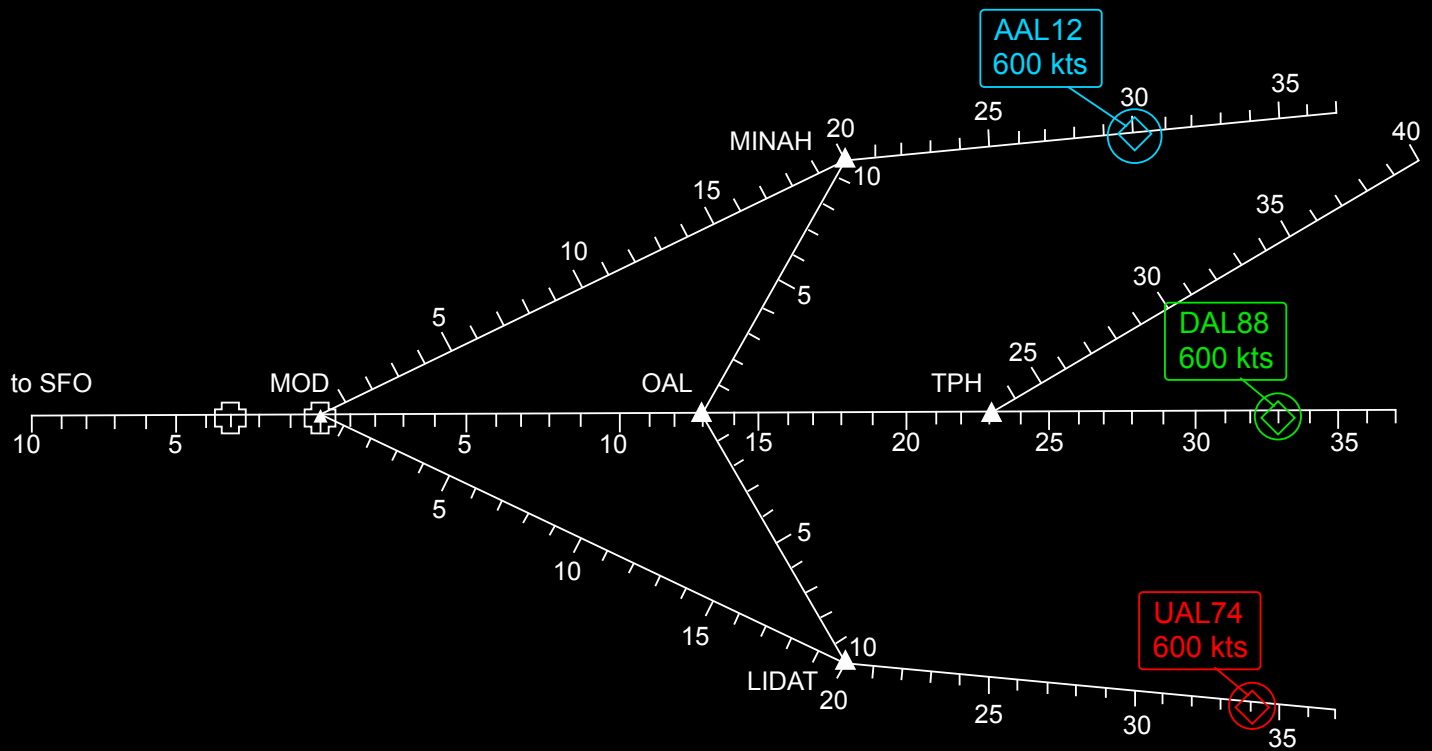




LineUp with Math

Math-Based Decisions in Air Traffic Control

FACILITATOR GUIDE D

Teacher Guide with Answer Sheets

Introduction to Speed Reductions to Resolve Plane Traffic Conflicts

Facilitator Guide with Answer Sheets

Overview of Problem Set D

Estimated class time: 1 to 2 hours

In Problem Set D, students are introduced to the effects of speed changes on airplane spacing learning more about knots, nautical miles per hour, and exploring speed changes using mathematical concepts.

Objectives

Students will:

- Learn about travel at different speeds using steps per minute (steps/minute) as an example.
- Learn how to relate a decrease in plane speeds in knots to a decrease in distance traveled each minute.
- Learn how to use mathematical concepts to understand the relationship between the reduction in plane speed and the resulting decrease in distance traveled.

