Drawing and Measuring Courses

Session Time: Three, 50-minute sessions

DESIRED RESULTS

ESSENTIAL UNDERSTANDINGS

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

A wide range of resources is required when planning a flight.

Planning a safe and successful flight involves compliance with applicable Federal Aviation Regulations and guidance from the Aeronautical Information Manual.

ESSENTIAL QUESTIONS

1. What tools allow a pilot to begin plotting the course for a flight?

LEARNING GOALS

Students Will Know

- How to draw a course for a planned flight on a sectional aeronautical chart
- How to use a rotating plotter to determine the true course for each leg of a planned route of flight.
- How to measure the length of each leg of a planned route of flight.

Students Will Be Able To

- *Measure* distances on an aeronautical chart using two methods. [DOK-L1]
- *Measure* true course on an aeronautical chart using two methods. [DOK-L1]

ASSESSMENT EVIDENCE

Warm-up
In pairs, students will evaluate a compass rose to determine headings to review course calculation basics. To reinforce those objectives, students will then discuss the conceptual application of course information.

Formative Assessment
As a class, students will review compass and course calculations, flight planning tools, and their application to notional scenarios.

Summative Assessment
Working individually, students will analyze flight planning tools and calculations and apply them to a notional planning scenario to determine True Course and distance data for a realistic multi-leg cross country flight.

LESSON PREPARATION

MATERIALS/RESOURCES

- Drawing and Measuring Courses Presentation
- Drawing and Measuring Courses Student Activity 1
- Drawing and Measuring Courses Student Activity 2
- Drawing and Measuring Courses Student Activity 3
- Drawing and Measuring Courses Student Activity 4
- Drawing and Measuring Courses Student Activity 5
- Drawing and Measuring Courses Student Activity 6
- Drawing and Measuring Courses Student Activity 7
- Drawing and Measuring Courses Teacher Notes 1
- Drawing and Measuring Courses Teacher Notes 2
- Drawing and Measuring Courses Teacher Notes 3
- Drawing and Measuring Courses Teacher Notes 4
- Drawing and Measuring Courses Teacher Notes 5
- Drawing and Measuring Courses Teacher Notes 6
- Drawing and Measuring Courses Teacher Notes 7
- **Sporty's Sectional Training Chart for each student or pair of students**
- **Local Sectional Aeronautical Charts for each student or pair of students**
- **VFR Sectional Plotter with Rotating Azimuth Wheel**
- **Ruler for each student or pair of students**
- **Protractor for each student or pair of students**

Flight Simulation Activity: Student Activity 7

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

LESSON SUMMARY

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

The lesson will begin with a warm-up activity that asks students to recall the degrees that are associated with common compass directions. This is intended to get them thinking about headings and courses which segues into a foundational skill of flight planning: plotting a course on a VFR sectional chart. Students will then handle, discuss, and predict the ways in which pilots use the flight planning tools for this lesson.

Next, the lesson will walk through the steps to plot and measure the true course and distance for a chosen route using the available pilot tools. They will review the concepts as a group, practice the techniques in pairs, and then demonstrate their understanding individually. The two methods used will be the traditional use of an aviation plotter and the use of SkyVector.com. Students will then answer sample FAA Private Pilot Knowledge Exam questions relating to course calculations.

Finally, teachers have the option of teaching expanded methods of determining true course and distance, and students can apply their true course determination by attempting to fly it in the simulator.

BACKGROUND

Pilots use VFR sectional charts as the basis for their planning and navigation. One of the key foundational concepts of flight planning is determining the true course and distance between the origin and destination points on a planned flight route. While it may sound complex, it is the same concept that is also used in both maritime and land navigation.

In concept, pilots use protractors to measure the difference between their intended course and a true north line (longitude) to determine their true course. They use scales, just like those on any other map, to determine distance, with the one difference being that pilots can use a plotter designed specifically for aeronautical charts that has the scale built into it.

Using tools like plotters, protractors, rulers, and paper charts may seem inefficient when so many electronic tools like flight computers, apps, and navigation devices can perform the same tasks nearly instantly; however, a pilot must be able to perform the same course calculations should the electronics ever fail. Additionally, when pilots have a basic understanding of what information the electronics should provide, they will be more likely to recognize when a computer's results are incorrect whether from a data entry error or technological fault.

This is similar to using a calculator to solve a math problem. Students should have an estimated answer in mind before using a calculator to solve a problem. Simply writing the result from the calculator screen may not account for a mis-entered number, a misplaced decimal point, or an incorrectly pressed operation key.

