Unit 2 - Course B

For classes that wish to go further, the second 10 hour course builds on the skills students developed in Course A through the development of a simple video game. Students will delve deeper into the intersection of Math and CS by studying topics such as boolean logic, piecewise functions, and collision detection with the Pythagorean Theorem, using these concepts to build supporting functions that will eventually drive the logic in their culminating game.

Week 1

Lesson 1: Video Games and Coordinate Planes

Students discuss the components of their favorite video games and discover that they can be reduced to a series of coordinates. They then explore coordinates in Cartesian space, identifying the coordinates for the characters in a game at various points in time. Once they are comfortable with coordinates, they brainstorm their own games and create sample coordinate lists for different points in time in their own game.

Lesson 2: The Big Game - Variables

Students get their first look at the inside of their own video games. They will start development by substituting in new Images, Strings, and Numbers for existing variables.

Lesson 3: The Big Game - Animation

Returning to the Big Game we started in stage 7, students will use the Design Recipe to develop functions that animate the Target and Danger sprites in their games.

Lesson 4: Booleans and Logic

Booleans are the fourth and final data type that students will learn about in this course. In this stage, students will learn about Boolean (true/false) values, and explore how they can be used to evaluate logical questions.

Lesson 5: Boolean Operators

Using Boolean operators, students will write code that compares values to make logical decisions.

Lesson 6: Sam the Bat

Using Boolean operators, students will write code that checks the location of a sprite to make sure it doesn't go off-screen.

Week 1

Lesson 7: The Big Game Booleans

Using the same logic from the previous lesson, students will write code that checks whether their Target and Danger sprites have left the screen. If their function determines that a sprite is no longer visible on screen, it will be reset to the opposite side.

Lesson 8: Conditionals and Piecewise Functions

Currently, even when passing parameters to functions, our outputs follow a very rigid pattern. Now, suppose we want parameters with some values to create outputs using one pattern, but other values to use a different pattern. This is where conditionals are needed. In this stage students will learn how conditional statements can create more flexible programs.

Lesson 9: Conditionals and Update Player

Using conditionals, students will write functions and programs that change their behavior based on logical evaluation of input values.

Lesson 10: Collision Detection and the Pythagorean Theorem

Determining when objects on the screen touch is an important aspect of most games. In this lesson we'll look at how the Pythagorean Theorem and the Distance Formula can be used to measure the distance between two points on the plane, and then decide whether those two points (or game characters) are touching.

Lesson 11: The Big Game - Collision Detection

To finish up their video games, students will apply what they have learned in the last few stages to write the final missing functions. We'll start by using booleans to check whether keys were pressed in order to move the player sprite, then move on to applying the Pythagorean Theorem to determine when sprites are touching.

Lesson 1: Video Games and Coordinate Planes

Overview

Students discuss the components of their favorite video games and discover that they can be reduced to a series of coordinates. They then explore coordinates in Cartesian space, identifying the coordinates for the characters in a game at various points in time. Once they are comfortable with coordinates, they brainstorm their own games and create sample coordinate lists for different points in time in their own game.

Purpose

This lesson introduces students to the idea that computer programs in general, and video games in particular, are built on a grounding of basic mathematical concepts. By exploring the interactions of different characters in a video game, students will see that the world of a 2 dimensional video game is represented in software by a basic coordinate plane. With that knowledge we can begin to describe (and later program) the movement of game elements with relatively simple mathematical functions.

Agenda

Coordinate Planes
Video Game Analysis
  Reverse Engineering a Demo
Wrap-up
  Brainstorming for a Game

Anchor Standard

Common Core Math Standards

- **6.NS.8** - Solve real-world and mathematical problems by graphing points in all four quadrants of the coordinate plane. Include use of coordinates and absolute value to find distances between points with the same first coordinate or the same second coordinate.

Objectives

Students will be able to:

- Describe the movements of video game characters by their change in coordinates.
- Create a data model that describes a simple video game.

Links

For the Teacher

- **Course B Lesson 1 Slide Deck** - Slide Deck
- **Example Game** - Interactive

For the Students

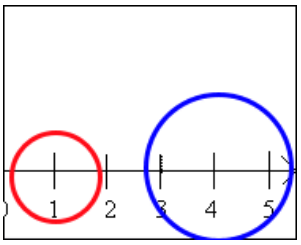
- **Reverse Engineering Table** - Worksheet
- **Video Game Design Template** - Worksheet

Vocabulary

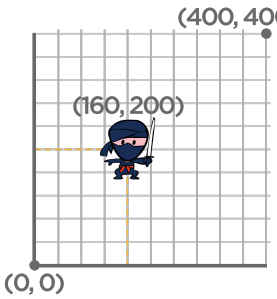
- **Apply** - Use a given function on some inputs.
- **Reverse Engineer** - To extract knowledge or design information from an existing product.
- **Sprite** - A graphic character on the screen with properties that describe its location, movement, and look.

Teaching Guide

Coordinate Planes



Computers use numbers to represent a character's position on screen, using number lines as rulers to measure the distance from the bottom-left corner of the screen. For our video game, we will place the number line so that the screen runs from 0 (on the left) to 400 (on the right). We can take the image of the Dragon, stick it anywhere on the line, and measure the distance back to the left hand edge. Anyone else who knows about our number line will be able to duplicate the exact position of the Dragon, knowing only the number. What is the coordinate of the Dragon on the right hand side of the screen? The center? What coordinate would place the Dragon beyond the left hand edge of the screen?



By adding a second number line, we can locate a character anywhere on the screen in either dimension. The first line is called the x-axis, which runs from left to right. The second line, which runs up and down, is called the y-axis. A 2-dimensional coordinate consists of both the x- and y-locations on the axes. Suppose we wanted to locate the Ninja's position on the screen. We can find the x-coordinate by dropping a line down from the Ninja and read the position on the number line. The y-coordinate is found by running a line to the y-axis.

