and VSI Teacher Notes 1
- Altimeter and VSI Teacher Notes 2
- Altimeter and VSI Teacher Notes 3

Flight Simulation Activity

- Flight simulation equipment

Recommended Student Reading

- **Pilot's Handbook of Aeronautical Knowledge**
  Chapter Eight, Flight Instruments, pages 8-1 through 8-8 https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/phak/media/10_phak_ch8.pdf

LESSON SUMMARY

Lesson 1: Altimeter and VSI
Lesson 2: Airspeed Indicator
Lesson 3: Pitot-Static Failures

In this three-session lesson, students will learn different types of air pressures, the system that utilizes air pressure to determine altitude and airspeed, and two of the three pitot-static instruments. Students will warm up by having a discussion about everyday experiences with atmospheric pressures: high altitude on a mountain and changing speed out a car window.

During the first session, students will then learn what air pressures are important to a pilot and the mechanics of the system all aircraft use to measure those pressures. The students will then discuss how that system reacts as the aircraft moves through different pressure environments. Students will learn how the altimeter works and demonstrate that they can read an altimeter during a formative assessment.

Students will then focus on the effects of non-standard atmospheric conditions on the altimeter. They will also learn the 5 different types of altitudes and why each is important to a pilot.

Finally, students will learn about the operation of the vertical speed indicator. Students will practice interpreting the displays and understanding the information presented through a simulation activity. During a summative assessment, students will recall important details related to the different types of altitude. Then, they will analyze flight scenarios to correct the misconceptions of a misinformed co-pilot.

BACKGROUND

To fly an airplane safely, pilots needs to know the altitude at which they are flying, how their altitude is changing, and how fast they are moving. This information is derived from the pitot-static system. A pitot-static system is a series of pressure-sensitive instruments that generally consists of a pitot tube, a static port, and the pitot-static instruments. The pitot-static system of instruments uses the principle of air pressure gradient. It works by measuring pressures or pressure differences and using these values to assess the speed and altitude. These pressures can be measured either from the static port (static pressure) or the pitot tube (pitot pressure). The static pressure is used in all measurements, while the pitot pressure is used only to determine airspeed.

Among the systems that power the basic flight instruments, the pitot-static system is the most important. It is responsible for three of the six basic instruments (commonly called the "six-pack.") These include the altimeter, the vertical speed indicator (VSI), and the airspeed indicator. None of these instruments require any electricity, motor, or computers. The information all comes from the air surrounding the airplane.

The pressure altimeter, also known as the barometric altimeter, is used to determine changes in air pressure that occur as the aircraft's altitude changes. Pressure altimeters must be calibrated prior to flight to register the pressure as an altitude above sea level. The instrument case of the altimeter is airtight and has a vent to the static port. Inside the instrument, there is a sealed aneroid wafer or "bellows". As pressure in the case decreases, the aneroid wafer expands, which is mechanically translated into a determination of altitude. The reverse is true when descending from higher to lower altitudes.

The vertical speed indicator, commonly referred to as the VSI, is the pitot-static instrument used to determine whether an aircraft is flying in level flight. The vertical speed specifically shows the rate of climb or the rate of descent, which is measured in feet per minute. The vertical speed is measured through a mechanical linkage to an aneroid wafer or "bellows" located within the instrument. The area surrounding the diaphragm is vented to the static port through a calibrated leak. When the aircraft begins to increase altitude, the bellows will begin to contract at a rate faster than that of the calibrated leak, causing the needle to show a positive vertical speed. The reverse of this situation is true when an aircraft is descending.

MISCONCEPTIONS

Students are likely familiar with the idea that altitude is a measurement of height. However, there are many different types of altitude, and many of them have nothing to do with the height above the ground. Pilots need to understand these different types of altitude and when to use them in order to fly safely. Within this lesson the students will discuss five different "types" of altitude and their relative importance to pilots.