This lesson requires students to physically manipulate mechanical tools to determine calculations and read measurements. Teachers should consider reviewing any instructions that accompany the plotter and watching the video below (which is also included within the lesson material) to prepare for the lesson.

- "How Pilots Know Where to Go - Using a Plotter" (Length 2:31)
  https://video.link/w/06Qw
- For teachers who are unable to access Safe YouTube links, the video is also available here: https://www.youtube.com/watch?v=5igMoXj8Nqo

MISCONCEPTIONS

Aeronautical charts are not just maps that pilots use to find their way around by looking at the symbols on the chart. In fact, charts are used to pre-plan a route based not only on visual references, but also on compass headings and distance calculations. These calculations will help pilots execute the flight using the correct heading, altitude, and speeds while accurately planning for time, distance, and fuel used. Pilots use charts to be intentional and proactive to prepare for their environment, not reactively wandering around from visual point to point.

Latitude and longitude lines are not printed only to specify locations. They are a grid reference system for all phases of flight. By calculating the difference between two locations, pilots are able to determine a heading and distance between the two. Further, because the latitude and longitude lines are fixed, consistent, and predictable, they can be used to measure angles between routes and distances in all directions.

DIFFERENTIATION

The activities in this lesson are appropriate for all learners. Additional learning activities include, but are not limited to:

- Watching instructional videos about using a rotating plotter on aeronautical charts
- Additional practice with sectional charts and plotters
- ENRICHMENT: See **GOING FURTHER** Activity 2

LEARNING PLAN

ENGAGE

Teacher Materials: Drawing and Measuring Courses Presentation, Drawing and Measuring Courses Teacher Notes 1
Student Material: Drawing and Measuring Courses 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

Divide the class into pairs and distribute **Drawing and Measuring Courses Student Activity 1**. As a review, students will work together to analyze a chart excerpt and determine compass headings on the chart. Sample responses are available in **Drawing and Measuring Courses Teacher Notes 1**.

Teaching Tips

For these lessons, actual paper FAA aeronautical sectional charts are preferable. They can be obtained new from some pilot shops and flight schools, but out-of-date charts can often be obtained for free. Ask at flying clubs, flight schools, and on social media for donations of old charts. Out-of-date charts are not intended for navigation, but they are perfect for flight planning lessons.

SkyVector.com may be used by students to check their paper and pencil work.

Reminder: Right-clicking ("secondary clicking") on the SkyVector aeronautical chart allows a person to designate any point. A small pop-up appears to allow the user to select the nearest airport, navigation aid, intersection, or latitude/longitude coordinates for the exact point. When two points are selected, a magenta line appears between the points. The magnetic course and distance between the points is indicated in a small label near the first of the two points marked. It is important to know that SkyVector gives a magnetic course number. This lesson is about true course values. A magnetic course determination is made based on magnetic variation, which is a component of the next lesson, 6B2: Which Way to Steer?

NOTE: The course displayed by SkyVector is based on the order in which the airports are selected.

EXPLORE

Teacher Materials: Drawing and Measuring Courses Presentation, Drawing and Measuring Courses Teacher Notes 2
Student Material: Drawing and Measuring Courses Student Activity 2

Slide 5: Divide the class into groups, one group to each station, and distribute **Drawing and Measuring Courses Student Activity 2**. Students should have paper and a pencil with an eraser (not a pen) readily available. Students will discuss the planning tools and share their thoughts about how they might be used. Sample responses are available in **Drawing and Measuring Courses Teacher Notes 2**.

EXPLAIN

Teacher Material: Drawing and Measuring Courses Presentation

Slide 6: Because there are no roads in the sky, pilots who want to fly to another location need to figure out on their own which direction to fly and the distance of that route. This flight planning begins with pilots determining their course and distance using a sectional chart.

Step 1: Find the two airports on the sectional chart. For this example, the flight will begin at Halifax Northampton Regional Airport (KIXA) and end at Wakefield Airport (KAKQ). These two airports are on the southern side of the Washington VFR Sectional Chart.

Once the airports are located, it is best to lay the sectional chart out flat. Due to the size of sectional charts, a large, flat workspace is ideal.

Slide 7: Step 2: Draw a line between the two airports. This is an ideal task for the plotter, with its long straightedge. The line should be drawn with an easily erasable pencil so the chart may be reused for planning different flights. When drawing the line, it's a good technique to hold the plotter down with spread-out fingers to keep it from slipping.

