Level	Aircraft and Newton's Second Law of Motion
High School	

Time Required	Lesson Summary
100 minutes (2 50-minute class periods)	This lesson introduces students to how planes are tracked using radio waves. The lesson continues as students collect data on local planes and use this information to calculate the net force acting on the aircraft according to Newton's second law of motion.

Standards

NGSS
HS – PS2 – 1 Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship between the net force on a macroscopic object, its mass, and its acceleration.

PS4.C Information Technologies and Instrumentation. Multiple technologies based on understanding waves and their interactions with matter are part of everyday experiences in the modern world and scientific research. They are essential tools for producing, transmitting, and capturing signals and storing and interpreting information.

Vocabulary	Objectives
Thrust Drag Lift altitude	• Students will understand how a small device plugged into a computer can allow a person to receive and analyze radio waves. • Students will be able to calculate net force using data collected in class.

Materials

- Dongle and antenna
- Student activity sheets
- Individual student computers

Pre-Requisites

Students should be able to explain the electromagnetic spectrum and radio waves. If they are not knowledgeable about these topics' complete lessons 2 and 3 before proceeding.

Students should also be familiar with the RTL-SDR dongle and how it receives radio waves. If you have not completed either of the previous two lessons, you must take additional class time to explain this concept to students.

Safety Considerations

None

Pacing Notes

This lesson will take 100 minutes or two 50-minute class periods. This depends on how much time you spend talking about Newton's laws. A brief introduction to these laws is included (~ 5 minutes), so add the appropriate time for your coverage of this topic. Also, if your class has not used the dongle before, allow extra time for explanations.

Day 1 – Read the Wall Street Journal article, discuss the article, introduce Newton's laws, and collect plane data.
Day 2 – conversions and calculating forces, essay

Before the Lesson

Print the Wall Street Journal for students or make it available on your Learning Management System (LMS).

Follow the instructions in chapters 1-3 of the technical guide to install the required software.

Check that you can scan for planes using the provided hardware and the appropriate software. See chapter 3 of the technical guide for instructions.

Print the student activity page. Each student needs a copy.

Assessments	Classroom Instructions
Pre-Activity Assessments	Introduction
Having students discuss this in small groups instead of as a whole class gives more people	While taking attendance and dealing with other administrative tasks, the students should read the Wall Street Journal Article "Air-Traffic Control Is in the Midst of a Major Change."

a chance to contribute to the conversation. Walk around while groups are discussing. Listen to their conversations. If you notice a student not participating in the discussion, **ask**: (student's name), what do you think about what (group member's name) just said? Do you think that is correct? Why or why not? Also, ensure students provide reasoning from the article for their answers. If you hear a student give an answer without a reason, **ask**: What part of the article are you basing that on?	After students have finished the article, have them discuss it in small groups. Some suggested discussion questions: • What are the two uses of radio waves mentioned in the article? • How does radar work? • How does the new system work? • How are the new transponders going to improve the airline industry? (Students should provide evidence from the article) • Why is it taking so long to change from radar to the new system? • Would you feel safer flying to Europe with the new system? Why or why not?
Activity Embedded Assessments	Activities
If students cannot offer these explanations, stop the lesson and	1. See the pre-requisite section of this plan. If your students do not know the electromagnetic spectrum, pause this lesson and return to lessons 2 and 3. If your students have not participated in lessons one and two, you must explain the RTL-SDR dongle. 2. Follow the instructions in chapter 3 of the technical guide to scan for aircraft in your area. Then, explain, with students' help, how your computer can display planes that are flying in the area. **Say**: This display shows planes that are flying in our area. **Ask**: How is this possible based on your knowledge of the hardware and your reading? **Allow as many students as possible to participate in the explanation**. Try not to evaluate their answers; instead, allow students to politely correct their peers. Students should provide the following information. Ask additional questions