> **Teaching Tip**
>
> The key point for students here is precision and objectivity. There are many possible correct answers, but students should understand why any solution should be accurate and unambiguous. This requires students to propose solutions that share a common "zero" (the starting point of their number line) and direction (literally, the direction from which a character's position is measured).

A coordinate represents a single point, and an image is (by definition) many points. Some students will ask whether a character's coordinate refers to the center of the image, or one of the corners. In this particular program, the center serves as the coordinate - but other programs may use another location. The important point in discussion with students is that there is flexibility here, as long as the convention is used consistently.

When we write down these coordinates, we always put the x before the y (just like in the alphabet!). Most of the time, you'll see coordinates written like this: (200, 50) meaning that the x-coordinate is 200 and the y-coordinate is 50.

Depending on how a character moves, their position might change only along the x-axis, only along the y-axis, or both. Look back to the table you made. Can the Ninja move up and down in the game? Can he move left and right? So what's changing: his x-coordinate, his y-coordinate, or both? What about the clouds? Do they move up and down? Left and right? Both?

OPTIONAL ACTIVITY: Depending on timing and the background of your students, having one student place a character on a large graph and another student stating the coordinates is excellent practice. Students often need extra practice remembering which coordinate comes first. Coordinates do not have to be exact but they should be in the correct order. Extending this to all four quadrants to include negative numbers is also excellent practice.

Fill in the rest of the reverse-engineering table, identifying what is changing for each of your characters.

Video Game Analysis

Reverse Engineering a Demo

Let's begin by exploring a simple video game, and then figuring out how it works. Open **this link** to play the game, and spend a minute or two exploring it. You can use the arrow keys to move the up and down - try to catch the unicorn and avoid the dragon!

This game is made up of characters, each of which has its own behavior. The unicorn moves from the left to the right, while the dragon moves in the opposite direction. The ninja only moves when you hit the arrow keys, and can move up and down. We can figure out how the game works by first understanding how each character works.

Directions:

1) Divide students into groups of 2-4.

2) Provide each student with a copy of the reverse-engineering table.

3) As students demo the game, ask them to fill in the "Thing in the game..." column with every object they see in the game.

4) Discuss with the whole group which things they came up with. Characters? Background? Score?

5) Next, for each of the things in the game, fill in the column describing what changes. Size? Movement? Value?

6) Ask students to share back with the whole group. Note how students described changes - how detailed were they? What words did they use to describe movement?

Wrap-up

Brainstorming for a Game

Use the **Video Game Design Template - Worksheet** to make your own game. Just like we made a list of everything in the Ninja game, we're going to start with a list of everything in your game. To start, your game will have four things in it:

- A Background, such as a forest, a city, space, etc.
- A Player, who can move when the user hits a key.
- A Target, which flies from the right to the left, and gives the player points for hitting it.
- A Danger, which flies from the right to the left, which the player must avoid.

Teaching Tip

The structure of your students' games will very closely resemble the demo they've just played. Many students will want to reach for the stars and design the next Halo. Remind them that major games like that take massive teams many years to build. Some of the most fun and enduring games are built on very simple mechanics (think Pacman, Tetris, or even Flappy Bird).

Standards Alignment

CSTA K-12 Computer Science Standards (2011)

- **CT** - Computational Thinking

Common Core Math Standards

- **MP** - Math Practices
- **NS** - The Number System
- **OA** - Operations And Algebraic Thinking
- **Q** - Quantities

Lesson 2: The Big Game - Variables

Overview

Students get their first look at the inside of their own video games. They will start development by substituting in new Images, Strings, and Numbers for existing variables.

Agenda

Getting Started
Variables in the Big Game
    Online Puzzles

Anchor Standard

Common Core Math Standards

- **6.EE.4** - Identify when two expressions are equivalent (i.e., when the two expressions name the same number regardless of which value is substituted into them). For example, the expressions y + y + y and 3y are equivalent because they name the same number regardless of which number y stands for.

Objectives

Students will be able to:

- Examine the structure of an existing program.
- Substitute new values into existing variables of an existing program and describe the effects.

Vocabulary

- **Mod** - Short for modification. Games in the real world are often a mod of another game. Othello (or Reversi) is usually considered a mod of the ancient game of “Go”. A mod of a program is one that has been altered to do something slightly different than its original purpose.
- **Stub** - A function whose domain and range have been designated, but the process to transform the domain into the range has not yet been defined.
- **Troubleshooting** - When a program generates an unexpected result, a programmer must examine the code to determine the source of the unexpected results (usually an unanticipated input or incorrect handling of an expected input). Sometimes called debugging.

Teaching Guide

Getting Started

Diving into the Big Game

The students will create a mod of an existing game. As they make changes to the game, it is possible that they will add code that will either “break” the program (cause nothing to happen) or cause an unexpected outcome. If either of these conditions exist, they will need to troubleshoot or debug the code to determine how to get it working in the proper way. **If things go terribly awry and finding a problem is too frustrating, use the Clear Puzzle button in the upper right corner of the workspace.** This button will clear your game back to its initial state, so it should only be used as a last resort.

This exercise is a simplified version of a very common real world programming task. Programmers often create mods of programs about which they know very little. They slowly unravel which pieces require further understanding in order to make the mod work the way they want, while leaving other parts of the program completely unexplored.

Many programs and functions are customizable through their arguments (which can be variables or values). When a function is called, its arguments are passed in as variables into the function. In other cases, variables that someone might want to change (sometimes called constants) are often at the top of a piece of code. Having access to the code allows the programmer to change the way the program behaves by setting these variables to different values.

