Hypersonics STEM Curriculum

Scaling Down at Supersonic Speeds

Grade	Time	Subject Area	Key Concepts
5	55 min	Mathematics	Fractions

Lesson Overview

In this lesson, students will calculate and use scale ratios to compare model vehicles to the actual objects they represent. In addition to using measurements from the SR-71 Blackbird and the Bell X-1, students will use their own measurements of toy model vehicles for their calculations. This lesson has three distinct parts that could be broken up over a couple days.

CCSS Standards

CCSS.MATH.CONTENT.5.NF.B.5a Interpret multiplication as scaling (resizing), by comparing the size of a product to the size of one factor on the basis of the size of the other factor, without performing the indicated multiplication.

CCSS.MATH.CONTENT.5.NF.B.5b Interpret multiplication as scaling (resizing), by explaining why multiplying a given number by a fraction greater than 1 results in a product greater than the given number (recognizing multiplication by whole numbers greater than 1 as a familiar case); explaining why multiplying a given number by a fraction less than 1 results in a product smaller than the given number; and relating the principle of fraction equivalence a/b = (n×a)/(n×b) to the effect of multiplying a/b by 1.

CCSS.MATH.CONTENT.5.NF.B.6 Solve real world problems involving multiplication of fractions and mixed numbers, e.g., by using visual fraction models or equations to represent the problem.

Learning Objectives

By the end of this lesson, students will be able to:

- Calculate scale ratios given measurements for a model and the actual object is represents.
- Use scale ratios to calculate measurements of an actual object given the measurements of a model.
- Use scale ratios to create a model of an actual object.

Essential/Overarching Question

How does a toy airplane compare to the actual airplane it is modeled after?

Key Vocabulary

Speed – the rate at which an object is moving. Speed is calculated by dividing the distance travelled by the time it took to travel that distance.

Speed of Sound – the rate at which sound moves through a medium. The speed of sound depends on both the density and the temperature of the medium. The speed of sound through air at 20° C (68° F) at sea level is 343 m/s (767 mph).

Mach – the ratio of the speed of an object to the speed of sound or how many times the speed of sound an object is moving. It is often followed by a number indicating the ratio; for example: Mach 1 is the speed of sound, Mach 2 is twice the speed of sound, Mach 5 is five times the speed of sound.

Sonic – speeds equal to the speed of sound (Mach 1).

Subsonic – speeds smaller than the speed of sound (less than Mach 1).

Transonic – speeds near (Mach 0.8-1.2) the speed of sound where drag is highest (e.g. sound barrier).

Supersonic – speeds greater than the speed of sound (Mach 1 and greater).

Hypersonic – speeds greater than five times the speed of sound (Mach 5 and greater).

Fluid – a substance with no fixed shape; a liquid, gas, or plasma. A substance that flows when an external force is applied to it.

Flow – the motion of a fluid (liquid, gas, or plasma) when it experiences unbalanced forces.

Fraction – a numerical quantity that describes the amount or proportion of a substance. A representation of the parts of a whole.

Scale Ratio – a ratio that defines the relation between the actual figure and its model. Typically written as model measurement:actual measurement such as 1 cm:1 m or 1:100.

Science Concepts Overview

As objects move faster, understanding how that object will interact with the flow (the motion of the fluid – liquid or gas – around it) becomes more important. Many times, wind tunnel experiments are used to better understand this interaction. In many cases, especially in the early stages of testing, wind tunnel testing is done on a smaller scale model. When using scale models, it is important that the scale ratios are exact so that the most realistic data is gathered.

Materials List

- ☐ Rulers (one per student)
- ☐ An assortment of model/toy cars, airplanes, etc. with known scale ratio
- ☐ Calculators (one per student)
- ☐ Devices with access to the internet (one per student or group)
- ☐ Scaling Down at Hypersonic Speeds handout (one per student)

Lesson Preparation

Prior to the lesson, the instructor should gather materials and make copies of the Scaling Down at Supersonic Speeds handout. Instructors can encourage students to bring in their own models to use in the lesson.

