Which Way to Steer?

Session Time: Four, 50-minute sessions

DESIRED RESULTS

ESSENTIAL UNDERSTANDINGS

Comprehensive preflight planning is an integral (and regulatory) component of safety for all flights.

Natural factors such as wind and magnetic fields affect aircraft navigation. Pilots must understand these factors and account for them accordingly.

ESSENTIAL QUESTIONS

1. How does a pilot compensate for natural factors, such as winds and magnetic fields, that may affect the course of a flight?

LEARNING GOALS

Students Will Know

- How wind affects the heading a pilot must steer to remain on course.
- How Earth's magnetic field affects the heading a pilot must steer to remain on course.
- How wind affects the groundspeed of an aircraft.

Students Will Be Able To

- *Calculate* compass headings after taking true course, wind correction angle, magnetic variation, and magnetic deviation into account. [DOK-L1]
- *Construct* a wind triangle to model the effect of wind on true course. [DOK-L2]
- *Apply the concepts* of wind and magnetic corrections in an explanation of how an aircraft compensates for those effects during flight. [DOK-L4]

ASSESSMENT EVIDENCE

Warm-up
In pairs, students will match terms to their definitions in order to differentiate and highlight the distinctiveness of certain flight planning terminology. To reinforce those objectives, students will then discuss which terms were intuitive and which seemed very similar.

Formative Assessment
Formative Assessment 1 Individually, students will calculate a compass heading given several no-wind scenarios with varying magnetic influences based on VFR sectional chart excerpts.

Formative Assessment 2 In pairs, students will work together to calculate compass headings given several different scenarios of wind and magnetic variation, requiring them to draw wind triangles.

Summative Assessment
Working individually, students will calculate compass headings and groundspeeds for a multiple-leg flight and then analyze what effect the winds and magnetic field have on the planned flight with regard to fuel and time.

LESSON PREPARATION

MATERIALS/RESOURCES

- Which Way to Steer? Presentation
- Which Way to Steer? Student Activity 1
- Which Way to Steer? Student Activity 2
- Which Way to Steer? Student Activity 3
- Which Way to Steer? Student Activity 4
- Which Way to Steer? Student Activity 5
- Which Way to Steer? Student Activity 6
- Which Way to Steer? Student Activity 7
- Which Way to Steer? Teacher Notes 1
- Which Way to Steer? Teacher Notes 2
- Which Way to Steer? Teacher Notes 3
- Which Way to Steer? Teacher Notes 4
- Which Way to Steer? Teacher Notes 5
- Which Way to Steer? Teacher Notes 6
- Which Way to Steer? Teacher Notes 7
- VFR sectional chart (local area, Memphis, or any)
- Aeronautical chart plotter with rotating azimuth wheel
- Box fan and balsa gliders

Solving the Triangle Activity: Student Activity 4 (per student)

- Paper
- Protractor
- Straightedge or ruler

Flight Simulation Activity: Student Activity 6 (per group)

- Computer with flight simulation software or flight simulator
- Joystick or yoke
- Optional: Throttle quadrant, rudder pedals, additional monitors

Wind Correction Diagramming Activity: Student Activity 7 (per group)

- Card stock
- Ruler
- Protractor
- Tape

- Scissors

LESSON SUMMARY

Lesson 1: Drawing and Measuring Courses
Lesson 2: Which Way to Steer?
Lesson 3: Flight Computers

The lesson begins with a warm-up in which students will match terms to their definitions in an attempt to find the distinction between similar terms. This is followed by an activity in which the students attempt to figure out magnetic courses using only the information from the sectional charts. The differences between magnetic and true are then explained, as well as the equations to convert one to the other. The first session ends with an assessment on conversions to compass headings.

During the next session, students learn the effect of winds on courses and headings. Students are introduced to the equations to calculate the changes in speed that occur with wind as well as the wind correction angle pilots must use to fly a planned course. Students are introduced to the wind triangle and complete an assessment in pairs solving several different wind problems.

In the third session, students learn how to use the groundspeed results determined earlier to figure out distances, times, and fuel consumption in flight. The session ends with a summative assessment in which students plan the courses, headings, fuel, and timing of a two-leg long-distance flight.

In the final session, students will experience the physical effects of the points learned in the first three sessions by flying a simulator and observing the effects of headwinds, tailwinds, crosswinds, and winds of varying speeds. Students will then answer sample FAA Private Pilot Knowledge Exam questions relating to course calculations. Finally, teachers have the option of presenting a video that explains the underlying trigonometry of the wind triangle to those students who may benefit from it.