Prerequisites

Complete Problem Set A, B, and C which provides essential air traffic control vocabulary, units of measurement, graphical representations, and familiarity with the ATC simulator.

Materials

- Student Workbook D:
 - Fillable PDF versions
 - Printed copies

Answer Sheets

The worksheet answer keys for Student Workbook D can be found in Appendix I. More explanation about the mathematical concept, distance = rate $\times$ time ($d = r \cdot t$), can be found in Appendix II.

Facilitator Guide with Answer Sheets (continued)

Student Workbook

Workbook D consists of three worksheets; Introduction to Travel at Different Speeds, Change Knots to Nautical Miles per Minute, and Plot Distances for Different Plane Speeds.

Worksheet #1: Introduction to Travel at Different Speeds

- Use number lines to plot the positions of two students walking at different rates (steps/minute). Understand that the slower student will fall behind each minute.
- Relate knowledge of steps/minute to nautical miles per minute (NM/min) when traveling by air and sea.

Worksheet #2: Change Knots to Nautical Miles per Minute

- Controllers need to make quick decisions so, students learn how to change knots (nautical miles per hour) to nautical miles per minute.
- Understand a 60-knot (nautical miles per hour) speed decrease is equal to 1 nautical mile per minute speed decrease.

Worksheet #3: Plot Distances for Different Plane Speeds

- Practice using mathematical concepts to understand distance = rate $\times$ time with two planes traveling at different speeds. Plot their travel progress on the jet route diagram.
- Plane speeds are given in knots (nautical miles per hour) but, the table shows corresponding speeds converted to nautical miles per minute.

APPENDIX I

Answer Sheets

WORKSHEET #1

Introduction to Travel at Different Speeds

Gaby and Tonisha are walking together from school to the park. Their steps are the same, but they walk at different speeds, as shown in the Walking Speed Table.

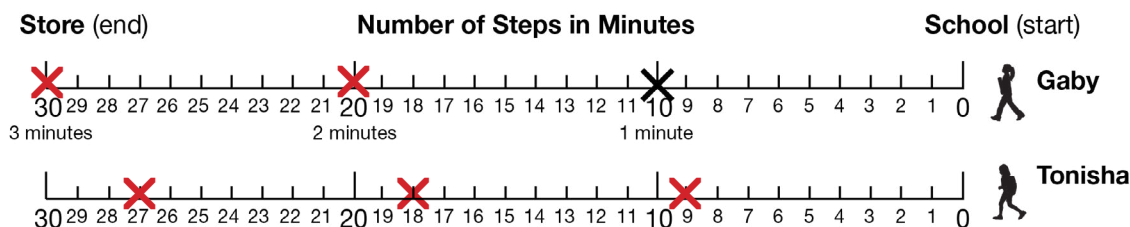
Walking Speed Table

Name	Speed
Gaby	10 Steps/minute
Tonisha	9 Steps/minute

1. How many steps does each student take in 1 minute?

Gaby 10 steps Tonisha 9 steps

2. On the first line below, draw an **X** to mark Gaby's position at 1 minute.



3. On the second line above, draw an **X** to mark Tonisha's position at 1 minute.

4. How many steps in Tonisha behind Gaby after 1 minute? 1 steps

5. On the number lines above, mark Gaby's position and Tonisha's position after 2 minutes.

6. How many steps in Tonisha behind Gaby after 2 minutes. 2 steps

7. On the number lines above, mark Gaby's position and Tonisha's position after 3 minutes.

8. How many steps is Tonisha behind Gaby after 3 minutes? 3 steps

9. How many steps does Tonisha fall behind Gaby **each** minute? 1 step per minute

10. How many steps would Tonisha fall behind in 5 minutes? 5 steps

11. If Tonisha takes 8 steps per minute, how many steps would she fall behind Gaby in 5 minutes?

Speed difference is now 2 steps/min
2 steps/min × 5 min = 10 steps

10 steps

The number of steps Tonisha falls behind each minute is the same as the difference between the speeds.

WORKSHEET #2

Change Knots to Nautical Miles per Minute

Planes fly very fast, so air traffic controllers need to make quick decisions. To be effective, air traffic controllers need to know how many nautical miles a plane will travel in 1, 2, and 3 minutes.