DIFFERENTIATION

To support student collaboration and reflective thinking in the **EXPLORE** section, allow students to work in small groups to perform calculations and learn about the five types of altitude. Encourage students to collaborate with peers about why pilots care about the various types of altitude before returning to a whole group discussion on the topic.

To support student motivation and comprehension in the **EXPLORE** and **EXTEND** sections, allow students to compete in a 60 second Altimeter Reading Challenge. Their points will be recorded on the website leaderboard.

LEARNING PLAN

ENGAGE

Teacher Material: Altimeter and VSI Presentation

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

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

Warm-Up

Split the class into two groups, and assign each group one of the two scenarios/questions. Once the students have had time to discuss, solicit responses from each to be shared with the entire class, and see if they can relate their descriptions to how an aircraft might sense or respond to the atmosphere in similar situations. If necessary, help them make this connection as part of the discussion.

- Group 1 - You dive to the bottom of the deep end of a swimming pool. What are some ways your body lets you know you are deep below the surface?

While the students may cite a variety of physical indications of their environment, the one most relevant to this lesson is the feeling of pressure squeezing or compressing them more strongly than at the surface. Students may also talk about feeling pressure in their ears or having their ears "pop." This is a physical manifestation very similar to how the airplane will sense a higher static pressure at lower altitudes. Some students may also note the water feels "thicker" or harder to move through, which is similar to how air density increases at lower altitudes.

- Group 2 - As a passenger at a stoplight, you stick your hand out your car window. What does your hand experience that lets you know when you begin moving?

While the students may cite a variety of physical indications of movement, the one most relevant to this lesson is the feeling their hand is being pushed back by the increasing air pressure as the car accelerates. The pressure increases with increasing speed. This is very similar to how an aircraft is able to determine airspeed by changes in air pressure.

[DOK-L2; *describe*]

EXPLORE

Teacher Materials: Altimeter and VSI Presentation, Altimeter and VSI Teacher Notes 1
Student Material: Altimeter and VSI Student Activity 1

Slide 5: An airplane measures static, dynamic, and total air pressures around the aircraft to display information to the pilot.

- Static or "ambient" pressure is the pressure from still air. It is the pressure of a fluid on a body when the body is at rest relative to the fluid - in this case, the fluid is air. With static pressure, air presses equally in all directions. It is always present on an aircraft, whether it is at rest or in motion.
- Dynamic pressure is the pressure of the air that results only from its motion. Because static pressure from still air is always present, it cannot be separated to directly measure only dynamic pressure. Instead, the difference between the total pressure and the static pressure is used to find dynamic pressure. Total Pressure - Static Pressure = Dynamic Pressure.
- Total or "ram" pressure is the pressure from moving air as it is brought to a stop. Everyone has put their arm out of the car window while driving on a nice day and felt the pressure against the hand. The pressure against the hand, where the moving air is stopping against the skin, is total pressure. The pressure behind the hand, where the air is still, is static pressure. Static Pressure + Dynamic Pressure = Total Pressure

Slide 6: The system that utilizes static air pressure and dynamic pressure is called the pitot-static system (pronounced "pee-toe"-static). It derives part of its name from Henri Pitot, a French scientist who invented a device for measuring the total pressure of the River Seine in the 1700s. Pitot tubes can be found on not only aircraft but also boats and other fast-moving machines.

Among the systems that power the basic flight instruments, the pitot-static system is the most important. It is responsible for three of the six basic instruments (commonly called the "six-pack.") These include the altimeter, the vertical speed indicator (VSI), and the airspeed indicator. During this lesson, students will learn about the altimeter and the vertical speed indicator. The next lesson is dedicated to the airspeed indicator.

Slide 7: The pitot-static system includes a pitot tube, one or more static ports, and all the associated plumbing that runs from the pitot tube and the static ports to the airspeed indicator, vertical speed indicator, and altimeter. Although it's described as a full system regardless of the associated instruments, only the static port is used for the altimeter and vertical speed indicator, while both the pitot tube and static port are used with the airspeed indicator.