BACKGROUND

With a wind from the left, how far does a pilot need to angle the aircraft to fly a straight course? Calculating the answer can be very complex; indeed, in many aircraft today the answer is derived by onboard computers. However, the question is as old as flight itself, or potentially older, since the concepts apply to maritime travel, as well. There are structured ways to solve the heading problem so pilots can accurately plan a flight based on the winds they expect to encounter. Importantly, these methods do not require extensive or advanced mathematics, but instead rely on the same plotting tools and graphical techniques previously introduced.

Ultimately, pilots start by planning a true course on a VFR sectional chart and then correct it for the forecast true winds. Then, they make a correction for magnetic effects. The final result is a heading in degrees that pilots can fly on a compass and expect to arrive at their planned destination. These same methods help pilots understand how wind affects their speed, and speed affects how much fuel they'll use in flight. Thus, with just a ruler, protractor, and chart, a pilot is able to reliably plan and predict the time, distance, fuel, speed, and heading necessary to safely and efficiently complete a flight.

MISCONCEPTIONS

Some people think that once a pilot plots a course on a VFR sectional chart, that true course will keep the aircraft on course to the destination. Instead, determining the true course is just the first step in figuring out what path the pilot needs to fly. The pilot needs to take that true course and correct for winds that might otherwise cause the aircraft to drift off course.

The magnetic compass is the navigation instrument upon which aircraft heading displays are based. This is because if all other instrumentation fails, the magnetic compass is the most basic instrument the pilot can rely upon for navigation information.

The magnetic compass provides a consistent and reliable reference, but to get a magnetic heading the pilot needs to correct for variations in the Earth's magnetic field as well as the magnetic influences of the aircraft itself. Only after these calculations are complete, will the pilot have a reasonable heading to fly toward the destination. Even then, the pilot will plan to verify and update the heading in flight to account for real-world conditions. In short, there are many steps, planning resources, and calculations in between the line drawn on a map and the heading of an airplane.

DIFFERENTIATION

To support student comprehension of complex topics, create learning centers for students to gain additional instruction and/or practice related to compass heading and wind triangles. Learning centers may include additional instructional videos, reading resources and demonstrations, and additional practice problems.

Demonstrate how to use a protractor to refresh students' memory on using the tool.

High ability students may be assigned the **Going Further Activity** which applies trigonometry to aircraft navigation.

LEARNING PLAN

ENGAGE

Teacher Materials: Which Way to Steer? Presentation, Which Way to Steer? Teacher Notes 1
Student Material: Which Way to Steer? 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

Navigation in aviation has many related terms, including a few that sound suspiciously similar. The objective of this warm-up is to get students comfortable using navigation terminology and understanding the distinct and proper meanings.

Divide the class into pairs and distribute **Which Way to Steer? Student Activity 1**, in which students will match terms and their definitions. Sample responses are available in **Which Way to Steer? Teacher Notes 1**. When the students are finished, have them share insights with the rest of the class related to which terms were intuitive, and which they may have found confusing.

EXPLORE

Teacher Materials: Which Way to Steer? Presentation, Which Way to Steer? Teacher Notes 2
Student Material: Which Way to Steer? Student Activity 2

Slide 5: With the foundational terminology established, students can now attempt to expand on previous lessons and put the terms into practice. Divide the class into groups of three or four and distribute **Which Way to Steer? Student Activity 2**, in which students will build on the material from prior lessons to plan flight routes. Sample responses are available in **Which Way to Steer? Teacher Notes 2**.

EXPLAIN

Teacher Materials: Which Way to Steer? Presentation, Which Way to Steer? Teacher Notes 3, Which Way to Steer? Teacher Notes 4
Student Materials: Which Way to Steer? Student Activity 3, Which Way to Steer? Student Activity 4

Slides 6-7: Remember that the geographic, or "true," North Pole is where lines of longitude converge, and the magnetic north pole is where the north needle of a compass points. They are not at the same location. In fact, they are about 300 miles apart. Since VFR sectional charts have lines of longitude on them, all courses determined based on those lines will be true courses. However, pilots navigate using compasses, which are magnetic. A compass points to the magnetic north pole, not the geographic North Pole. Pilots need to convert a true course they plot on a sectional chart to one they can steer in the airplane.

