



# My Imaginary Friend, Part 2

## Operations with Complex Numbers



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<b>Grade Level</b>	10th – 12th Grade	<b>Time Frame</b>	60-80 minutes
<b>Subject</b>	Mathematics	<b>Duration</b>	2-3 class periods
<b>Course</b>	Algebra 2, Precalculus		

### Essential Question

Why do we perform operations on complex numbers?

### Summary

To complete this lesson, students need to know how to simplify the square root of a negative number and how to simplify  $i$  to a power.\* This lesson is contained within an escape room. Students will navigate through a spaceship and, along the way, will perform operations on complex numbers so they can make it to the escape pods in time. Students will see the real-world applications of these operations through learning about electrical circuits. Students also will watch a video of an electrical engineer speaking about his career, describing how he uses electrical circuits, and explaining how to divide complex numbers using complex conjugates. \*See the "My Imaginary Friend, Part 1" lesson for the prerequisite content. This is a multimodality lesson, which means it includes face-to-face, online, and hybrid versions of the lesson. The attachments also include a downloadable Common Cartridge file, which can be imported into a Learning Management System (LMS) such as Canvas or eKadence. The cartridge includes interactive student activities and teacher's notes.

### Snapshot

#### Engage

Students read a story that sets the scene for the escape room in a spaceship. Students use their reasoning skills to turn given clues into a passcode as they learn how to navigate through the escape room.

#### Explore

Students are introduced to electrical circuits and perform calculations using electrical circuits. Students add and subtract complex numbers to find the total impedance, then multiply complex numbers to find the voltage.

#### Explain

Students watch a video of an electrical engineer speaking about his career and describing how he uses electrical circuits. Students then learn about complex conjugates and how to use them to divide complex numbers.

#### Extend

Students apply what they have learned about performing operations with complex numbers to progress through the escape room.

**Evaluate**

Students use the Fist to Five strategy to reflect on what they have learned during the lesson.

## Standards

*ACT College and Career Readiness Standards - Mathematics (6-12)*

**N 606:** Multiply two complex numbers

**N 704:** Apply properties of complex numbers and the complex number system

*Oklahoma Academic Standards Mathematics (Algebra 2)*

**A2.N.1.2:** Simplify, add, subtract, multiply, and divide complex numbers.

*Oklahoma Academic Standards Mathematics (Algebra 2)*

**PC.T.4.1:** Use the relation  $i^2 = -1$  and the mathematical properties to add, subtract, and multiply complex numbers.

## Attachments

- [Calibration Dial—My Imaginary Friend Part 2 - Spanish.docx](#)
- [Calibration Dial—My Imaginary Friend Part 2 - Spanish.pdf](#)
- [Calibration Dial—My Imaginary Friend Part 2.docx](#)
- [Calibration Dial—My Imaginary Friend Part 2.pdf](#)
- [Cargo Bay—My Imaginary Friend Part 2 - Spanish.docx](#)
- [Cargo Bay—My Imaginary Friend Part 2 - Spanish.pdf](#)
- [Cargo Bay—My Imaginary Friend Part 2.docx](#)
- [Cargo Bay—My Imaginary Friend Part 2.pdf](#)
- [Go With the Flow—My Imaginary Friend Part 2 - Spanish.docx](#)
- [Go With the Flow—My Imaginary Friend Part 2 - Spanish.pdf](#)
- [Go With the Flow—My Imaginary Friend Part 2.docx](#)
- [Go With the Flow—My Imaginary Friend Part 2.pdf](#)
- [Lesson Guide and Escape Room Script—My Imaginary Friend Part 2.docx](#)
- [Lesson Guide and Escape Room Script—My Imaginary Friend Part 2.pdf](#)
- [Lesson Slides—My Imaginary Friend Part 2.pptx](#)
- [Power Control Hub—My Imaginary Friend Part 2 - Spanish.docx](#)
- [Power Control Hub—My Imaginary Friend Part 2 - Spanish.pdf](#)
- [Power Control Hub—My Imaginary Friend Part 2.docx](#)
- [Power Control Hub—My Imaginary Friend Part 2.pdf](#)
- [User Manual Calculations Sample Responses—My Imaginary Friend Part 2.docx](#)
- [User Manual Calculations Sample Responses—My Imaginary Friend Part 2.pdf](#)
- [User Manual Calculations—My Imaginary Friend Part 2 - Spanish.docx](#)
- [User Manual Calculations—My Imaginary Friend Part 2 - Spanish.pdf](#)
- [User Manual Calculations—My Imaginary Friend Part 2.docx](#)
- [User Manual Calculations—My Imaginary Friend Part 2.pdf](#)
- [User Manual Definitions—My Imaginary Friend Part 2 - Spanish.docx](#)
- [User Manual Definitions—My Imaginary Friend Part 2 - Spanish.pdf](#)
- [User Manual Definitions—My Imaginary Friend Part 2.docx](#)
- [User Manual Definitions—My Imaginary Friend Part 2.pdf](#)