Slide 8: The pitot tube is normally an L-shaped device that is usually mounted on the wing of the airplane so that it faces into the relative wind. The pitot tube senses the total pressure or "ram" pressure (dynamic plus static) when an aircraft is in motion. A small hole in the pitot tube faces the wind and allows ram air pressure to enter. The pitot tube also has static holes and a static chamber.

As the ram pressure changes, normally due to speed or wind changes, the pressure moves freely through small lines or tubes that connect to the instruments.

There's a small drain hole in the back to allow moisture to drain out. A pilot must ensure all openings in the pitot tube are clear prior to flight because the presence of debris or insects could prevent the pitot tube from doing its job. Some types of pitot tubes have an electronic heating element inside of the tube that prevents ice from blocking the air inlet or drain hole.

Slide 9: A static port is normally a small hole located on the side of the aircraft, flush against the fuselage where there is free, undisturbed air. The static port senses only static (non-moving) air pressure, which is also known as ambient pressure. As the ambient pressure changes, the pressure moves freely in and out of the static port through small lines that connect to the instruments.

Some aircraft have more than one static port, and some aircraft have an alternate static source in case one or more of the ports becomes blocked. The alternate static source is often located inside the cockpit, instead of on the outside on the fuselage. Because the air pressure inside the cockpit is usually lower than ambient pressure outside, if the alternate static must be used, an error correction must be applied. This will be discussed in further detail in a lesson on pitot-static failures.

Just like for the pitot tube, a pilot must ensure all openings in the static system are clear prior to flight.

Slide 10: Ask the students which type of air pressure each of the three pitot-static instruments use.

Questions

What type of air pressure does each of these instruments use?

Vertical Speed Indicator - *static pressure*
Airspeed Indicator - *static and ram pressure*
Altimeter - *static pressure*

As a review, show students the following video, which provides a brief verbal and graphical explanation of the pitot-static system.

- "Pitot-Static Instruments" (Length 2:33)
  https://video.link/w/Pxxi

Slide 11: The chief source for information on level flight (or altitude) is the altimeter. This instrument may look and act somewhat like a clock, but it reads altitude instead of time. The altimeter works on a basic principle. As an airplane ascends, air pressure decreases. The instrument senses this by taking the ambient air pressure from the static port. That air is plumbed through the back of the panel and into the back case of the altimeter. Inside the altimeter is a sealed disc called an aneroid, or "bellows," which has a constant, calibrated internal pressure.

In the graphic on the slide, the aneroid wafer is what looks like stacked plates on the left or back portion of the altimeter. An aneroid wafer is sealed with an internal pressure of 29.92 inches of mercury (inHg). The wafers are free to expand and contract like an accordion with changes to the static pressure. A higher static pressure presses down on the wafers and causes them to collapse. A lower static pressure (less than 29.92 inHg) allows the wafers to expand. When the static pressure decreases, the lower pressure is sensed through the static port and the pressure inside the case also decreases. In the presence of lower pressure, the wafers expand. Similarly, when the pressure increases inside the case, the wafers contract due to the higher pressure. The bellows are mechanically connected to the face of the instrument through gears. As the wafers expand and contract with changes in static pressure, they move the pointers and display an altitude based on the sensed pressure.

Show students the following video which describes how an altimeter works.

- "Pitot-Static Instruments" (Length 1:08)
  https://video.link/w/6nDi

Slides 12-13: Indicated altitude is simply what the hands on the altimeter point to. The long medium-width needle reads hundreds of feet (the calibrations are 20 feet), the short wide needle indicates thousands of feet, and the long thin needle reads in tens of thousands of feet.

- 100-ft pointer = long medium-width needle indicates hundreds of feet
- 1,000-ft pointer = short wide needle indicates thousands of feet
- 10,000-ft pointer = long thin needle with upside-down triangle indicates tens of thousands of feet

The video provides a brief verbal and graphical explanation of how to read an altimeter.