Slides 8-9: Pilots make this conversion by accounting for the magnetic difference between the poles, which is known as *magnetic variation*. On the east coast of the United States, if a pilot were to fly directly toward the geographic North Pole, the compass would be pointing to the west of true north because that is the relative position of the magnetic north pole from the pilot's position. This is known as westerly variation. On the west coast of the United States, the compass would point to the east of true north because that is the relative position of the magnetic north pole from the pilot's position. This is known as easterly variation. There is a line of zero variation that runs through the midwestern United States known as the *agonic line*. It divides easterly and westerly magnetic variations and runs near Minneapolis, Minnesota, Cedar Falls, Iowa, and Baton Rouge, Louisiana. On this line, if a pilot were to fly toward true north, the compass would indicate directly toward true north because, from the pilot's perspective, the poles would be aligned.

To convert from the chart's true course to a magnetic course, pilots must add or subtract the variation. Whether they add or subtract depends on whether the pilot is in an area of westerly or easterly variation.

Slides 10-13: A pilot flying in the western half of the United States is in an area of easterly variation. To account for easterly variation, a pilot must subtract the magnetic variation value from the true course. For example, if a pilot on the west coast plotted a course of 108 degrees in an area of 14-degree easterly variation, the pilot would subtract 14 degrees from 108 degrees. The result is a magnetic course of 94 degrees. A saying pilots use to remember this procedure is "east is least." TC - MV = MC is one way pilots may see this calculation abbreviated.

A pilot flying in the eastern half of the United States is in an area of westerly variation. To account for westerly variation, a pilot must add the magnetic variation value to the true course. For example, if a pilot on the east coast plotted a course of 309 degrees in an area of 17-degree westerly variation, the pilot would add 17 degrees to 309 degrees. The result is a magnetic course of 326 degrees. A saying pilots use to remember this procedure is "west is best." TC + MV = MC is one way pilots may see this calculation abbreviated.

Again, pilots remember this mathematical procedure with the rule of thumb "East is least, West is best." "East is least" reminds pilots to subtract easterly variation, while "West is best" reminds pilots to add westerly variation.

In areas along the agonic line, the true course is equal to the magnetic course.

Slide 14: Using the excerpt from the sectional on Slide 14, discuss the following question.

Questions

If a pilot were plotting a course of 085 degrees, what would the magnetic course be?

The isogonic line near Cape May says "12°W," meaning 12 degrees westerly variation. Since "west is best," the magnetic course would be 085 + 12 = 097 degrees.

As a class, have students suggest airports in different regions and have the class attempt to determine the local magnetic variation and the effect it would have on a true course.

Slides 15-16: The magnetic forces of the earth aren't the only ones to consider. The airplane itself can affect the local magnetic field which, in turn, affects the magnetic direction indicated on the aircraft's compass. The magnetic field can be influenced by electrical circuits, radios, lights, tools, the engine, and magnetized metal parts. The difference between the actual magnetic direction and the compass reading is known as compass deviation. The amount of compass deviation is unique to every aircraft, and it can even be different for different headings in the same aircraft. The deviation can also change if the configuration of the aircraft changes (for example, if a new radio is installed). The deviation can sometimes be corrected slightly by a mechanic, who can adjust small screws on the compass to compensate for the unique magnetic field of the airplane. Any error that remains can still be measured, allowing a pilot to correct for the deviation. These measurements are placed on a deviation card that is normally displayed directly below the compass. The corrections are normally displayed in 30-degree increments, and pilots can estimate intermediate values if necessary. The card shows the degrees a pilot needs to fly to obtain a particular desired course.

Slides 17-21: Slides 17 through 21 provide examples based on the equation for no-wind magnetic correction of a true course. Compass deviation is provided in the graphic on the right of the slide.

Compass Heading = TC +/– MV +/– DEV

Questions

If the true course is 238 degrees in an area of 5 deg West variation, then 5 degrees must be added to the TC. From the compass deviation card, at a heading of 240 degrees, the pilot needs to steer +3 degrees. Therefore,

238 + 5 + 3 = 246 degrees

If the true course is 090 degrees in an area of 3 deg East variation, then 3 degrees must be subtracted from the TC. From the compass deviation card, at a heading of 090 degrees, the pilot needs to steer –4 degrees. Therefore,

090 – 3 – 4 = 083 degrees

Slide 22: Complete **Formative Assessment 1.**

Formative Assessment 1

Students will individually calculate the Compass heading given several different scenarios. Provide students with **Which Way to Steer? Student Activity 3** worksheet. Sample responses are available in **Which Way to Steer? Teacher Notes 3.**

[DOK-L1; *calculate*]

Session 2

Slide 23: There are two key words used to describe an aircraft's direction of flight: course and heading. What is the difference between the two?

