



STEM ACTIVITY: Weighed Down

Grades 5–12

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WEIGHED DOWN

NASA is always looking for ways to improve aviation, making air travel safer and more sustainable. These goals are attained by designing new aircraft, modifying existing aircraft, and developing ways to use aircraft more efficiently.

SUMMARY

In this activity, students learn how the fuel efficiency of airplanes is affected by the aircraft's weight--both the weight of the aircraft itself and what it carries. Further, they will investigate how the impact of small changes can be magnified to make larger differences when considering the number of flights over the course of a day/month/year.

OBJECTIVES

Students will:

- Learn how changes in the weight carried by an airplane can affect the amount of fuel used.
- Investigate how small changes in the weight carried by airplanes can lead to large changes in fuel usage, especially when considering the number of flights over the course of a week, a month, and a year.
- Brainstorm possible new ways to reduce the weight carried by passenger airliners.

SAFETY NOTE

There are no safety concerns with this activity.

DIFFERENTIATION AND GOING FURTHER

There are many ways this activity can be modified to address the needs of your students. Some suggestions include:

Differentiation

- Students can work in groups to help those students who might struggle with this activity.
- Calculators can be allowed or disallowed depending on students abilities.
- For part 2 of the student worksheet, the first example, the weight of entertainment systems, can be done as a whole class before letting students complete the second example, the weight of paint, on their own.

Grade Level: 5–12

Materials Needed:

- Copies of the student worksheet for each student or group
- Access to background information (can be printed or accessed in digital form)

Time required: 1 hour



Figure 1. One of the most common airplanes used for carrying passengers is the 737. An earlier version of the 737 was used by NASA for airborne experimentation before being retired in 1997.

Going Further

- You can give the students examples of possible weight reduction measures and have them determine how much it would save. Some examples include:
 - What if drinks were not provided on the flight? How much would one can of soda per passenger save? What if each passenger only received half a can of soda?
 - The average passenger seat weighs about 25 pounds (this varies greatly). What if you could decrease the weight of each seat by 10%?
- In part 3, have students estimate the weight savings for their ideas and calculate the total saving over the course of a year.

ANSWER KEY

Answers for the Student Worksheet:

Part 1:

- NASA is helping work towards the U.S. climate goal of achieving net-zero greenhouse gas emissions from the aviation sector by 2050. Sustainable technology and techniques will help achieve this goal.
- Minor changes in aircraft weight can result in significant fuel savings because there are about 10 million flights per year.
- When airplanes burn fuel, they emit gases into the atmosphere that can harm the environment. Burning less fuel will help decrease the environmental impact of airplanes.

Part 2:

Question 1:

- $149 * 7 = 1,043$ pounds
- $1,043 / 80 = 13.0$ gallons
- $13 * 5,000,000 = 65,000,000$ gallons
- Answers will vary. Possible answers include passenger comfort, communicating information to passengers, and more.

Question 2:

- $50 * 5 = 250$ pounds
- $250 / 80 = 3.1$ gallons
- $3.1 * 10,000,000 = 31,000,000$ gallons

Part 3:

- Answers will vary.

ADDITIONAL INFORMATION

- [Sustainable Aviation \(NASA\)](#)
- [Air Traffic by the Numbers \(Federal Aviation Administration\)](#)
- [Why Budget Airlines Could Soon Charge You to Use the Bathroom](#)

BACKGROUND

NASA is committed to supporting the U.S. climate goal of achieving net-zero greenhouse gas emissions from the aviation sector by 2050. Under the Sustainable Flight National Partnership, NASA is leading federal agencies and industry to accelerate the development of sustainable technologies and techniques. This includes developing new aircraft, exploring more efficient aviation fuels, and improving aircraft operations.

When thinking about ways to make aviation more environmentally friendly, it is important to think about how many commercial flights fly in the United States each year. According to the Federal Aviation Administration (FAA), there are over 10 million scheduled passenger flights yearly. Because there are so many flights each year, even small reductions in fuel usage by airplanes can amount to very significant savings. This helps decrease the environmental impact of commercial aviation because airplanes release gases into the atmosphere that can harm the environment.