- "Altimeter" (Length 1:01)
  https://video.link/w/Piyi

Important Note: Like analog clocks, not all pointers on all altimeters look exactly the same, but they are the same in concept.

Have students practice reading the altimeters on slide 13.

Questions

Read the altitudes on each of the altimeters.

1 - 1,760 feet. The ten-thousand pointer is less than 1, the thousand pointer is between 1 and 2, the hundreds pointer is 3 20-foot increments above 7.

2 - 2,360 feet. The ten-thousand pointer is less than 1, the thousand pointer is between 2 and 3, the hundreds pointer is 3 20-foot increments above 3.

3 - 14,500 feet. The ten-thousand pointer is between 1 and 2, the thousand pointer is on 4, the hundreds pointer is on 5.

Slide 14: Complete the **Formative Assessment**. This activity should conclude the first session.

Formative Assessment

To check for understanding, distribute a copy of **Altimeter and VSI Student Activity 1** to each student. For the first 3 questions, students should identify the indicated altitude on each instrument. For the next 2 questions, students will be asked to draw an altimeter with a specific altitude shown. Correct responses are provided in **Altimeter and VSI Teacher Notes 1**.

[DOK-L1; *identify*]

EXPLAIN

Teacher Material: Altimeter and VSI Presentation

Slide 15: Begin the second session with a brief summary and review of the previous session.

Questions

Ask the students to recall from the previous session:

What are the three types of air pressure?
The three types of pressure are static (ambient), dynamic, and total (ram).

What does an aircraft use to measure these pressures?
A static port on the side of the fuselage senses static pressure. The pitot probe senses total pressure. Dynamic pressure isn't directly measured. It can be calculated as the difference between total pressure and static pressure.

What three instruments in the cockpit use one or more of these pressures?
The three instruments are altimeter, vertical speed indicator (VSI), and airspeed indicator.

How does an altimeter use static pressure to display altitude?
The altimeter compares the static pressure to a sealed aneroid at standard pressure, which moves pointers on the face of the altimeter to indicate the altitude.

This session will focus on the effects of non-standard atmospheric conditions on the altimeter.

Slide 16: Recall that students learned in the previous semester (Unit 3) that:

- Standard pressure at sea level is equal to 29.92 inches of mercury (inHg).
- Pressure decreases at a standard rate, or “lapse” rate, with increasing altitude: 1 inHg for each 1,000 ft.

The altitude displayed or "indicated" on an altimeter is only correct when the aircraft is in scientifically defined “standard” pressure and temperature conditions, which rarely happens in the real world. Instead, pilots must account for the actual conditions by adjusting the “altimeter setting,” which is input into the “Kollsman window” on the altimeter. Pilots adjust the altimeter setting in the Kollsman window to tell the altimeter what the pressure is at sea level. The altimeter is able to compare this value to the current static pressure it senses, allowing it to display an indicated altitude for the current non-standard pressure. When the altimeter setting is 29.92, the altimeter is calibrated to sea level standard pressure and the altitude displayed on the altimeter will be the current Pressure Altitude.

The graphic shows a standard altimeter, and the Kollsman window is highlighted. The current altimeter setting in the graphic is 30.20 inHg.

Slide 17: The altimeter setting is first adjusted on the ground prior to takeoff and is updated regularly throughout the flight. The altimeter setting for an airport is normally broadcast on an automated weather radio frequency or is available from air traffic control. A knob is located at the bottom of the instrument for this adjustment.

In some cases, an altimeter setting may not be available. In that case, prior to takeoff the pilot should adjust the altimeter setting in the Kollsman window until the altimeter indicates the elevation of the airport. With the correct altimeter setting in the Kollsman window, the indicated altitude should be within 75 feet of the known airport elevation. If it isn't, the altimeter could be malfunctioning.

The altimeter setting should be continuously updated for changing weather conditions or if flying from one area to another.