- The course is the intended path of the aircraft over the ground.

- The heading is the direction the aircraft is pointing, which is not necessarily the direction it is moving across the ground.

In a no-wind situation, or in a situation where all of the wind is exactly along the flight path (no left or right component), the course and the heading will be the same. Otherwise, the aircraft heading will be different than the course, because the pilot has to correct for winds.

The slide contains an image of an aircraft flying a course with a heading correction for winds.

Slide 24: How does wind affect the path of an aircraft? An aircraft flies through an air mass. Wind is the result of an air mass moving across the ground. The aircraft's flight through an air mass is the same regardless of the wind; however, the aircraft's movement across the ground varies based on the speed and direction of that air mass.

For example, assume an aircraft is flying at 100 knots in an air mass that is moving across the ground at 15 knots. The aircraft is flying a heading of 090 degrees (toward the east). The air mass is moving in a direction of 270 degrees (toward the west). To a person on the ground, the aircraft would appear to be traveling in an easterly direction at a speed of 85 knots. This is an example of a headwind.

Slide 25: A pure headwind will reduce the aircraft's groundspeed, while a pure tailwind will increase it. For example, an aircraft travelling at **100 knots airspeed** into a **10-knot headwind** will have a **90-knot groundspeed**. Importantly, the aircraft's airspeed indicator will indicate 100 knots. The airspeed indicator in an aircraft only measures the aircraft's speed through the air, not its speed across the ground.

The same aircraft with a **10-knot tailwind** will have a **110-knot groundspeed**, but the airspeed indicator will still indicate **100 knots**. In both cases, the aircraft is at the same indicated airspeed of 100 knots.

The movement of the air mass is what causes a change in how the aircraft moves in relation to the ground. In this example, because the winds are directly along the flight path, there is no effect on the aircraft's direction of flight—only on its groundspeed.

Slide 26: Have students answer the following questions with a partner, then discuss answers as a class.

Questions

Consider a Cessna 172 flying an airspeed of 125 knots. If it is flying into a 13-knot headwind, what is its groundspeed?

125 – 13 = 112 knots GS

A Boeing 777 flying at 270 knots indicated airspeed experiences a 110-knot tailwind. What is its groundspeed?

270 + 110 = 380 knots GS

Slide 27: Ask students: How is an aircraft affected if the wind is not a direct headwind or tailwind?

Perform a demonstration using the box fan and balsa gliders from previous lessons in Grade 9 (**Build and Test a Wind Tunnel and Glider Flight**). Start the gliders at Point A (the origin airport) and designate a target airport on the other side of the room (Point B). Fly the glider from A to B with no wind (no fan). Then place the fan so that it blows across the flight path from the left, and attempt to fly the gliders directly from A to B. Do the same with the wind blowing from the right.

Discuss how the track of the aircraft is affected by the wind from the fan. Have the students discuss how a pilot might compensate for winds.

Questions

What happens to the flight path with the crosswind?

The glider tends to drift with the wind, causing it to miss its destination.

How might a pilot compensate for the winds?

Responses may vary. If a pilot "aims into the wind," the pilot can compensate for the tendency to drift downwind.

Teaching Tips

Can anyone make the plane hit its target destination

Ask one or two students to attempt to fly the plane to its intended target while the fan is running. You may want to move the fan back from the flight path so the balsa glider has some chance of reaching its destination.

Have students try to observe the degree to which the balsa glider must be angled into the wind to maintain its course to the destination. You may want to select one student to shoot high speed video so the class can view the balsa glider's flight in slow motion.

Slide 28: The example provided by the gliders of having to aim into the wind to mitigate downwind drift is applicable even to large aircraft. The images on the slide are from the navigation displays on a jet traveling at 43,000 feet. The pilot's desired track across the ground is 233° (look for a magenta DTK 233). The aircraft's heading is 242° and can be seen in green at the top of the heading indicator (right-hand photo). The airplane is in an air mass that is moving at 75 knots from right to left. This is indicated by a magenta arrow near a number 75 (seen on the left side of both photos). The depiction of the aircraft on the course line shows that it is angled into the wind to compensate for the wind blowing from the right side of the aircraft.

To see a video showing the source of these images, click below.

- "Wind, Drift Angle, Heading, and Track" (Length 1:20) https://safeYouTube.net/w/NWWw

For teachers unable to access Safe YouTube links, the video is also available here: https://www.youtube.com/watch?v=crnrJ9jWDuw

Questions

How many degrees has the pilot altered the aircraft's heading off of the magnetic course to account for the winds?