In this lesson, we are creating the mod by changing the variables inside the code. The student has access to the game code and is changing the initial value of the Title, Subtitle, Player, Danger, and Target. As a reminder, the **ultimate** goal of this game will be to manipulate the player through pressing keys, to avoid the danger, and to make contact with the target. The **current** lesson has no motion or interactivity. It only changes the look of the game. The motion and interactivity function stubs, such as `update-target` and `update-danger`, will be completed in later lessons.

The blocks menu displays a few new items (Boolean, Conditionals, and Functions) which will be examined in more detail in future lessons. The students should be encouraged to explore each of the sub-menus. However **the only navigation required for this level is editing the five color blocks at the top of the function:** Title, subtitle, bg (background), player, target, and danger. The difference between the color and black blocks will also be explained in a future lesson.

Variables in the Big Game

Online Puzzles

In this stage you'll define and modify variables to changes how some games function. Head to **Course B stage 2** in Code Studio to get started programming.

Standards Alignment

Common Core Math Standards

- **CED** - Creating Equations
- **EE** - Expressions And Equations
- **IF** - Interpreting Functions
- **LE** - Linear, Quadratic, And Exponential Models★
- **MP** - Math Practices
- **OA** - Operations And Algebraic Thinking
- **Q** - Quantities
- **SSE** - Seeing Structure In Expressions

Lesson 3: The Big Game - Animation

Overview

Returning to the Big Game we started in stage 7, students will use the Design Recipe to develop functions that animate the Target and Danger sprites in their games.

Agenda

Getting Started

- **Introduction**

Activity

- **Online Puzzles**

Anchor Standard

Common Core Math Standards

- **F.LE.2** - Construct linear and exponential functions, including arithmetic and geometric sequences, given a graph, a description of a relationship, or two input-output pairs (include reading these from a table).

Objectives

Students will be able to:

- Design functions to solve word problems.
- Use the Design Recipe to write contracts, test cases, and function definitions.

Links

For the Students

- **Update-target Design Recipe** - Worksheet
- **Update-danger Design Recipe** - Worksheet

Teaching Guide

Getting Started

Introduction

Let's get back into that Big Game that we started in stage 7.

> **Teaching Tip**
>
> A contract can be quite long and often scrolls off the screen. To make dragging into the Definition area easier, consider collapsing the "1. Contract" and "2. Examples" areas by clicking on the arrow to the left of them.

The primary goal here is to get the **target** (starting in the upper left) to travel from left to right and the **danger** (starting in the lower right) to travel from right to left. This is accomplished in the update-target and update-danger blocks by changing the output of the function from its current default value of an unchanging x to some value relative to x.

Similar to the rocket-height puzzle, the update-target and update-danger functions are executed in order about every 10th of a second, to create the flip-book effect of movement. Each time these updates are executed, the functions take the CURRENT x coordinate as input and then return a new x coordinate such that the image's position changes. For each new execution of the update, the x coordinate set by the previous execution becomes the starting point.

One new thing the students should notice is that their modifications from stage 7 should still be in place. The Big Game will save a file for each student, and each level that they work on will benefit from the the changes made in previous levels. This means that it is very important that every student gets each Big Game level working correctly before moving on to the next stage.

It should also be noted that if a student returns to a previous level, or even a previous stage, that the MOST RECENT changes which they made will be the ones that they will see. Backing up to a previous level does NOT restore the previous state of the student's Big Game. Students are always looking at their most recent changes no matter which puzzle they are in.

Activity

Online Puzzles

Using what you've learned about the Design Recipe you'll be writing functions that add animation to your game. Head to **CS in Algebra course B, Stage 3** in Code Studio to get started programming. Note that when you click run, the title and subtitle will display for about 5 seconds before the other functions start.

Standards Alignment

Common Core Math Standards

- **BF** - Building Functions
- **EE** - Expressions And Equations
- **F** - Functions
- **IF** - Interpreting Functions
- **LE** - Linear, Quadratic, And Exponential Models★
- **MP** - Math Practices
- **NS** - The Number System
- **OA** - Operations And Algebraic Thinking
- **Q** - Quantities

Lesson 4: Booleans and Logic

Overview

Booleans are the fourth and final data type that students will learn about in this course. In this stage, students will learn about Boolean (true/false) values, and explore how they can be used to evaluate logical questions.

Agenda

Getting Started

- **Booleans - True or False?**

Activity

- **Boolean 20 Questions**

Anchor Standard

Common Core Math Standards

- **7.EE.4** - Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities.

Objectives

Students will be able to:

- Evaluate simple Boolean expressions.
- Evaluate complex Boolean expressions.