Slide 18: Without this ability to adjust the altimeter setting, a hazardous situation could occur as pilots fly through air masses of different pressure.

For example, let's say a pilot has an altimeter setting of 29.90 inHg, but based on the weather conditions, the actual altimeter setting is supposed to be 30.15. This is a difference of 0.25 inHg (30.15 - 29.90 = 0.25).

Recall from previous lessons that for every 1,000 feet increase in altitude, there is a 1 inHg decrease in pressure (the "lapse rate"). Based on the lapse rate, the altimeter setting error in this example would result in an error of 250 feet:

$\frac{1000\text{ ft}}{1\text{ inHg}} \times 0.25\text{ inHg} = 250\text{ ft}$

Because the erroneous altimeter setting is lower than the actual, the displayed altitude would be lower than the actual altitude. So, if the pilot in this example continued to fly with the wrong altimeter setting at a displayed altitude of 2,000 feet, the aircraft would actually be at 2,250 feet, or 250 feet higher than the pilot meant to be.

Slide 19: Use this example to ask students to calculate the difference between the displayed and actual altitude.

Let's say a pilot flies from a high pressure area (Airport A) to a low pressure area (Airport B) at a constant indicated altitude of 5,000 feet without adjusting their altimeter setting for the new pressure. This is the opposite of the previous example, so the actual altitude of the aircraft in the lower pressure area would be 1,000 ft lower than it was in the higher pressure area.

Ask the students the following questions related to this example.

Questions

If the pilot fails to update the altimeter setting, what will the displayed altitude be?
The pilot will continue to see 5,000 feet displayed on the altimeter despite the change in pressure.

How much higher or lower is the displayed altitude than the actual one?

30.74 - 29.74 = 1 inHg

$\frac{1000\text{ ft}}{1\text{ inHg}} \times 1\text{ inHg} = 1000\text{ ft}$

The graphic on this slide shows that 5,000 feet over Airport A (on the left side) with an altimeter setting of 30.74 is equal to 4,000 feet over Airport B (on the right side) with an altimeter setting *of 29.74, but the pilot will continue to see 5,000 feet on his altimeter even as he flies at 4,000 feet. This is a dangerous situation, because the pilot is flying 1,000 feet closer to the ground than intended.*

In other words, the pilot would be closer to the ground in the lower pressure area. In an area where terrain is a concern, this could lead a pilot to unintentionally fly into the ground. That's why when discussing non-standard pressure effects on the altimeter, some pilots remember the mantra, "Going from HIGH to LOW, look out below."

Slide 20: Recall that students learned in the previous semester (Unit 3) that:

- Sea-level standard temperature is 15 C.
- Temperature decreases at a standard rate with an increase in altitude: 2 C for each 1,000 ft.

If two columns of equal volumes of air were stood side by side and the temperature of one was lowered, the height of the cold column would decrease as the air molecules cooled and moved closer together, making the cold air denser. Because cold air is more dense than warm air, when operating in temperatures colder than standard, aircraft will be at a lower altitude than that the altimeter displays. Thus, similar to pressure, pilots remember "From HOT to COLD, look out below."

Unlike with pressure, altimeters cannot be adjusted for non-standard temperature. There is no option on an altimeter to make an adjustment for temperature. Instead, when conditions are much colder than standard, pilots must reference data tables to correct their altitude.

To use the ICAO Cold Temperature Error Table (found on the slide) find the temperature on the left side of the chart, then locate the altitude above the airport on the top row. Where the two values intersect, that's how much lower than indicated an aircraft could be. As an example, for a temperature of -10 C and an aircraft altitude of 1000 feet above the airport elevation, the chart shows that at the current altimeter setting the aircraft may be as much as 100 feet below the altitude indicated on the altimeter.

Slide 21: Ask students to calculate the potential errors in the given examples, using the lapse rate and their learning to this point.