Slides 8-9: Step 3: Find the distance between the two airports. The same plotter used to draw the straight line also has several chart scales printed directly on it. Use caution to choose the correct scale. Each scale should be labeled for its intended chart: Most plotters will have scales labeled for sectional charts and terminal area charts. Some plotters may have a world aeronautical chart (WAC) scale; however, WACs are no longer printed.

To determine the distance between the airports, place the origin of the correct scale on the starting location and lay the scale along the line drawn in Step 2. Note where the destination airport appears on the scale and directly read the distance off the scale. In this example, the distance from KIXA to KAKQ is 50 NM.

Some older aircraft have their airspeed indicators and performance data calculated in miles per hour (MPH). In that case, a pilot would use the plotter's statute mile scale. AOPA High School Aviation STEM Curriculum lessons will typically use nautical miles and knots in their examples.

Slides 10-11: Step 4: Find the true course (TC). Place the course arrow edge of the plotter along the pencil line drawn between the airports. Rotate the azimuth wheel so the arrows are pointing north/south parallel to the lines of longitude. It may help to slide the plotter along the pencil line until one of the longitude arrows on the azimuth wheel aligns with a line of longitude on the chart. Some pilots "eyeball" the alignment, but the many arrows on the wheel usually allow a pilot to accurately align at least one arrow with a line of longitude.

The true course in degrees can now be read directly off the plotter where the azimuth wheel intersects the pencil line. In this example, the TC is approximately 038 degrees. Due to measurement error and variation in where the pilot chooses to put the "dot" on an airport, it is not uncommon for courses to vary by one to three degrees.

Teaching Tips

If none of the vertical arrows on the azimuth wheel align with a line of longitude, a pilot may choose to align one of the horizontal lines with a line of latitude.

Questions

Based on a true course (TC) of 038 degrees, what would the TC be for the return flight from KAKQ to KIXA?

218 degrees. The opposite direction of a compass heading (reciprocal heading) is 180 degrees from the original course. In this example, 038 is less than 180, so 180 is added to 038.

Slide 12: Many pilots use computerized flight planning software like the SkyVector website. Plot the flight between KIXA and KAKQ in SkyVector. The distance is confirmed as 50 NM, but the course says approximately 048 degrees.

Questions

Why do you think the SkyVector course is different?

Just northeast of KIXA the course crosses a dashed magenta line indicating 10 degrees of west magnetic variation. Magnetic variation was discussed in Semester 1 Unit 4.A.1. The 10°W reading indicates that 10 degrees needs to be added to the true course, so 038 + 10 = 048. This will be explained in more detail in the next lesson.

The fact SkyVector made this correction automatically can be confirmed by viewing the Navigation Log (Nav Log), which should be accessible through a button on the pop-up "Flight Plan" window on the corner of the screen. The Nav Log shows the working values for the course, true, magnetic, and other information. In this case, the Nav Log shows a true heading (TH) of approximately 038 and a magnetic variation (VAR) of +10 degrees. Note that SkyVector uses the term "TRACK" instead of true course or TC on the Nav Log page.

Slide 13: To summarize the steps, have the students watch the following video to see another explanation of how to use the azimuth wheel on the plotter.

- "How Pilots Know Where to Go - Using a Plotter" (Length 2:31) https://video.link/w/06Qw

For teachers unable to access Safe YouTube links, the video is also available here: https://www.youtube.com/watch?v=5igMoXj8Nqo

Slides 14-18: Complete the **Formative Assessment**.

Formative Assessment

As a class, discuss the questions on the following slides. Though the consensus should converge on a most correct answer, encourage class discussion about *why* it is the most correct answer.

Slide 14: Reference the compass rose image. The blue highlighted "348" at the top of the compass rose is a label of a federal airway, indicating the VOR radial in degrees on which the airway lies. What is the radial in degrees for the airway located under the CC label?

196 (answers from 195 to 197 are also acceptable)

Slide 15: If a pilot wanted to fly toward the VOR from point A, what heading would they fly? How do you know?

The heading would be 180 degrees. The heading would be the reciprocal of the 000-degree heading which indicates magnetic north on the compass rose. Others may state that this direction is magnetic south.

Slide 16: You've determined a course of 069 degrees from your sectional chart, but when you plot the same course on SkyVector it indicates the course is 079 degrees. What's the reason for the difference?

SkyVector automatically includes magnetic variation. (In this example, it is a variation of 10 degrees West.) The important lesson is that when using automated navigation tools, pilots need to know what calculations and/or corrections are already included (or aren't included) in the number that is displayed on the screen.

Slide 17: You're planning to fly from Kansas City, Kansas, east to Washington DC. When you align your plotter, you determine the true course to be 260 degrees. What plotting error did you make? How can you correct it?