1. There are 60 minutes in one hour. To understand how many nautical miles an airplane travels in one minute, divide by 60.

Speed in Knots (NM/hour)	NM/hr ÷ <u>60</u>	Speed in NM/minute
600 knots	600 ÷ <u>60</u>	= <u>10</u> NM/min
540 knots	540 ÷ <u>60</u>	= <u>9</u> NM/min
480 knots	<u>480</u> ÷ <u>60</u>	= <u>8</u> NM/min

2. Use the completed number line above to fill in the chart below to show the distance a plane travels after 1, 2, and 3 minutes for each speed shown.

	1 minute	2 minutes	3 minutes
600 knots	10 NM	<u>20</u> NM	<u>30</u> NM
540 knots	<u>9</u> NM	<u>18</u> NM	<u>27</u> NM
480 knots	<u>8</u> NM	<u>16</u> NM	<u>24</u> NM

3. How much less distance does a plane travel after 1, 2, and 3 minutes for each plane reduction shown?

Speed Reduction	1 minute	2 minutes	3 minutes
60 knots	1 NM	<u>2</u> NM	<u>3</u> NM
120 knots	<u>2</u> NM	<u>4</u> NM	<u>6</u> NM

4. If a plane slows its speed by 60 knots, how many nautical miles less will it travel each minute? 1 nautical miles
5. A controller reduces a plane’s speed from 600 knots to 540 knots. How many nautical miles less will the plane travel in 5 minutes? 5 nautical miles

1 NM/min • 5 mins = 5 NM

WORKSHEET #2 CONTINUED

Change Knots to Nautical Miles per Minute

Let's look at planes
at different speeds!

Recall:
1 Knot =
1 Nautical mile
per hour

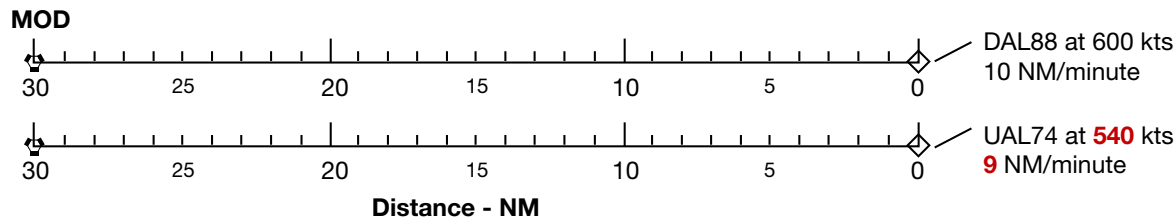
1 hour =
60 minutes

Let's translate all of this to airplanes! Use the conversion chart above as a reference for the remaining questions.

DAL88 and UAL74 are 30 nautical miles from MOD.

DAL88 is traveling at 600 knots, or 10 NM/min.

UAL74 is traveling at 540 knots, or 9 NM/min.



6. Use the number line below to plot an **X** at the travel distances for DAL88 and UAL74 after 1 minute, 2 minutes, and 3 minutes.

7. How many miles is UAL74 behind DAL88 after:

1 minute: 1 NM 2 minutes: 2 NM 3 minutes: 3 NM

8. How many fewer nautical miles will UAL74 travel in **each** minute? 1 nautical miles per minute **10 NM/min – 9 NM/min = 1 NM/min**