Questions

Example 1

If the pilot fails to update their altimeter setting as they approach the destination airport, how far off will their altitude be?
500 feet. Multiply the difference in pressure settings (30.15 – 29.65 = 0.50) by the lapse rate (1,000 ft per inHg): 0.50 x 1,000 = 500

Will they be high or low?
The aircraft will be at a higher altitude than indicated on the altimeter because he is flying from a lower pressure area to a higher pressure area.

Example 2

If the pilot fails to consider the temperature change as they approach the destination airport, do they risk being too high or low?
Because of the dramatic drop in temperature from hot to cold, the pilot risks being too low if they do not adequately account for the lower temperature.

Slides 22-23: Altitude is the vertical distance (height) above some reference line. There are 5 types of altitude relevant to a pilot. As each type of altitude is explained, ask students *why* a pilot cares about this type of altitude.

Indicated Altitude - the altitude read directly off the altimeter when it's set to the local pressure (current altimeter) setting. The altimeter is not very useful if the most current altimeter setting is dialed into the Kollsman window. Indicated altitude is not corrected for other factors like temperature.

- Knowing the aircraft's altitude is vitally important to a pilot. The pilot must be sure that the aircraft is flying high enough to clear the highest terrain or obstruction along the intended route. In addition, to reduce the possibility of a mid-air collision, it is essential to maintain altitude in accordance with air traffic rules.

True Altitude - The vertical distance of the aircraft above sea level, as if measured with a tape measure. Mean Sea Level (MSL) is an agreed-upon engineering datum or reference that approximates the average ocean level (since the actual sea level is variable). For example, when driving into a town and the "Welcome" sign says "Elevation: 250 feet," it means the town is 250 feet above mean sea level. An airplane displaying true altitude while sitting on the ground at that town would show 250 feet on its altimeter. This altitude is not related to the local terrain, so it has nothing to do with how high the aircraft is above the ground.

When the current altimeter setting is dialed into the Kollsman window, indicated altitude is used as if were "mean sea level" or MSL.

- Commonly expressed as "feet MSL" (feet above mean sea level), a pilot cares about this altitude because many of the airspace altitudes, terrain figures, airways, and obstacles found on aeronautical charts are expressed in true altitude (MSL), feet above sea level.

Absolute Altitude - The vertical distance of an aircraft above the ground, or above ground level (AGL), as if measured with a tape measure. It is the exact height above ground level, or the actual height above the earth's surface.

- A pilot cares about this altitude because this is the altitude that tells them how much clearance they have above terrain or obstacles.

Pressure Altitude - Read from the altimeter when it is set to 29.92 inHg. This is the altitude of the aircraft above the standard datum plane, the theoretical location where at 15 degrees Celsius the altimeter setting will equal 29.92 inches of mercury. Many aircraft performance calculations require knowledge of the pressure altitude.

All aircraft flying above 18,000 feet MSL are required to set their altimeters to 29.92 inches Hg. This means that all aircraft flying in the flight levels (above 18,000' MSL) will have the same altimeter setting.

- A pilot cares about this altitude because this number is used to compute other types of altitude, including true altitude and density altitude, as well as performance data like true airspeed.

Density Altitude - Pressure altitude corrected for variations from standard temperature (15 degrees C at sea level with a standard lapse rate of 2 degrees centigrade per thousand feet). In practical terms, density altitude is a way of describing the density of the air as a height above mean sea level. When the density altitude is higher than standard for a given location, the density of the air itself is lower than standard for that location. In standard conditions, pressure altitude and density altitude are the same. When the temperature is higher than standard, the density altitude is higher than pressure altitude. When the temperature is lower than standard, density altitude is lower than pressure altitude.

Students should recall they first learned about density altitude in Unit 3.

- A pilot cares about this altitude because density altitude directly affects aircraft performance. A pilot knows that when density altitude is very high or low, aircraft performance will change as well.

This should complete the second session.

Slide 24: Begin the third session with a brief summary and review of the previous session.