With a desired track of 233 degrees and a heading of 242, the pilots have aimed the aircraft 9 degrees into the wind in order to maintain the correct course to their destination.

Slide 29: Students may recall vectors from the Grade 10 lesson "Vectors of Flight." Pilots can create a wind triangle using the wind direction and speed as one vector component and the aircraft's course and speed as a second vector component. The resultant vector is the aircraft's direction and speed across the ground. The three legs of this wind triangle are illustrated in the diagram on Slide 29.

- Blue/white hatched line = direction and speed (velocity) of aircraft
- Fading blue line = direction and speed (velocity) of wind
- Yellow line = resultant vector

The figure on the slide is from the Pilot's Handbook of Aeronautical Knowledge and shows the principle of a wind triangle. How to draw a similar wind triangle will be addressed in the coming slides. The key point is that every wind triangle is composed of these three legs.

Slide 30: Have the students watch the following short video which demonstrates how the FAA might ask a test question about the legs of the triangle.

- "FAA Test Question: Wind Triangle" (Length 1:04)
  https://safeYouTube.net/w/voKx

For teachers unable to access Safe YouTube links, the video is also available here: https://www.youtube.com/watch?v=0AuY1VNjcr4

Teaching Tips

These calculations for wind triangles are based on vector math. Some students may find the following mathematical explanation helpful:

- "Find the Component Form of a Vector From the Graph of a Vector" (Length 1:59)
  http://safeyoutube.net/w/QUQd

For teachers unable to access Safe YouTube links, the video is also available here: https://www.youtube.com/watch?v=C7iVmueqkZ0

Slide 31: Emphasize this important note for students: correcting for winds requires obtaining wind data. Winds aloft, forecast winds, and winds in METARs are all given in true directions. Reported winds (those heard on ASOS, ATIS, etc., or from PIREPs) are given in magnetic directions. One way to remember this is the saying "If it's written, it's true," which means if you see it on a chart or a printed forecast, the directions are true, but if you hear it on the radio, the direction is a magnetic value. This makes sense since a pilot flying is referencing a magnetic compass and magnetic runway headings, not a paper chart, so they need to know the magnetic winds.

Slides 32-34: The following three slides demonstrate how a pilot can create and solve a wind triangle to determine the proper heading to fly to their intended destination.

Teaching Tips

The following procedure is from pages 16-14 to 16-16 of the Pilot's Handbook of Aeronautical Knowledge (PHAK). It may be useful to print those pages of the PHAK for students or direct them to the online version of PHAK, Chapter 16: Navigation:

https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/phak/media/18_phak_ch16.pdf

If an aircraft is flying to the east (from point E) and is experiencing a wind from the northeast, the aircraft will need to have a heading slightly toward the northeast (into the wind) to fly the desired easterly ground track.

In the first diagram, a line is drawn on the VFR sectional chart from point E to the east representing the true course of 90°. A weather forecast has indicated the winds aloft at the planned altitude are 40 knots from a direction of 045 degrees. Since winds aloft are in a true direction, they can be directly applied to the true course previously determined. The final piece of information is the speed of the aircraft, which in this example is 120 knots.

Draw a vertical line representing a north/south line of longitude. Place the base of a protractor on the line. At the centerpoint of the base of the protractor, make a mark indicating the airport of origin (Point E). On the curved edge of the protractor, make a mark at 90 degrees (marking the planned true course) and another at 45 degrees (marking the wind direction).

1. The first line drawn indicates the true course of 90 degrees. Draw a line from Point E through the true course mark. Label the line "TC 090 deg."

2. The next line will indicate the wind direction and velocity. Place a straight edge from the 45-deg wind mark to Point E. To determine the direction of the line, realize that the wind in this example is opposite the direction of the aircraft's travel. Therefore, beginning at Point E, draw a line away from the wind mark. The length of the line is based on its speed. In this example, the wind is 40 knots, so the line needs to be 40 units long. The units can be any increment that makes sense (for example, 1/4 inch = 10 knots). Remember that the aircraft speed will also have to use the same units. Label this wind vector "Wind," and indicate the end of the line with a point labeled "W."

3. On a ruler, mark out 120 units to match the 120-knot airspeed of the aircraft, using the same units as those used for the wind vector. Place the origin of the ruler on the end of the wind vector and then rotate the ruler until the 120-unit mark intersects the TC 090-degree line created earlier. Mark the intersection, and then draw a line from that point to point W. Label the line "AS 120 knots" and label the intersection "Point P." Point P represents the position of the aircraft after 1 hour of flight. The diagram is now complete and can be used to determine the wind correction angle.