You have the reciprocal of the course, or the course from Washington to Kansas City instead. This is an easy mistake to make, but also an easy one to correct if it is caught with a "common sense check."

The pilot should know that a flight from Kansas City to Washington DC is generally in an easterly direction. A course in the vicinity of 090 degrees should be expected.

To correct this error, the pilot could reverse the plotter and remeasure the actual course to Washington DC, or they could simply correct the heading by 180 degrees.

Slide 18: A businessperson has been driving 500-mile one-way trips to a major city for work. They live next to their local airport, and their place of employment is next to an airport, so they decide to fly instead.

After plotting the route, they find the distance on the sectional to be only 435 miles. Their car's GPS states the distance as 500 miles, while SkyVector agrees their plotted 435 miles is correct.

Why do you think the car trip has been registering 500 miles, while an airplane flight plan is indicating a distance of 435 miles?

The primary difference is that the drive is not a direct route (it follows roads with curves and turns) while the flight is a direct route. A direct route is shorter than one that involves turns.

Another difference is that the distance driven by the car is displayed in statute miles while the distance derived from the sectional chart is in nautical miles. The difference in units is partly responsible for the discrepancy in values. The next lesson will discuss conversions, noting that 1 NM = 1.15 SM.

EXTEND

Teacher Materials: Drawing and Measuring Courses Presentation, Drawing and Measuring Courses Teacher Notes 3
Student Material: Drawing and Measuring Courses Student Activity 3

Session 2

Slide 19: Divide the class into groups and distribute **Drawing and Measuring Courses Student Activity 3**. Students should have paper and a pencil/eraser (not a pen) readily available. Students will determine the courses and distances of various flight planned routes. Sample responses are available in **Drawing and Measuring Courses Teacher Notes 3**.

EVALUATE

Teacher Materials: Drawing and Measuring Courses Presentation, Drawing and Measuring Courses Teacher Notes 4
Student Material: Drawing and Measuring Courses Student Activity 4

Slides 20-39: Review the Private Pilot Knowledge Test questions.

Slide 40: Conduct the **Summative Assessment**.

Summative Assessment

Distribute **Drawing and Measuring Courses Student Activity 4**. In this summative assessment, students will individually analyze flight planning tools and calculations and apply them to a notional planning scenario. Additional notes and tips are available in **Drawing and Measuring Courses Teacher Notes 4**.

[DOK-L3; *application; short-term strategies*]

Summative Assessment Scoring Rubric

- Follows assignment instructions
- Answers show evidence of one or more of the following:
  - Correct recall of flight planning tools and calculations
  - Reasonable application of route planning measurements
  - 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 flight planning tools and calculations and makes a reasonable application and analysis to scenarios, with explanation.

7-8 Correctly understands most flight planning tools and calculations with some errors, and makes generally reasonable application and analysis to scenarios, with some incomplete analysis or errors.

5-6 Correctly understands some flight planning tools and calculations with errors, or makes generally reasonable application and analysis to scenarios but lacks adequate explanation.

0-4 Provides few, if any, correct ideas about flight planning tools and calculations and/or makes poor application and analysis to scenarios with inadequate explanation.

GOING FURTHER

Teacher Materials: Drawing and Measuring Courses Presentation, Drawing and Measuring Courses Teacher Notes 5, Drawing and Measuring Courses Teacher Notes 6, Drawing and Measuring Courses Teacher Notes 7
Student Materials: Drawing and Measuring Courses Student Activity 5, Drawing and Measuring Courses Student Activity 6, Drawing and Measuring Courses Student Activity 7

Slide 41: Though this lesson highlighted the use of the scales printed on the plotter, pilots don't absolutely require plotters to determine distances. Another method of measuring distance is to use the scale printed directly on the sectional chart. Printed in the margin of the southern edge of the sectional chart should be a scale in three units: NM, SM, and KM.

Slides 42-43: To use these scales, start by laying a straightedge or piece of paper along the course line and mark the locations of both the origin and destination on the straightedge. In this example, the pilot marks a "0" at the origin airport of Halifax (KIXA), lines the paper up with the private airfield of Glover and makes a second mark on the paper.

Slide 44: Then, place the straightedge along the scale on the sectional chart, with one mark on the origin of the scale (marked with "0" on the scale). Mark the highest full value from the scale on the straightedge. For the NM scale, this will be in tens of NMs.

In the example of Glover, there is one full unit of 10 NM before getting to Glover.