Questions

Ask the students to recall from the previous session:

When a properly functioning altimeter has the correct altimeter setting in the Kollsman window, how close should the displayed altitude be to the airport's actual elevation?
The displayed altitude should be within 75 feet.

What are the 5 types of altitude a pilot is concerned about?
The 5 types of altitude are Indicated, True, Absolute, Pressure, and Density.

How do you determine the current pressure altitude if sitting in your airplane?
Dial 29.92 in the Kollsman window of the altimeter. This tells the altimeter it's a "standard pressure day," and the altimeter will display the current pressure altitude.

If a pilot flies into an area of lower pressure without adjusting the altimeter setting, what happens?
The pilot will continue to fly at the same indicated altitude, but the actual altitude will be lower; in other words, the aircraft will be closer to the ground than the pilot thinks it is.

Slide 25: Ask students to recall the three instruments that the pitot-static system powers: altimeter, vertical speed indicator, and airspeed indicator.

Students will now learn about the vertical speed indicator, commonly referred to as the VSI. The vertical speed indicator is an instrument that tells the pilot whether the aircraft is climbing or descending and at what rate (indicated in feet per minute).

Like an altimeter, the VSI has an aneroid (or bellows) inside its case that is connected through a mechanical linkage with the needle on the face of the instrument. The bellows are connected to the static port. The bellows may also be referred to as a diaphragm.

A key feature of the VSI is the calibrated leak. The calibrated leak is a tiny hole in the instrument case that is also connected to the static port. The hole in the calibrated leak is small enough that it restricts airflow, so air can't move in and out as fast as the air in the bellows can.

The VSI works on the principle of differential pressure. As an airplane climbs, the static pressure decreases, and it decreases immediately in the bellows. But the pressure doesn't change immediately in the instrument casing. Since the calibrated leak lets air out slowly, it creates a higher pressure in the casing than the bellows. When that happens, it creates a pressure differential, the bellows is squeezed down, and the gears connected to the VSI needle make it move up.

The faster the climb, the greater the pressure differential, and the more the needle moves up. The exact opposite occurs in a descent.

Because the VSI relies on air leaking out of (or into) the casing, it takes a second or two for everything to stabilize. That's where trend versus rate comes into play. When an airplane initially starts climbing or descending, the VSI needle will start moving, but it can't immediately indicate how fast the airplane is climbing. This is called *trend* information. When a pilot sees the direction of the needle moving up, they know climb rate is increasing, and when it moves down, they know the climb rate is decreasing. After a second or two, the calibrated leak has a chance to catch up and reach equilibrium, and the VSI will stabilize at a certain climb or descent rate. When that happens, the pilot has *rate* information.

Because of this lag, it's important for pilots to know that any climb or descent may *register* immediately, but they won't immediately know the actual *rate* of the climb or descent. That information is only accurate when the climb or descent has stabilized.

When the pressure stops changing (the aircraft returns to level flight), the pressure in the case and the aneroid slowly equalize. This prompts the needle to move back to zero, showing level flight.

Show students a video which provides a brief explanation of how a VSI works.

- "Vertical Speed Indicator" (Length 3:46)
  https://video.link/w/vbch

Slide 26: The face of the VSI has one needle/pointer. Ask students to interpret the climb or descent of the VSI pictured on the slide.

Questions

What's the rate of climb or descent on this VSI?
The VSI is showing a 500 feet per minute climb. The pointer is in the top half of the instrument, which indicates a positive climb rate; each large index number is 1,000 feet per minute, as indicated in the text on the face of the instrument. The pointer is halfway to the first index number.

What should a VSI read on the ground prior to takeoff?
The VSI should read zero when on the ground, prior to takeoff.

EXTEND

Teacher Materials: Altimeter and VSI Presentation, Altimeter and VSI Teacher Notes 2
Student Material: Altimeter and VSI Student Activity 2

Slide 27: In this activity, students will practice reading and flying with an altimeter and VSI. Divide the class into pairs. Provide each group with **Altimeter and VSI Student Activity 2**, and direct students to complete the steps in the outlined procedure and answer the questions, alternating between roles of pilot and observer.