## Materials

- Common Cartridge (attached)
- Desmos account
- Student devices with internet access
- Paper
- Pencils

5 minutes

## Engage

### Teacher's Note: Desmos Activity Preparation

Before starting the activity, assign student pairs. In an asynchronous setting, advise students to schedule a time to meet with their partners.

To use this [Desmos Classroom](#) activity, select the following link: "[My Imaginary Friend, Part 2: Asynchronous](#)." Create an account or sign in under the "Activity Sessions" heading. After you log in, the green "Assign" dropdown button will be active. Click the arrow next to the word "Assign," then select "Single Session Code." After making some setting selections, select "Create Invitation Code" and give the session code to students. For more information about previewing and assigning a Desmos Classroom activity, go to <https://k20center.ou.edu/externalapps/using-activities/>.

For more detailed information about Desmos features and how-to tips, go to <https://k20center.ou.edu/externalapps/desmos-home-page/>.

Provide students with your session code. Then, have students go to [student.desmos.com](https://student.desmos.com) and enter the session code.

### Teacher's Note: Sign-in Options

If students sign in with their Google or Desmos accounts, then their progress is saved, and they can resume the activity or view their work later. If students continue without signing in, they can complete the activity, but they must do so in one sitting. It is strongly recommended that students sign in; otherwise, they risk losing their work.

Students must solve their first riddle on **screen 4**, where they are given a circuit diagram, a list of symbols with corresponding letters, and a clue that says, "Go with the flow." Students are expected to use the three symbols in the diagram, find the corresponding letters, and enter those three letters in the table to unlock the next screen. Later in the lesson, students learn what a circuit diagram is and what those symbols mean.

If students enter the code backwards, they see an error message (orange triangle) with a hint to go the opposite direction. If students enter a correct letter but do not capitalize the letter, they see an error message with a hint to capitalize the letter. Once students enter the correct three-letter code, they can progress to the next screen.

20 minutes

## Explore

On **screen 5**, students continue to read the story and learn that they need to read the user manual. On **screens 6–9**, students read the user manual, which contains definitions and examples regarding electrical circuits. Learning about computations with electrical circuits is a real-world application of operations with complex numbers.

On **screen 6**, students learn about circuits, current, and voltage. On **screen 7**, students learn about impedance and circuit components: source, resistor, inductor, and capacitor.

On **screen 8**, students walk through an example of how to calculate the total impedance of a circuit. Going through this example unlocks the next screen. On **screen 9**, students see a second, more complicated example of calculating total impedance. Again, going through this example unlocks the following screen.

Students on **screen 10** are asked to calculate the total impedance of a circuit on their own. Submitting the correct answer unlocks the next screen. On **screen 11**, students must find the total impedance of a second circuit. Again, submitting the correct answer unlocks the following screen.

On **screens 12–13**, students are given the voltage formula:  $\text{Voltage} = (\text{Current}) \cdot (\text{Impedance})$ . Students then are asked to calculate the voltage, given the current and impedance. Submitting a correct answer on each screen unlocks the next.

### Teacher's Note: Purpose

Finding the total impedance requires students to add and subtract complex numbers and recall their knowledge of combining like terms. Calculating voltage requires students to multiply complex numbers and recall their knowledge of expanding binomials and simplifying  $i$  to a power. The goal is for these real-world connections to help students understand why they are learning about operations with complex numbers.