9. When DAL88 has traveled 30 nautical miles to MOD, how many nautical miles behind is UAL74?

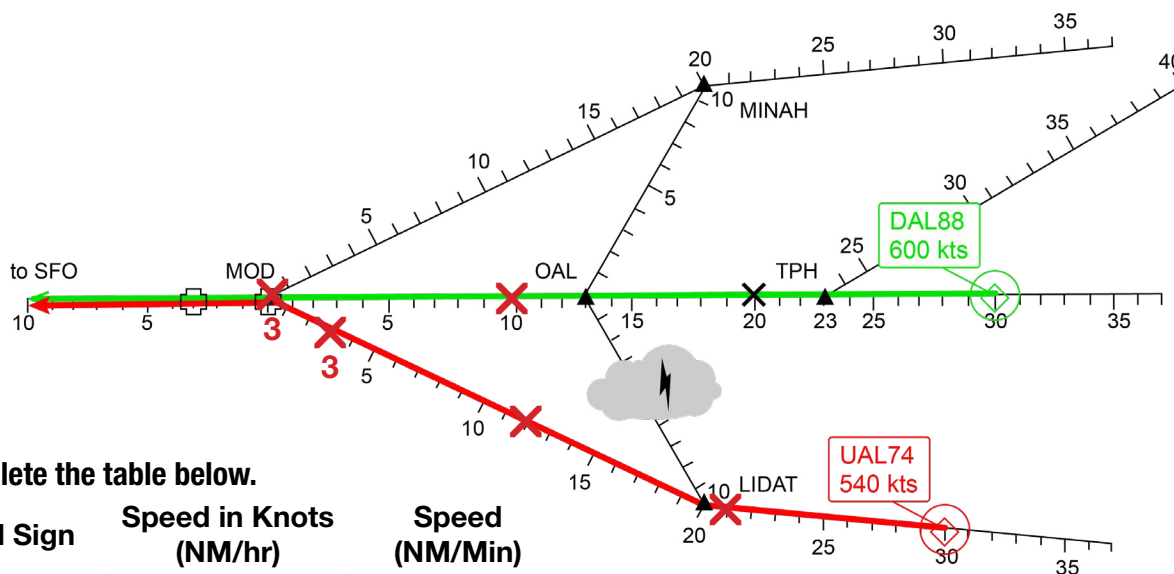
3 nautical miles **1 NM/min • 3 mins = 1 NM**

At 600 knots, a 60-knot speed drop causes a 1 nautical mile distance drop every *minute*.

In 1 minute, a plane travels 1/60th
the distance it travels in 60 minutes.

WORKSHEET #3

Plot Distances for Different Plane Speeds



Complete the table below.

Call Sign	Speed in Knots (NM/hr)	Speed (NM/Min)
DAL88	600	10
UAL74	540	9

- How many nautical miles does each plane travel in 1 minute?
 DAL88 10 nautical miles
 UAL74 9 nautical miles
- In the diagram above, use an **X** to plot each plane's position at 1, 2, and 3 minutes. Put a 3 near each plane's 3-minute mark.
- How many nautical miles does UAL74 fall behind DAL88 each minute? 1 nautical miles per minute.
- Using the speed table, the difference in plane speeds in nautical miles per minute is 1 nautical miles per minute.
- The number of nautical miles that UAL47 fall behind each minute is the ☒ **same as** or ☐ **different than** the difference between plane speeds in nautical miles per minute.
- How far will UAL74 fall behind in 3 minutes? 3 nautical miles
- Suppose the difference in speed is 2 nautical miles/minute.
 - ➔ How far would UAL74 fall behind in 3 minutes? 6 nautical miles
 $2 \text{ NM/min difference} \times 3 \text{ min} = 6 \text{ NM}$
 - ➔ How many minutes will it take UAL74 to fall 8 nautical miles behind? 4 minutes
 $8 \text{ NM} \div 2 \text{ NM/min} = 4 \text{ min}$

APPENDIX II

Appendix II

Two planes are traveling at the same speed to MOD. When one plane's speed is reduced, the difference between the distances traveled by the planes in a given amount of time can be calculated by multiplying the difference in plane speeds by the time traveled.

To derive this relationship between the difference in speeds and the difference in distances traveled, we use the formula

$$\text{distance} = \text{rate} \bullet \text{time}.$$

Let d_1 , r_1 , and t be the original distance, speed, and time for each plane. Then

$$d_1 = r_1 \bullet t$$

Let d_2 and r_2 be the reduced distance and speed, respectively for one plane. The plane whose speed is not reduced will cover the distance to MOD in the original amount of time, t . We want to know where the plane with the reduced speed will be at this time t . So we again use t to represent time. We have

$$d_2 = r_2 \bullet t$$

The difference in the distances covered at the reduced speed is $d_1 - d_2$.

We have

$$\begin{aligned} d_1 - d_2 &= r_1 \bullet t - r_2 \bullet t \\ &= (r_1 - r_2) \bullet t \end{aligned}$$

So,

$$d_1 - d_2 = (r_1 - r_2) \bullet t$$

Thus, the difference in distances traveled is equal to the difference in speeds times the original time.

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