Preparation

- [ ] 3x5 cards

Links

For the Teacher

- **Algebra Booleans** - Slide Deck

Teaching Guide

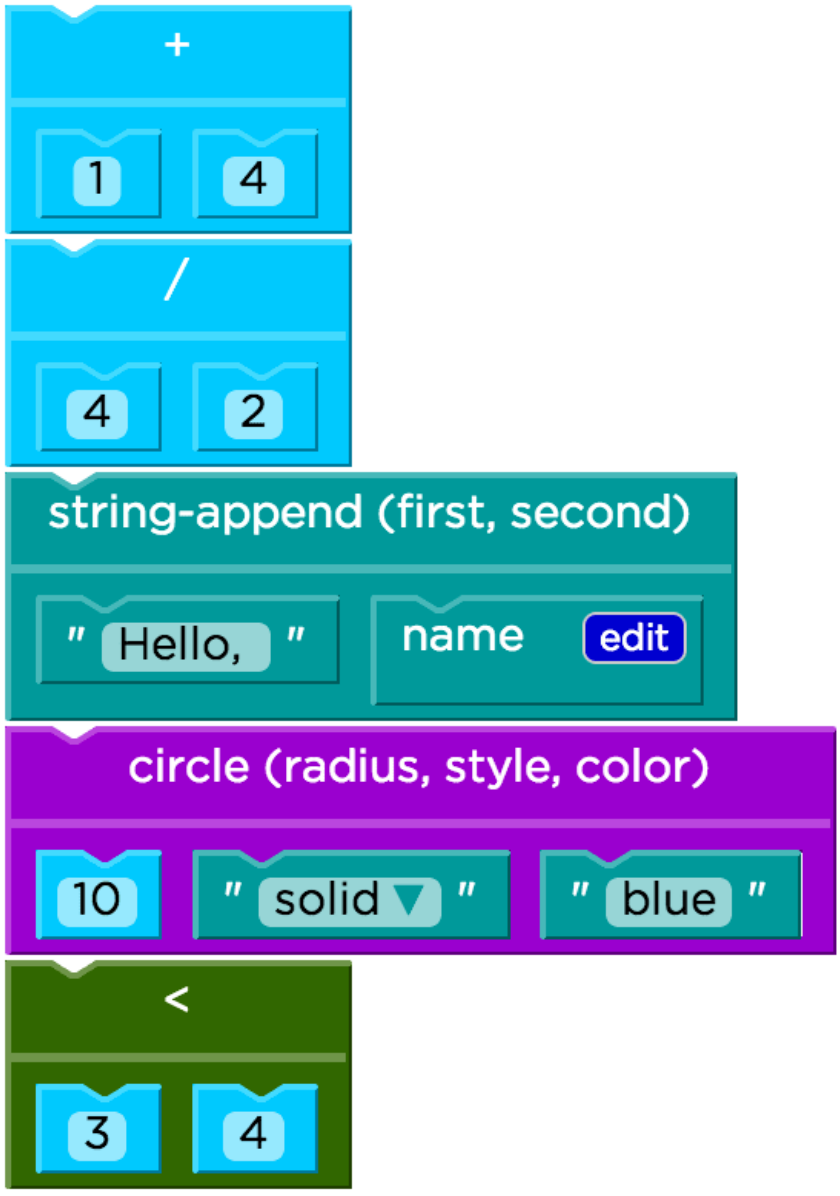
Getting Started

Booleans - True or False?

What types of data have we used in our programs so far?

- Can you think of Number values?
- String values? Image values?
- What are some expressions that evaluate to a Number?
- How about the other datatypes?

What would each of the following expressions evaluate to?



The last expression, **(3 < 4)**, uses a new function that compares Numbers, returning**true** if 3 is less than 4. What do you think it would return if the numbers were swapped?

The function **<** tests if one number is less than another. Can you think of some other tests?

Functions like **<**, **>** and **=** all consume two Numbers as their Domain, and produce a special value called a Boolean as their Range. Booleans are answers to a yes-or-no question, and Boolean functions are used to perform tests. In a videogame,

you might test if a player has walked into a wall, or if their health is equal to zero. A machine in a doctor's office might use Booleans to test if a patient's heart rate is above or below a certain level.

Boolean values can only be true or false.

Activity

Boolean 20 Questions

Give each student a card and have them answer the following questions on it (feel free to add some of your own)

1. What is your hair color?
2. Do you wear glasses or contacts?
3. What is your favorite number?
4. What is your favorite color?
5. What month were you born?
6. Do you have any siblings?
7. What is the last digit of your phone number?
8. What is something about you that people here don't know and can't tell by looking at you?

Then collect the cards and shuffle them. To play the game, follow these steps:

- Select a card
- Say: I'm going to read the answer to #8 but if it is you, don't say anything.
- Say: Now everyone stand up and we are going to ask some questions with Boolean answers to help determine who this person is.
- Begin the following true/false questions. Preface each one with "If you answer false to the following question, please sit down." The person whose card you are reading should always answer true so you will need to change the example questions below. For this example, the answers were:
- What is your hair color? -**brown**
- Do you wear glasses or contacts? -**yes**
- What is your favorite number? -**13**
- What is your favorite color? -**blue**
- What month were you born? -**December**
- Do you have any siblings? -**yes**
- What is the last digit of your phone number? -**7**

With that example, you might make the following statements:

- My hair color is brown.
- I wear contacts or glasses. (you only have to answer true to One of these to remain standing)
- My favorite number is greater than 10 and less than 20. (you must answer true to both these.)
- My favorite color is blue or green.
- I was not born in April.
- I have at least one sibling.
- The last digit of my phone number is a prime number.

Because of how numbers 3,4, 5, and 7 were asked it is likely that some people will still be standing. You will need to revisit these and ask them again in a more narrow fashion such as "My favorite color is blue".

Play this several times. Be creative with using _or_s and _and_s. Remind students that the OR means that either part of the statement being true will result in the entire statement being true. In English, an "or" is often an "exclusive or" such as "You can have chicken or fish." In English, you only get to pick one, but with Boolean logic you could have chicken, fish, or both!! For the example person above, "I was born in December OR my favorite number is 13" is true. Note that "I was born in December AND my favorite number is 13" is also true.

Have a student try to act as the quizmaster after several rounds. If a mistake is made by you, a student quizmaster, or the person whose card you are reading, see if you can analyze where the mistake was made or why the question being asked might not have been clear.

How does this activity connect with our game? In our game, we may need to determine: Is a target too far left or too far right? If so, then perhaps some action should occur.

Standards Alignment

Common Core Math Standards

- **EE** - Expressions And Equations
- **F** - Functions
- **MP** - Math Practices
- **NS** - The Number System
- **OA** - Operations And Algebraic Thinking
- **Q** - Quantities
- **REI** - Reasoning With Equations And Inequalities

Lesson 5: Boolean Operators

Overview

Using Boolean operators, students will write code that compares values to make logical decisions.