Instructors may want to look up the actual measurements of the models ahead of time for student to use. Instructors can also have students look up the measurements online.

Safety

There are no additional safety concerns beyond normal classroom procedures for this lesson.

Procedure

Engage (15 minutes)

1. As a class, or individually, read the Introduction section of the Scaling Down at Supersonic Speeds handout.
2. Have a set of toy vehicles on display and ask students to share their thoughts on how many times bigger the actual object is compared to those models.
3. Students can work individually or in small groups for the remainder of the lesson.
4. Students will practice using scale ratios by calculating the missing SR-71 Blackboard measurements, model SR-71 measurements, and scale ratios in the table in the Scale Ratios Practice with the SR-71 Blackbird section.

Explore (10 minutes)

5. Students will be asked to choose two toys/models to measure and calculate the scale ratios using the following directions:
    - Choose two model vehicles.
    - For each model vehicle, draw a sketch of the model from the side, top, and front views.
    - Measure the maximum length, width, and height for the model vehicle, plus make two other measurements of your choice. Examples of the two extra measurements could be wheel diameter, propeller length, height off the ground, etc.
    - Look up and record the measurements for the actual vehicle your model represents.
    - Calculate each scale ratio.
    - Answer the analysis questions.

Explain (10 minutes)

6. For each model vehicle that they measure, students will be asked to explain their understanding of scale ratio calculations by answering three Calculating Scale Ratios analysis questions:
    - Are all of the scale ratios you calculated for your vehicle the same?
    - If you scale ratios are not the same, are they close to being the same or very different?
    - If you could improve this model to make it more realistic, what would you do?

Elaborate (10 minutes)

7. Students will use their understanding of scale ratios to calculate and choose a scale ratio that could be used to create a model Bell X-1 for wind tunnel testing. Students are given length, width, and height measurements for both the Bell X-1 and the wind tunnel.
8. Students will elaborate on their scale ratio choice by answering three Scaling Down the Bell X-1 for Testing analysis questions:
    - Based on your calculations, what is the best scale ratio to use for your model?
    - What information did you consider when making your decision?
    - We need to make sure that we have more room for the model to move inside the wind tunnel. How should you adjust your scale ratio?

Evaluate (10 minutes)

9. Have each student or group share out what scale ratio they chose for the Bell X-1 and why they chose that ratio. Instructors can record the students' answers on the board to show the variety of responses.

STEM Career Connections

- Aerospace engineer
- Materials scientist
- Mechanical engineer
- Testing engineer
- Wind tunnel technician
- Machinist

Extensions

Students could further *elaborate* on their understanding of scale ratios by building their own model of the Bell X-1 and testing it in a wind tunnel test. See Grades 3-5 | Engineering Design: Trash Can Rocket Ship or Grade 4 | Physical Science: Wind Tunnel Energy for instructions on building a wind tunnel.

Students could further *elaborate* on their understanding of scale ratios by making a map of the classroom to scale.

References & Resources

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Scaling Down at Supersonic Speeds

✈ Introduction

Many of the toy cars, trains, airplanes, spaceships, and boats that we play with are smaller models of actual objects. This means that the toys look exactly the same as the actual object, just a fraction of the size. The ***scale ratio*** is the fraction that tells you how the model's measurements compare to the actual object's measurements. For example, a scale ratio of 1:100 means that each centimeter in the model represents 100 centimeters on the actual object. You could also say the actual object is 100 times larger than the model. In another example, 2:5 means that for each 2 cm measured on the model, the actual object measures 5 cm. This would make the actual item 2.5 times larger than the model.

Many times, there are different models, using different scale ratios for the same object. The picture to the right shows the scale ratios for two different models of an SR-71 Blackbird – a supersonic aircraft. An object traveling at s***upersonic*** speeds means that the object is moving faster than the speed of sound. We are going to practice using scale ratios to compare models to their actual objects.