They will modify their altimeter settings and perform a series of climbs and descents to specific altitudes at specific rates of climb. Sample responses to analysis questions are provided in **Altimeter and VSI Teacher Notes 2**.

EVALUATE

Teacher Materials: Altimeter and VSI Presentation, Altimeter and VSI Teacher Notes 3
Student Material: Altimeter and VSI Student Activity 3

Slides 28-33: Quiz students on several questions from the Private Pilot Knowledge Test.

Slide 34: Conduct the **Summative Assessment**.

Summative Assessment

In this activity, students will recall important details related to the different types of altitude. Then, they will analyze flight scenarios to apply what they learned in this lesson.

Distribute a copy of **Altimeter and VSI Student Activity 3** to each student, and direct them to answer the questions individually. Correct responses are provided in A**ltimeter and VSI Teacher Notes 3**.

[DOK-1; *list*, DOK-2; *describe, explain, DOK-3; assess*]

Summative Assessment Scoring Rubric

- Follows assignment instructions
- Student work shows:
  - Ability to identify and describe the different kinds of altitude.
  - An understanding of the meaning of different kinds of altitude.
  - An accurate comprehension of the types of altitudes and VSI lag in order to correct misconceptions
- Contributions show in-depth thinking including synthesis of lesson objectives.

Points **Performance Levels**

9-10 The student lists indicated altitude, true altitude, absolute altitude, pressure altitude, and density altitude. The student identifies absolute altitude which tells a pilot how far the aircraft is above the ground/terrain which helps to avoid collision with terrain and other obstacles. The student identifies true altitude which gives every pilot the vertical distance above sea level which helps to avoid midair collisions. The student accurately and thoroughly responds to each scenario-based question to correct the inexperienced pilot's misconceptions.

7-8 The student lists 4 out of the 5 kinds of altitude: indicated altitude, true altitude, absolute altitude, pressure altitude, and/or density altitude. The student identifies absolute altitude and gives an adequate definition and explanation of why this is important to the pilot. The student identifies true altitude and gives an adequate definition and explanation of why this is important to the pilot. Minor gaps in understanding is evident. The student sufficiently responds to each scenario-based question to correct the inexperienced pilot's misconceptions.

5-6 The student lists fewer than 4 out of the 5 kinds of altitude: indicated altitude, true altitude, absolute altitude, pressure altitude, and density altitude. The student identifies absolute altitude but gives an inadequate definition and explanation of why this is important to the pilot. The student identifies true altitude but gives an inadequate definition and explanation of why this is important to the pilot. Many gaps in understanding is evident. The student attempts to respond to each scenario-based question, but does not fully correct the inexperienced pilot's misconceptions.

0-4 The student does not correctly list the five kinds of altitude. The student is unable to identify absolute altitude as the distance above the ground. The student is unable to identify true altitude as an aircraft's distance above sea level. Student work shows little or no understanding of the five kinds of altitude. The student inaccurately responds to each scenario-based question.

STANDARDS ALIGNMENT

NGSS STANDARDS

Three-dimensional Learning

- **HS-PS1-5** - Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.
  - Science and Engineering Practices
    - Using Mathematics and Computational Thinking
    - Constructing Explanations and Designing Solutions
  - Disciplinary Core Ideas
    - None
  - Crosscutting Concepts
    - Patterns
    - Energy and Matter
    - Stability and Change

COMMON CORE STATE STANDARDS

- **RST.9-10.4** - 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 9-10 texts and topics.
- **WHST.9-10.9** - Draw evidence from informational texts to support analysis, reflection, and research.
- **MP.1** - Make sense of problems and persevere in solving them.
- **MP.2** - Reason abstractly and quantitatively.
- **MP.8** - Look for and express regularity in repeated reasoning.

REFERENCES

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