4. Measure the TC 090 degree line from Point E to Point P, using the same units of measure as the wind vector and AS line. In this example, the line is 88 units long. This indicates a ground speed of 88 knots.

5. Determine the true heading one of two ways:

    1. Find the true heading: Place the base of the protractor on the north/south line so that the center of the protractor's base is at the intersection of the north/south and AS lines. The true heading can be read directly off the protractor in degrees.

2.

Find the wind correction angle: Place the base of the protractor on the TC line, with the vertex at Point P. The angle between the TC and AS lines is the wind correction angle (WCA).

How does a pilot know whether to add or subtract this WCA from the TC? If the wind is blowing from the left side of the TC, the WCA is subtracted from the TC. If the wind is from the right of the TC, the WCA is added to the TC.

In this example, the wind is from the left, so the WCA of 14 degrees is subtracted from the TC of 090 degrees, resulting in a true heading of 076 degrees. The pilot knows the wind is from the left because the wind direction of 045 degrees is to the left of the aircraft's true course of 090 degrees.

1.

Remember to do a common-sense check: With a planned course to the east and a wind from the northeast, it makes sense that the aircraft would have to angle toward the northeast to fly the planned course.

2.

The true heading needs to be corrected for magnetic variation and deviation to obtain a compass heading. Then, the pilot can fly the compass heading to the destination.

Slide 35: Complete **Formative Assessment 2**.

Formative Assessment 2

Students will work in pairs to calculate a Compass heading given several different scenarios of wind and magnetic variation. Provide students with **Which Way to Steer? Student Activity 4 worksheet**. Sample responses are available in **Which Way to Steer? Teacher Notes 4**.

[DOK-L3; *construct*]

Session 3

Slide 36: How long will it take you to reach your destination? Pilots can determine the distance to a destination by looking at the VFR sectional chart. Pilots can then use their planned airspeed to calculate groundspeed (GS). With the known distance and GS, pilots can then compute the time to the destination.

Time = Distance / Groundspeed

Slides 37-38: The first slide contains two scenarios. With partners, students should solve each scenario; then, discuss the answers provided on the second slide.

Questions

- If the distance between two airports is 150 nautical miles, and you can fly at 100 knots groundspeed, what is your approximate flight time between the airports?

Time = 150/100 = 1.5 hours

- You pass over your final checkpoint at a groundspeed of 120 knots. You have 40 miles to go until you reach your destination. Approximately how much flight time will elapse until you reach the destination airport?

Time = 40/120 = 1/3 hour (20 min)

Slides 39-41: Similarly, with a known groundspeed and a given flight time, pilots can determine how far they can fly.

Distance = Groundspeed Time

The slides contain the following two scenarios. Discuss the first as a class, and then challenge students to solve the second individually or with a partner.

Questions

- Based on the current winds and the performance of your aircraft, your groundspeed is 140 knots. You have 40 minutes until sunset, and your destination airport is 60 nautical miles away. Will you land before or after sunset?

40 minutes = 2/3 hour. Distance = 140 (2/3) = 93.3 NM

Since you can travel 93 NM in 40 minutes, and you only have to go 60 NM, you'll arrive at the airport before sunset.

- You've had a long day and decide you'll only fly for 30 more minutes. Your groundspeed is 120 knots. When you check your chart, you see there are airports 30, 60, and 90 miles in front of you. At which airport should you plan to land?

30 minutes = 0.5 hours

Distance = 120 0.5 = 60 NM

You should plan for the airport that is 60 NM in front of you.

Slides 42-44: Finally, with a known flight time and distance, pilots can determine the required groundspeed for the flight.

Groundspeed = Distance / Time

The slides contains the following two scenarios. Discuss the first as a class, and then challenge students to solve the second individually or with a partner.

Questions

- You are 120 nautical miles from your destination. Your passenger has an event that requires them to be on the ground in 20 minutes. What groundspeed would you need to fly to arrive at your destination in time?

20 minutes = 1/3 hour

Groundspeed = 120 / (1/3) = 360 knots.

- You've logged 199.5 hours. You'd like your next flight to get you to exactly 200 hours. Your favorite airport is 35 nautical miles away. What groundspeed would you need to fly to land with exactly 200 hours?