✈ Scale Ratio Practice with the SR-71 Blackbird

The table below lists measurements for an SR-71 Blackbird, measurements of different SR-71 Blackbird models, and their scale ratios. Use the given information to calculate the missing measurements.

SR-71 Blackbird Measurement	Model Size (cm)	Actual Size (cm)	Scale Ratio
length		3273 cm	1:250
width		1694 cm	1:250
height	2.3 cm		1:250
nose probe	0.9 cm		1:160
tire diameter	0.74 cm	74 cm	
wing length	20 cm	2000 cm	

Calculating Scale Ratios

Calculate the scale ratio for two different model vehicles using the following directions. Record all data in the tables below.

- ☐ Choose two model vehicles.
- ☐ For each model vehicle, draw a sketch of the model from the side, top, and front views.
- ☐ Measure the maximum length, width, and height for the model vehicle, plus make two other measurements of your choice. Examples of the two extra measurements could be wheel diameter, propeller length, height off the ground, etc.
- ☐ Look up and record the measurements for the actual vehicle your model represents.
- ☐ Calculate each scale ratio.
- ☐ Answer the analysis questions.

Object #1 Description

Sketch From Side	**Sketch From Top**	**Sketch From Front**

Measurement Description	**Model Size (cm)**	**Actual Size (cm)**	**Scale Ratio**
Maximum length			
Maximum width			
Maximum height			

Are all of the scale ratios you calculated for your vehicle the same?
If you scale ratios are not the same, are they close to being the same or very different?
If you could improve this model to make it more realistic, what would you do?

Object #2 Description		
Sketch From Side	**Sketch From Top**	**Sketch From Front**

Measurement Description	**Model Size (cm)**	**Actual Size (cm)**	**Scale Ratio**
Maximum length			
Maximum width			
Maximum height			

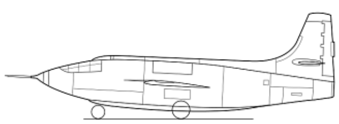
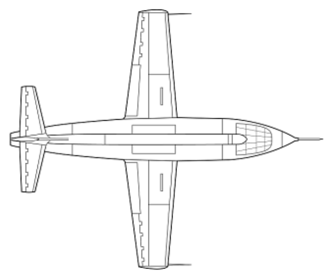
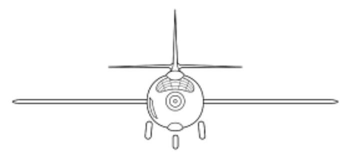
Are all of the scale ratios you calculated for your vehicle the same?
If you scale ratios are not the same, are they close to being the same or very different?
If you could improve this model to make it more realistic, what would you do?

✈ Scaling Down the Bell X-1 for Testing

We want to create a model of the Bell X-1, the first supersonic aircraft, for testing in our **wind tunnel**. A wind tunnel is a large tube that provides moving air. The movement of air is called the **flow**. Objects can be placed inside the wind tunnel to test how objects interact with the flow. This can simulate objects moving through air, such as an airplane flying, or air moving around an object, such as a house in a windstorm.

You are tasked with deciding what scale ratio we should use for our model Bell X-1 so that it fits in our wind tunnel. The table below shares the dimensions of both the Bell X-1 and our wind tunnel. Use the information to calculate the ideal scale ratio for our work.

Bell X-1 – Glamour Glennis
First airplane to fly faster than the speed of sound

Sketch From Side	**Sketch From Top**	**Sketch From Front**
		

Measurement Description	**Wind Tunnel (cm)**	**Bell X-1 (cm)**	**Scale Ratio**
Maximum length	30 cm	937 cm	
Maximum width	20 cm	853 cm	
Maximum height	25 cm	326 cm	

Based on your calculations, what is the best scale ratio to use for your model?

What information did you consider when making your decision?

We need to make sure that we have more room for the model to move inside the wind tunnel. How should you adjust your scale ratio?