The amount of fuel an airplane burns depends on many factors, one of which is the weight they carry. There are many different models of single-aisle passenger airplanes used for commercial aviation in the United States. For this activity, we will be looking at an older plane, the 737-700 to explore how weight reduction can impact fuel usage.

The 737-700 airplane weighs approximately 38,000 kilograms (kg), or 83,000 pounds (lbs), when it is empty of passengers and cargo. This plane can hold nearly 7,000 gallons of aviation fuel and has a range of over 5,000 miles (8,000 kilometers).

Researchers at the Massachusetts Institute of Technology (MIT) developed a model to determine how changes in weight affect the amount of fuel used by a 737-700 airplane. They used the flight route from Boston to Denver to come up with their numbers. They determined that for every pound carried on a plane, about \$0.05 worth of fuel is burned. This equates to about 1.6 ounces of fuel burned for each pound. This may not sound like much, but when you consider that there are 10 million flights per year, removing just one pound from each flight would result in burning more than 100,000 fewer gallons of fuel over the course of a year.

INSTRUCTIONS

Read the background information provided above before completing the student worksheet.

How Weight Affects the Fuel Usage by Airplanes

Student Worksheet

PART 1:

Read through the background information and answer the following questions.

1. Why is NASA exploring sustainable technologies and techniques?
2. How can minor changes in aircraft weight lead to large reductions in fuel use?
3. Why would it be important to reduce the amount of fuels burned by airplanes?

PART 2:

A one-pound reduction in weight on every flight over a one year period can result in a decrease in fuel usage of about 100,000 gallons. Let us explore how changes in what planes carry can result in significant fuel savings.

1. Many airplanes have entertainment systems built into the backs of seats. These allow passengers to watch movies, play games, and more. Each entertainment system weighs about seven pounds.
 - a. There are 149 seats on the 737-700 airplane. Assuming each seat had an entertainment system, what is the total weight of the entertainment systems on one airplane?
 - b. For every eighty pounds carried, an airplane uses an extra gallon of fuel for each flight. Based on this, how much fuel would be used to carry the entertainment systems?
 - c. If only one half of the commercial flights each year flown were airplanes with entertainment systems built into seat backs, there would be about 5 million of these flights. How much fuel would be saved if there were no entertainment systems?
 - d. What might be a reason that an airline might decide to have entertainment systems in the seat backs even though it increases the amount of fuel used by the airplane?

2. If you look at commercial passenger airplanes, you will see a wide variety of paint schemes. Some planes look basic while others can be quite decorative. But have you ever thought about how much paint it takes to paint a large airplane?
 - a. It takes approximately 50 gallons of paint to paint a 737-700. Once the paint is applied to the airplane and dries, each gallon adds about 5 pounds to the weight of the airplane. How much weight is added to the 737-700 airplane when it is painted?
 - b. If every eighty pounds results in one extra gallon of fuel burned on each flight, how much fuel is used on each flight for the paint?
 - c. If there are 10 million flights per year, and every plane burns fuel to carry the paint, how much fuel is used each year by all flights combined?

So, why are airplanes painted? Even though the paint adds weight to the airplane, it is actually beneficial to paint it. Many parts of the airplane are made of composite materials which can be damaged by prolonged exposure to ultraviolet rays from the sun. The paint helps protect them. Additionally, the paint protects all parts of the plane from damage caused by exposure to the weather and more.

PART 3:

In part 2, you looked at how entertainment systems and paint impact the weight of airplanes. Even though removing the entertainment systems or not painting an airplane would reduce the amount of fuel used, there are good reasons for not doing so. Now it is your turn to think of some ways that you might reduce the weight on airplanes to help save fuel and make aviation more environmentally friendly.

1. You are an aeronautical engineer working for a commercial airline. Your boss sent you an email tasking you with coming up with three possible ways that you might be able to reduce the weight of an airplane without impacting passenger safety and comfort. List your ideas below. For each of your ideas, explain how it would reduce the weight and why it would not impact passenger safety and comfort.

1. _____

2. _____

3. _____

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