30 minutes = 0.5 hours

Groundspeed = 35 / 0.5 = 70 knots

Slide 45: If a pilot knows how long a flight will take, they can estimate the amount of fuel to be consumed during the flight using the aircraft's fuel consumption charts in the pilot operating handbook (POH). Fuel consumption in aircraft is measured in gallons per hour because a known quantity of fuel is available onboard, and flight time is known.

To determine the amount of fuel a pilot should plan for a flight, they can multiply the calculated flight time in hours by the fuel burn rate in gallons per hour (GPH):

Fuel used = GPH Time

Fuel burn rates vary by aircraft and engine, but a common training aircraft fuel consumption rate is approximately 8 GPH.

Slides 46-48: The slides contain the following two scenarios. Discuss the first as a class, and then challenge students to solve the second individually or with a partner.

Questions

- Based on a fuel burn rate of 8 GPH, how much fuel would be required to fly for 2.5 hours?

Fuel used = 8 2.5 = 20 gallons

- With a fuel burn rate of 8 GPH, if a pilot calculates a flight time of 2.5 hours to the destination, what is the minimum fuel they should take off with? Remember, the FAA requires pilots to plan day VFR flights with 30 minutes of reserve fuel (see FAR 91.151(a)(1)).

Reserve of 30 minutes = 0.5 hour

Fuel Used = 8 0.5 = 4 gallons

20 gallons + 4 gallons for reserve = 24 gallons

Slides 49-51: These calculations aren't just for show. Pilots make decisions about how they will fly a sortie based on the solutions to all of these equations discussed in this lesson. For example:

- A pilot has 12 gallons of fuel available (in addition to required reserves) and a fuel burn rate of 8 GPH. If the aircraft flies at 110 knots groundspeed, how far can the pilot fly?

Time = Fuel used / GPH = 12 / 8 = 1.5 hours

Distance = 110 1.5 = 165 NM

These calculations can also help pilots choose speeds and altitudes as they attempt to determine what flight conditions are most advantageous to their flight. Have students complete the following scenario individually or in pairs; then, discuss the answer as a class.

Questions

A pilot has 20 gallons of fuel available, in addition to required reserves. At a groundspeed of 150 knots, their aircraft will use 20 GPH. At 100 knots, they will use 10 GPH. If the pilot needs to fly to an airport 200 NM away, what speed should they plan to use? (Assume no wind in this example.)

Option 1: Flight time = 200 / 150 = 1 hour 20 minutes. Fuel used = 20 1.3 = 26 gallons

Option 2: Flight time = 200 / 100 = 2 hours. Fuel used = 10 2.0 = 20 gallons

Option 2 is the correct choice in this scenario. In order to preserve the reserve fuel, Option 1 is not correct since the pilot would use more than the available fuel (26 gallons are required, but 20 gallons are available).

Slide 52: These calculations have been almost exclusively based on nautical miles, which are the most common unit of measure in aviation today. However, a few years ago aircraft were frequently built with airspeed indicators and operating handbooks incremented in miles per hour—that is, statute miles. Because older aircraft are still very common, it is important to note what units you are using for airspeed and distance. Helpful hint: 1 nautical mile is 1.15 statute miles.

Slides 53-54: The slides contains the following two scenarios. Discuss the first as a class, and then challenge students to solve the second individually or with a partner.

Questions

- You and a friend are planning to fly together on a cross country trip. He's in his 1998 Cessna 172 and is planning to fly 115 knots. You'll be flying a 1968 PA-28 Cherokee, with an airspeed indicator in miles per hour. What airspeed will you need to use to fly alongside your friend?

115 1.15 = 133 mph

- The radius of Class D airspace is 4 SM. How many NM is that?

4 1.15 ffi 3.5 NM

EXTEND

Teacher Materials: Which Way to Steer? Presentation, Which Way to Steer? Teacher Notes 5, Which Way to Steer? Teacher Notes 6
Student Material: Which Way to Steer? Student Activity 5, Which Way to Steer? Student Activity 6

Slide 55: Conduct the **Summative Assessment**.

Summative Assessment

Distribute **Which Way to Steer? Student Activity 5**. In this summative assessment, students will individually analyze wind and chart symbology, evaluate compass headings corrected for magnetic variance and wind, understand the impact of these influences on a flight, and demonstrate that understanding in scenarios. Sample responses are available in **Which Way to Steer? Teacher Notes 5**.