For any remaining distance less than 10 NM, move the straightedge to the left side of the zero on the scale, where the scale is broken down to single nautical miles. Count the remaining NM, and then add to the previous measurement to obtain the total distance. Placing the remaining distance to Glover on this scale indicates an approximate distance of 5.5 NM.

Adding to the 10 NM already marked, the pilot finds the distance to Glover is approximately 15.5 NM.

Slide 45: Using the same technique in this example, the pilot determines the distance to KAKQ is 50 NM.

Slide 46: Another method of measuring distance is to use those same straightedge marks and place the straightedge along a line of longitude, where the tick marks represent minutes of latitude. One minute of latitude (one tick mark) is equal to one NM. Simply count the minutes of latitude between the two marks on the straightedge.

In this example, the yellow straightedge is placed along a line of longitude, where the tick marks for minutes of latitude clearly agree with the 15.5 NM and 50 NM distances already determined.

Slide 47: A final method to obtain the distance is to convert using the chart printing scale. Sectionals are printed at a scale of 1:500,000, meaning 1 inch is approximately 7 NM.

In this example, the distance from KIXA to KAKQ is 7.25 inches. At 7 NM per inch, the distance would be 50.75 NM, which is slightly longer than the distances previously determined. A more accurate conversion figure for a 1:500,000 chart is 1 in = 6.86 NM. Using this factor, the distance of 7.25 inches would be 49.74. This is 0.16 NM, or less than 1,000 feet, different than SkyVector, well within a reasonable tolerance for hand measuring.

Slide 48: This lesson also uses a plotter with a rotating azimuth wheel. Some plotters don't have a rotating wheel but only a fixed protractor instead attached to the straightedge. In other cases, pilots may not have plotters at all, but may have only a straightedge and a traditional protractor.

Using a protractor, pilots can determine the true course by placing the protractor along a line of longitude and finding the angle between the meridian and the course. To measure the angle, start at the 0-degree mark on the "north" end of the protractor and move clockwise until reaching the course line. Read the number, and then consider the general direction of flight. In the example scenario, the flight was planned from KIXA to KAKQ which is a northeasterly direction. A protractor reading of 038 degrees makes sense since 045 degrees is northeast. However, if the flight was actually traveling from KAKQ to KIXA—a southwesterly direction—038 degrees is the opposite direction, requiring the pilot to add 180 degrees to obtain a true course of 218 degrees. The reciprocal heading of 038 degrees is 218 degrees.

These examples demonstrate that while an aviation-specific plotter built for VFR Sectional Charts can be handy, pilots can plan their flights with nothing more than a piece of paper and a generic protractor.

Slide 49: Divide the class into groups and distribute **Drawing and Measuring Courses Student Activity 5**. Students should have paper and a pencil/eraser (not a pen) readily available. Students will determine the course and distance between two airports on opposite sides of a VFR Sectional. Sample responses are available in **Drawing and Measuring Courses Teacher Notes 5**.

Slide 50: If a pilot wants to fly “off the chart” onto another sectional chart, the charts can be aligned using the latitude and/or longitude lines on the edges of each chart so pilots can use them as one continuous sectional chart. The flight plan can then continue uninterrupted from one chart to another. However, a printed VFR sectional chart is two-sided, representing the north and south halves of the area represented by the chart. What happens if a pilot wants to fly between two airports that are on different sides of the same chart?

While the pilot could buy two identical charts, flip one over, and align them as described above, the FAA offers a different solution. Instructions for plotting a course from the north side of the chart to the south side of the chart (or vice versa) are printed on the chart telling pilots how to “bridge” the two sides with only a sheet of paper.

Divide the class into groups and distribute **Drawing and Measuring Courses Student Activity 6.** Students should have paper and a pencil/eraser (not a pen) readily available. Students will determine the course and distance between two airports on opposite sides of a VFR Sectional. Sample responses are available in **Drawing and Measuring Courses Teacher Notes 6**.

Slide 51: Finally, have the students try out the results of their course calculations and see if they work. Divide the class into groups and distribute **Drawing and Measuring Courses Student Activity 7**. Students will attempt to fly one of their previously calculated courses between two airports. Sample responses are available in **Drawing and Measuring Courses 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-ETS1-4** - 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
- 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.K5c** Plotting a course, to include estimating time, speed, and distance
- Skills - The applicant demonstrates the ability to:
    - **PA.VI.A.S1** Prepare and use a flight log.
    - **PA.VI.A.S3** Navigate by means of pre-computed headings, groundspeeds, and elapsed time.
    - **PA.VI.A.S5** Verify position within three nautical miles of the flight-planned route.

REFERENCES