Agenda

Getting Started

Introduction

Activity

Online Puzzles

Anchor Standard

Common Core Math Standards

- **7.EE.4** - Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities.

Objectives

Students will be able to:

- Use Boolean operators to compare values.
- Apply Boolean logic, such as AND, OR, and NOT, to compose complex Boolean comparisons.

Links

For the Teacher

- **Algebra Boolean Operators** - Slide Deck

Teaching Guide

Getting Started

Introduction

Creating some sample boolean expressions - both simple and complex - is an excellent warm-up activity before the puzzle stages. Some examples have been included in the slide deck. The slide deck also has extra practice related to expressions that the students will have seen in the puzzles.

Activity

Online Puzzles

Head to **Course B stage 5** in Code Studio to get started programming.

Standards Alignment

Common Core Math Standards

- **EE** - Expressions And Equations
- **F** - Functions
- **MP** - Math Practices
- **NS** - The Number System
- **OA** - Operations And Algebraic Thinking
- **Q** - Quantities

Lesson 6: Sam the Bat

Overview

Using Boolean operators, students will write code that checks the location of a sprite to make sure it doesn't go off-screen.

Agenda

Getting Started

- **Introduction**
- **Why not write just one function?**

Activity

- **Online Puzzles**

Extension Activities

- **Safe up and down**

Anchor Standard

Common Core Math Standards

- **6.NS.8** - Solve real-world and mathematical problems by graphing points in all four quadrants of the coordinate plane. Include use of coordinates and absolute value to find distances between points with the same first coordinate or the same second coordinate.

Objectives

Students will be able to:

- Use Boolean operators to compare values.
- Apply Boolean logic, such as AND, OR, and NOT, to compose complex Boolean comparisons.

Links

For the Students

- **Safe-left? Design Recipe** - Worksheet
- **Safe-right? Design Recipe** - Worksheet
- **Onscreen? Design Recipe** - Worksheet

Teaching Guide

Getting Started

Introduction

This is Sam the Bat, and his mother tells him that he's free to play in the yard, but he don't set foot (or wing) outside the yard! Sam is safe as long as he is always entirely onscreen. The screen size is 400 pixels by 400 pixels, so how far can Sam go before he starts to leave the screen?

In this stage students write functions that will take in Sam the Bat's next x-coordinate and a return a boolean. That function should return **true** if part of Sam will still be visible, or **false** if he would go too far off-screen. If the function returns **false**, Sam isn't allowed to move.

Students will start by writing functions to check the left and right side of the screen independently, before combining those with a single `onscreen?` function that prevents Sam from leaving on both the left and right.

Teaching Tip

It's extremely valuable in this stage to have three students stand, and act out each of these three functions:

- Ask each student to tell you their Name, Domain and Range. If they get stuck, remind them that all of this information is written in their Contract!
- Practice calling each function, by saying their name and then giving them an x-coordinate. For example, "safe-left? fifty" means that the number 50 is being passed into `safe-left?`. That student should return "true", since the code currently returns `true` for all values of x.
- Do this for all three functions, and have the class practice calling them with different values as well.

Note: the volunteer for `onscreen?` should first call `safe-left?`, bef ore replying with the value.

For each stage, make sure students try to get Sam to leave through the side they are checking. If Sam makes it all the way off-screen when he shouldn't, they'll get an error, but if he is successfully stopped they'll succeed and move to the next puzzle.

Why not write just one function?

Some students may wonder why they should write separate functions for `safe-left?` and `safe-right?` when `onscreen?` could just check the dimensions of the screen directly. There is more to being a writer than good spelling and grammar. There's more to being an architect or an artist than building a bridge or coloring in a canvas. All of these disciplines involved an element of **design**. Likewise, there is more to being a Programmer than just writing code.

Suppose you just built a car, but it's not working right. What would you do? Ideally, you'd like to test each part of the car (the engine, the transmission, etc) one at a time, to see which one was broken. The same is true for code! If you have a bug, it's much easier to find when every function is simple and easy to test, and the only complex functions are just built out of simpler ones. In this example, you can test your `safe-left?` and `safe-right?` functions independently, before stitching them together into onscreen?.

Another reason to define multiple, simple functions is the fact that it lets programmers be lazy. Suppose you have a few characters in a videogame, all of which need to be kept on the screen. Some of them might only need `safe-left?`, others might only need `safe-right?`, and only a few might need `onscreen?`. What happens if the game suddenly needs to run on computers with differently-sized monitors, where the width is 1000 pixels instead of 400? If you have simple and complex functions spread throughout your code, you'll need to change them all. If your complex functions just use the simpler ones, you'd only need to change them in one place!

Badly designed programs can work just fine, but they are hard to read, hard to test, and easy to screw up if things change. As you grow and develop as a programmer, you'll need to think beyond just "making code work". It's not good enough if it just works - as artists, we should care about whether or not code is **well designed**, too. This is what functions allow us to

do! Everyone from programmers to mathematicians uses functions to carve up complex problems into simpler pieces, which make it possible to design elegant solutions to difficult problems.

Activity

Online Puzzles

Using Boolean logic, you're going to write functions to help make sure Sam the Bat doesn't leave his mom's yard. Head to **Course B stage 6** in Code Studio to get started programming.

Extension Activities

Safe up and down

The final puzzle of this stage is a Free Play puzzle that will allow you amd your students to experiment with other ways to keep Sam in his yard. The basic activity only prevents Sam from leaving on the left and right, but what about the top and bottom of the screen?