[DOK-L3; *apply*]

Summative Assessment Scoring Rubric

- Follows assignment instructions
- Responses show evidence of one or more of the following:
  - Correct recall of magnetic and wind correction methods
  - Reasonable application of course correction methods 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 wind and magnetic course correction equations and methods, and makes a reasonable application and analysis of those corrections to scenarios, with appropriate explanations.
7-8 Correctly understands most wind and magnetic course correction equations and methods, with some errors, and makes generally reasonable application and analysis of those corrections to scenarios, with some incomplete analysis or errors.
5-6 Correctly understands some wind and magnetic course correction equations and methods, with errors, or makes generally reasonable application and analysis of those corrections to scenarios but lacks adequate explanation.
0-4 Provides few, if any, correct ideas about wind and magnetic course correction equations and methods, and/or makes poor application and analysis of those corrections to scenarios with inadequate explanation.

Session 4

Slide 56: Divide the class into groups and distribute **Which Way to Steer? Student Activity 6**. Have the students execute the flight simulator profile and discuss the questions. Sample responses are available in **Which Way to Steer? Teacher Notes 6**.

EVALUATE

Teacher Material: Which Way to Steer? Presentation

Slides 57-76: Review the Private Pilot Knowledge Test questions.

GOING FURTHER

Teacher Materials: Which Way to Steer? Presentation, Which Way to Steer? Teacher Notes 7
Student Material: Which Way to Steer? Student Activity 7

Slide 77: Some students with exposure to trigonometry may benefit from an explanation of how trigonometry underlies the wind triangles built earlier in this lesson. As appropriate, consider distributing **Which Way to Steer? Student**

Activity 7 and having the students watch the video to understand the computational math. Sample responses are available in **Which Way to Steer? Teacher Notes 7**.

STANDARDS ALIGNMENT

NGSS STANDARDS

Three-Dimensional Learning

- **HS-ETS1-2** - Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
    - Science and Engineering Practices
        - Asking Questions and Defining Problems
        - Constructing Explanations and Designing Solutions
    - Disciplinary Core Ideas
        - ETS1.A: Defining and Delimiting Engineering Problems
    - Crosscutting Concepts
        - None
- **HS-ETS1-3** - Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.
    - Science and Engineering Practices
        - Constructing Explanations and Designing Solutions
    - Disciplinary Core Ideas
        - ETS1.B: Developing Possible Solutions
    - Crosscutting Concepts
        - None
- **HS-ETS1-4** - Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.
    - Science and Engineering Practices
        - Using Mathematics and Computational Thinking
    - Disciplinary Core Ideas
        - ETS1.B: Developing Possible Solutions
    - Crosscutting Concepts
        - Systems and System Models

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 D. Cross-Country Flight Planning

- Knowledge - The applicant demonstrates understanding of:
  - **PA.I.D.K1** Route planning
  - **PA.I.D.K2** Altitude selection accounting for terrain and obstacles, glide distance of the airplane, VFR cruising altitudes, and the effect of wind.
  - **PA.I.D.K3a** Time, climb and descent rates, course, distance, heading, true airspeed, and groundspeed
  - **PA.I.D.K3b** Estimated time of arrival to include conversion to universal coordinated time (UTC)
  - **PA.I.D.K3c** Fuel requirements, to include reserve
- Skills - The applicant demonstrates the ability to:
  - **PA.I.D.S1** Prepare, present, and explain a cross-country flight plan assigned by the evaluator including a risk analysis based on real-time weather, to the first fuel stop.
  - **PA.I.D.S2** Apply pertinent information from appropriate and current aeronautical charts, Chart Supplements; NOTAMs relative to airport, runway and taxiway closures; and other flight publications.
  - **PA.I.D.S3** Create a navigation plan and simulate filing a VFR flight plan

VI. Navigation

Task A. Pilotage and Dead Reckoning

- Knowledge - The applicant demonstrates understanding of:
  - **PA.VI.A.K1** Pilotage and dead reckoning.
  - **PA.VI.A.K2** Magnetic compass errors.
  - **PA.VI.A.K4a** Selection of appropriate route
  - **PA.VI.A.K5a** Plotting a course, to include determining heading, speed, and course

- **PA.VI.A.K5b** Wind correction angle
- **PA.VI.A.K5c** Plotting a course, to include estimating time, speed, and distance
- **PA.VI.A.K7** Planned versus actual flight plan calculations and required corrections.

- Skills - The applicant demonstrates the ability to:
  - **PA.VI.A.S3** Navigate by means of pre-computed headings, groundspeeds, and elapsed time.

REFERENCES

Pilot's Handbook of Aeronautical Knowledge