20 minutes

## Explain

On **screen 14**, students are asked to use the voltage formula to calculate the current, given the voltage and impedance. This calculation requires students to divide complex numbers, which likely is not something they have done before.

To aid them in dividing complex numbers, students are asked to use the link on screen 14 to watch the "[My Imaginary Friend, Part 2](#)" video, which features an electrical engineer talking about his career, describing how he uses electrical circuits, and explaining how to divide complex numbers. The question on screen 14 is the example provided in the video.

### Embedded video

<https://youtube.com/watch?v=b4egCAQtzzk>

The video begins with the electrical engineer interview, which ends at the 12:45 mark. The rest of the video demonstrates how to divide complex numbers using a complex conjugate.

Watching the video provides students with the correct answer to the question on screen 14, and submitting it unlocks the following screen. On **screen 15**, students are asked to calculate the current on their own. Again, submitting a correct answer unlocks the next screen.

### Teacher's Note: ACT Prep

There is often one question on the ACT about complex conjugates, and it's usually as simple as this: Students are given a complex number and asked to find its complex conjugate.

Use this lesson to help students understand that a conjugate is *not* the opposite of the number, which is a common misconception. If students can grasp why a complex conjugate is used to divide complex numbers, they may become more comfortable with this concept without feeling like they need to memorize its formal definition.

30 minutes

## Extend

On **screen 16**, students continue to read the story. **Screen 17** prompts students to leave the Desmos activity and go to the provided link to the “Power Control Hub” [GeoGebra](https://www.geogebra.org/m/rwwffvkr) activity: [geogebra.org/m/rwwffvkr](https://www.geogebra.org/m/rwwffvkr).

In this activity, students must answer a series of questions about complex conjugates, dividing complex numbers, and simplifying radicals. Students should put their answers in the calibration dial (modified cipher wheel) within the GeoGebra activity to find a three-letter code.

Once they have the three-letter code, students should return to the Desmos activity to enter the code and unlock the next screen. If students enter a correct letter but do not capitalize the letter, they see an error message with a hint to capitalize the letter.

On **screen 18**, students continue reading the story. **Screen 19** prompts students to leave the Desmos activity and go to the provided link to the “Cargo Bay” [GeoGebra](https://www.geogebra.org/m/whtn2brj) activity: [geogebra.org/m/whtn2brj](https://www.geogebra.org/m/whtn2brj).

In this activity, students must answer a series of questions about adding and subtracting complex numbers, multiplying complex numbers, and simplifying  $i$  to a power. Using the given flashlight tool, students should input their answers to find a three-letter code.

Once they have the three-letter code, students should return to the Desmos activity to enter the code and unlock the next screen. If students enter a correct letter but do not capitalize the letter, they see an error message with a hint to capitalize the letter.

On **screen 20**, students read the conclusion of their escape room story and learn they have escaped successfully.

5 minutes

## Evaluate

On **screen 21**, students are asked to use a modified version of the [Fist to Five](#) strategy to reflect on what they've learned during the lesson. The screen shows a thumbs-down icon and a thumbs-up icon at the ends of a scale. Students should move a point along the scale to show how confident they feel about each of the operations on complex numbers: addition and subtraction, multiplication, and division.

Students also have the option to type and elaborate on how they feel. There is not a submit button on this screen since the written responses are optional.

## Resources

- K20 Center. (n.d.). Fist to Five. Strategies. <https://learn.k20center.ou.edu/strategy/68>
- K20 Center. (n.d.). GeoGebra. Tech tools. <https://learn.k20center.ou.edu/tech-tool/2352>
- K20 Center. (n.d.). Desmos Classroom. Tech tools. <https://learn.k20center.ou.edu/tech-tool/1081>
- K20 Center. (n.d.). My Imaginary Friend, Part 2 cover image [Composite image]. K20 Center.
- Vecteezy. (n.d.). Rocket Ship Flying [Image]. Vecteezy. <https://www.vecteezy.com/vector-art/1871713-happy-successful-businessman-holding-goal-flag-standing-on-rocket-ship-flying-through-starry-sky-business-startup-concept>
- Vecteezy. (n.d.). Round Spaceship on White Background [Image]. Vecteezy. <https://www.vecteezy.com/vector-art/359100-round-spaceship-on-white-background>