If you add a second variable to the `onscreen?` function to take in Sam's y coordinate, then you can check Sam's position on each axis. As students pursue this extension, encourage them to think about how they wrote small component functions to check the left and right. Could you follow a similiar approach to deal with the top and bottom?

Standards Alignment

Common Core Math Standards

- **EE** - Expressions And Equations
- **F** - Functions
- **MP** - Math Practices
- **NS** - The Number System
- **OA** - Operations And Algebraic Thinking
- **Q** - Quantities

Lesson 7: The Big Game Booleans

Overview

Using the same logic from the previous lesson, students will write code that checks whether their Target and Danger sprites have left the screen. If their function determines that a sprite is no longer visible on screen, it will be reset to the opposite side.

Agenda

Getting Started

Introduction

Activity

Online Puzzles

Anchor Standard

Common Core Math Standards

- **6.EE.9** - Use variables to represent two quantities in a real-world problem that change in relationship to one another; write an equation to express one quantity, thought of as the dependent variable, in terms of the other quantity, thought of as the independent variable. Analyze the relationship between the dependent and independent variables using graphs and tables, and relate these to the equation. For example, in a problem involving motion at constant speed, list and graph ordered pairs of distances and times, and write the equation d = 65t to represent the relationship between distance and time.

Objectives

Students will be able to:

- Using the same logic from the previous lesson, students will write code that checks whether their Target and Danger sprites have left the screen. If their function determines that a sprite is no longer visible on screen, it will be reset to the opposite s
- Apply Boolean logic, such as AND, OR, and NOT, to compose complex Boolean comparisons.

Links

For the Students

- **Safe-left? Design Recipe** - Worksheet
- **Safe-right? Design Recipe** - Worksheet
- **Onscreen? Design Recipe** - Worksheet

Teaching Guide

Getting Started

Introduction

Let's get back into that Big Game that we started in stage 7 and continued in stage 12.

When we last worked on the game, our danger and target were moving off the screen in opposite directions. Unfortunately, their update functions move them in one direction forever, so they never come back on screen once they've left! We'd actually like them to have a recurring role in this game, so we'll use some boolean logic to move them back to their starting points once they go off screen.

Once the students correctly implement `on-screen?` (and its sub-parts `safe-left?` and `safe-right?`), the new behavior of target and danger is that once they are off the screen they return to their starting position but with a new y-value. From this new vertical position they will continue to move across the screen. If one (or both) of the characters go off the screen and never reappear, the most likely source of the error is that one of the newly implemented boolean statements is incorrect.

Activity

Online Puzzles

Return to your Big Game to use Booleans to keep your player character on screen. Head to **Course B stage 7** in Code Studio to get started programming.

Standards Alignment

Common Core Math Standards

- **EE** - Expressions And Equations
- **F** - Functions
- **MP** - Math Practices
- **NS** - The Number System
- **OA** - Operations And Algebraic Thinking
- **Q** - Quantities

Lesson 8: Conditionals and Piecewise Functions

Overview

Currently, even when passing parameters to functions, our outputs follow a very rigid pattern. Now, suppose we want parameters with some values to create outputs using one pattern, but other values to use a different pattern. This is where conditionals are needed. In this stage students will learn how conditional statements can create more flexible programs.

Agenda

Getting Started

- **Conditionals**

Activity

- **Conditionals and Piecewise Functions**
- **Connection to Mathematics and Life**

Anchor Standard

Common Core Math Standards

- **F.IF.7.b** - Graph square root, cube root, and piecewise-defined functions, including step functions and absolute value functions.

Objectives

Students will be able to:

- Understand that piecewise functions evaluate the domain before calculating results.
- Evaluate results of piecewise functions.

Links

For the Teacher

- **Conditionals and Piecewise Functions** - Slide Deck

Teaching Guide

Getting Started

Conditionals

- We can start this lesson off right away
- Let the class know that if they can be completely quiet for thirty seconds, you will do something like:
  - Sing an opera song
  - Give five more minutes of recess
  - or Do a handstand
- Start counting right away.
- If the students succeed, point out right away that they succeeded, so they **do** get the reward.
- Otherwise, point out that they were not completely quiet for a full thirty seconds, so they **do not** get the reward.
- Ask the class "What was the **condition** of the reward?"
- The condition was if you were quiet for 30 seconds
  - If you were, the condition would be true, then you would get the reward.
  - If you weren't, the condition would be false, then the reward would not apply.
- Can we come up with another conditional?
  - If I say "question," then you raise your hand.
  - If I sneeze, then you say "Gesundheit."
  - What examples can you come up with?

Up to now, all of the functions you've seen have done the same thing to their inputs:

- green-triangle always made green triangles, no matter what the size was.
- safe-left? always compared the input coordinate to 0, no matter what that input was.
- update-danger always added or subtracted the same amount

Conditionals let our programs run differently based on the outcome of a condition. Each clause in a conditional evaluates to a boolean value - if that boolean is TRUE, then we run the associated expression, otherwise we check the next clause. We've actually done this before when we played the boolean game! If the boolean question was true for you, you remained standing, and if it was false you sat down.

Let's look at a conditional piece by piece:

```
(x > 10)  ->  "That's pretty big"
(x < 10)  ->  "That's pretty small"
else      ->  "That's exactly ten"
```

If we define x = 11, this conditional will first check if x > 10, which returns TRUE, so we get the String "That's pretty big" - and because we found a true condition we don't need to keep looking.

If we define x = 10, then we first check if x > 10 (FALSE), then we check x < 10 (FALSE), so then we hit the **else** statement, which only returns something if none of the other conditions were true. The **else** statement should be considered the catch-all response - with that in mind, what's wrong with replying "That's exactly ten"? What if x = "yellow"? If you can state a precise question for a clause, write the precise question instead of else. It would have been better to write the two conditions as (x > 10) and (x <= 10). Explicit questions make it easier to read and maintain programs.