return to the article. Then, have the class read it aloud, stopping periodically to ask students questions that will check their understanding.	or offer guidance if students cannot articulate this knowledge. - The plane has a transponder in it that releases a signal - The signal is received by ground stations and by satellites which reflect it to the ground stations - The antenna is picking up on those signals (Please note it is impossible to tell if the signal is originating from the plane or a satellite) - The dongle takes the signal and turns it into code that the software can analyze You will have to provide this information. - A program called RTL 1090 decodes those signals. - The visualization you see on the screen is provided by virtual radar.
	3. Talk about Newton and his three laws. Hand out the student page and have students read through the top. Please spend some time talking about Newton and his three laws in as much detail as you desire. There are some simulations based on these laws listed in the teacher resource section. Please remember that the amount of time you spend on this topic will extend the estimated time of the lesson.
You may have your students collect as much or as little data as you want. Add or subtract rows in the tables to meet your preferences before printing.	4. Collect data on the planes. Scan for airplanes in your area. When there are several on the screen, push the pause button. This freezes the list of planes and their details. There is a list of planes on the right side of the screen. If you click on an entry, the model of the aircraft will appear at the top of the screen. Click on each plane with a call number and allow students to collect data. You can also click on the aircraft without call numbers, but that data should not be recorded. If you only have one or two planes on the screen, allow students to collect that data and then rescan looking for additional aircraft. Continue this process until you are satisfied with how many planes students have collected information on.
	5. Second data point collection Once students have collected the data from the screen, have them go to flightaware.com and collect the rest of the data as instructed on their sheet.

6. Conversions and calculating forces
   Once students have collected their second set of data, stop the class.

   First, have students read through the conversion and calculating the force sections of their activity sheet.

   Ask: Is there anything in those sections you didn't understand?

Students should mention that one starts with knots, the other with mph.

   Ask: Who can tell me the difference between the two-speed conversions?

Students should say find the difference between t_0 and t_1

   Ask: What do you have to do before converting time?

Students should reply with drag, thrust, gravity, and lift

   Ask: What are the four forces in the system?

Students should reply that it allows the forces in the y direction, lift, and gravity to cancel out.

   Ask: Why was it important the altitude was the same for data points one and two?

If the students cannot answer these questions, it indicates they did not read the sections.

Go back and have students take a turn reading aloud. Stop after each section and ask students questions to test their understanding.

As you are working on the example, have students provide information about what you should do next. This will let you know if they understand what they are expected to do.	Go over an example. You could use some data you collected from a scan earlier in the day or the example page included in this folder.
As students are working, walk around and answer questions. **Ask**: What did you just finish doing? **Ask**: How did you do it? **Ask**: What are you doing next? **Ask:** How are you going to accomplish that task? **Ask**: What can I help you with at this time?	Students should work in pairs or individually to complete the calculations for each plane.
Post Activity Assessments	Closure
Grade the essay to determine if students understood how radio waves were connected to the assignment.	The closure activity is included on the student activity page. Students must write a short essay explaining how the class used radio waves to collect the data.
Culturally Inclusive/Responsive Components	
At some point during the lesson, you could compare how the FAA is tracking planes to how mothers keep track of their children in a crowded place like a festival. Invite students to share how their mothers keep	

track of their families in these settings. Encourage students to listen to one another with an open mind and not judge the methods of a different family.

Accommodations

If you have advanced students, you could increase the complexity of the assignment by removing the instructions for the conversions. This would require students to learn how to go from one unit to the next. However, you would need to place strict limits on how they could accomplish this task, or a student could google the conversion and plug numbers into the box of an online converter.

If you have students who struggle with reading, consider one of the following options:

- Provide a copy along with a glossary of key terms
- Allow students to read aloud in small groups
- Send an advanced copy home with the students who struggle so they can read it when they have plenty of time
- Send students to work with educational aides in the resource room

Educator Resources

Newton's Three Laws simulations
https://www.physicsclassroom.com/Physics-Interactives/Newtons-Laws (last accessed 6/27/23)
https://www.texasgateway.org/resource/newtons-three-laws-motion (last accessed 6/27/23)

Optional Extension Activities

Compare forces calculated from data measured to forces calculated from information collected in the flight log on Flight Aware. If you want to extend in this manner, you will need to take a screenshot of the flight log while students are working on the exercises. Then the following day, you can share this information with students and have them redo the calculations. Depending on their results, you could talk about errors with rounding, accuracy in data collection, and the importance of choosing the same altitude.

Acknowledgments

This is the sixth lesson in a nine-lesson series intended to increase student understanding of radio frequencies. You are welcome to just use this lesson but if you are interested in this topic consider checking out the others in the series.

Lesson One: Mechanical Waves
Lesson Two: Electromagnetic Waves
Lesson Three: Electromagnetic Spectrum
Lesson Four: Argumentation and Radio Waves
Lesson Five: Investigating Spectrum Users

Lesson Six: Aircraft and Newton's Second Law of Motion
Lesson Seven: Weather Forecasting and Radio Waves
Lesson Eight: Satellites and Society
Lesson Nine: Spectrum Management

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