Functions that use conditions are called piecewise functions, because each condition defines a separate piece of the function. Why are piecewise functions useful? Think about the player in your game: you'd like the player to move one way if you hit the "up" key, and another way if you hit the "down" key. Moving up and moving down need two different expressions! Without conditionals, you could only write a function that always moves the player up, or always moves it down, but not both.

Now let's play a game.

Activity

Conditionals and Piecewise Functions

Living Function Machines - Conditionals:

Explain to the class that they will be playing the role of Function Machines, following a few simple rules:

- Whenever your function is called, the only information you are allowed to take in is what's described in your Domain.
- Your function must return only what is described in your Range.
- You must follow the steps provided in your definition - no magic!

This time, however, everyone will be running the same function. And that function is called 'simon_says' and it has the following Contract: simon_says: String -> Movement
Given a String that describes an action, produce the appropriate movement. If an unknown action is called, lower both hands.

Examples

```
simon_says("left hand up")    = RaiseLeftHand
simon_says("right hand up")   = RaiseRightHand
simon_says("left hand down")  = LowerLeftHand
simon_says("right hand down") = LowerRightHand
```

Definition

```
simon_says(action) = cond {
                "left hand up"     : RaiseLeftHand,
                "right hand up"    : RaiseRightHand,
                "left hand down"   : LowerLeftHand,
                "right hand down"  : LowerRightHand,
                else               : LowerBothHands }
```

Review the contract parts: name, domain, range, parameters (input types), return types (output values)

Say to the class: “Here is what the initial code looks like. We will add several clauses but the clauses that are there will always be there and the final else action (often called the default result) will always be LowerBothHands

- simon_says("right hand up")
- simon_says("left hand up") - both hands should be up
- simon_says("right hand up") - both hands should still be up
- simon_says("left hand down") - left should be down, right should be up
- simon_says("right hand up") - left should be down, right should be up
- simon_says("hokey pokey") - both hands should be down
- simon_says("left hand up") - left hand should be up
- simon_says("right up") - trick, there are no matches so the else statement is called

If anyone makes a mistake, they must "reboot" by sitting down and waiting for the next round to start.

Say to the class: “Now we're going to rewrite our function a little bit - instead of taking a String as its Domain, simon_says will take a Number. Here's what our new function looks like:

```
simon_says(action) = cond {
                (action < 10)                  : RaiseLeftHand,
                (action < 20)                  : RaiseRightHand,
                (action > 20) and (action < 50)  : LowerLeftHand,
                (action > 50) and (action < 100) : LowerRightHand,
                else                           : LowerBothHands }
```

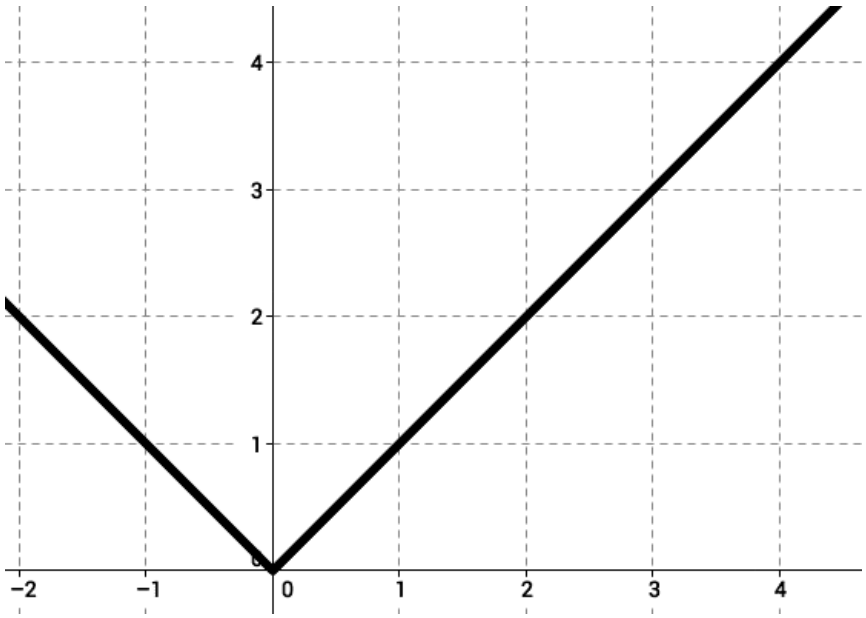
Continue playing using numbers in the `simon_says` function, such as `simon_says(15)`, which should result in `RaiseRightHand`. As students get comfortable with the new rules, you can throw in some trick questions, such as

`simon_says(20)` or `simon_says(50)`, both of which should call the else statement. You can extend this activity in many ways, for example:

- Call the function with a simple expression, such as `simon_says(30 / 2)`
- Add more conditions of your own
- Create multiple functions and divide the class into groups
- Allow students to take over as the 'programmer'

Connection to Mathematics and Life

There are piecewise functions in mathematics as well. The absolute value function y = |x| can be re-written as
y = { -x : x<0 , x : x>0, 0 }

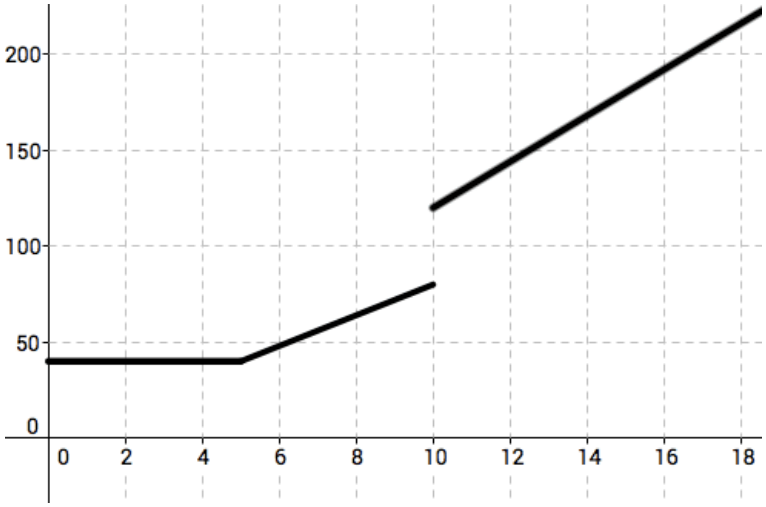


Note that in mathematical terms, the clause for the domain is usually listed second instead of first.

A data plan on a phone bill might be structured as:

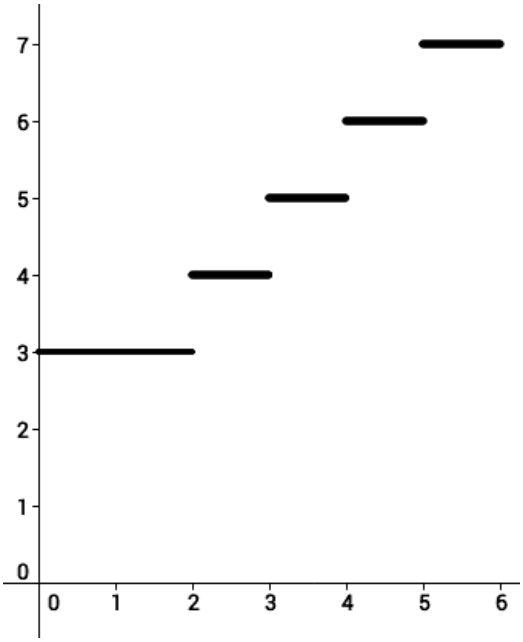
- $40 for less than 5 GB
- $ 8 per GB for 5-10 GB
- $12 per GB for using more than 10GB

This could be graphed with the following piecewise function y = { 40: x<5, 8x: 5 =< x =< 10, 12x: x>10 }



Another very common piecewise functions is for taxi cabs.

- $3 for 0 to 2 miles
- $1 for each partial mile after that



This could be graphed with the following piecewise function y = { 3: x<2, [[x]]+2: x>=2 } where [[x]] is the greatest integer function or what is often called a floor function in computer languages. The greatest integer function returns the greatest INTEGER less that the current value. For instance [[2.9]] is 2 and [[3.1]] is 3.

Standards Alignment

Common Core Math Standards

- **EE** - Expressions And Equations
- **F** - Functions
- **IF** - Interpreting Functions
- **MP** - Math Practices
- **NS** - The Number System
- **OA** - Operations And Algebraic Thinking
- **Q** - Quantities

Lesson 9: Conditionals and Update Player

Overview

Using conditionals, students will write functions and programs that change their behavior based on logical evaluation of input values.

Agenda

Getting Started
- **Introduction**

Activity
- **Online Puzzles**

Extension Activities
- **Improving Luigi's Pizza**
- **Update Player**

Anchor Standard

Common Core Math Standards

- **6.NS.8** - Solve real-world and mathematical problems by graphing points in all four quadrants of the coordinate plane. Include use of coordinates and absolute value to find distances between points with the same first coordinate or the same second coordinate.

Objectives

Students will be able to:

- Use Boolean operators to compare values.
- Apply Boolean logic, such as AND, OR, and NOT, to compose complex Boolean comparisons.
- Write conditional statements that evaluate differently based on their input values.

Links

For the Students

- **Cost Design Recipe** - Worksheet
- **Update-player Design Recipe** - Worksheet
- **Key Codes** - Reference

Teaching Guide

Getting Started

Introduction

Remind students of the game they played in the last stage. What were some of the tricky elements of constructing a good conditional statement?

- Order matters (the first condition in the list to return true wins).
- Write clear and explicit conditions.
- Use the else clause as a catch-all for conditions that you don't expect or can't write explicit conditions for.
- All conditionals must have at least one condition and an else statement, you can add or remove further conditions using the blue buttons.

At the end of this stage, students will return to their Big Game to complete the `update-player` function. This function contains a conditional that will check which key was pressed (using key codes), and move the player up or down accordingly. We've provided a key code reference for students in case they wish to use keys other than the default up (38) and down (40) arrows.

Teaching Tip

Be sure to check students' Contracts and Examples during this exercise, especially when it's time for them to circle and label what changes between examples. This is the crucial step in the Design Recipe where they should discover the need for `cond` .

Activity

Online Puzzles

Head to **Course B Stage 9** in Code Studio to get started programming.

Extension Activities

Improving Luigi's Pizza

The final puzzle in the Luigi's Pizza sequence is a Free Play puzzle that allows for students to extend the program in a number of different ways. While some of the potential extensions seem simple, they can be deceptively challenging to get working. Allow students to explore extensions individually, or choose one to work through as a whole class.

- **Coupon Code**: Write a function `coupon` that takes in a topping and a coupon code and returns the price of a pizza with that topping, with %40 off is the code is correct.
- **Multiple Toppings**: Write a function `two-toppings` that takes in two toppings and returns the price of a pizza with those toppings.
- **Picture Menu**: Write a function `pizza-pic` that takes in a topping and returns a simple image representing a pizza with that topping.

Update Player

The `update-player` function is one of the most extensible in the Big Game. Here's a brief list of potential challenge extensions to give students:

- **Warping**: instead of having the player's y-coordinate change by adding or subtracting, replace it with a Number to have the player suddenly appear at that location. (For example, hitting the "c" key causes the player to warp back to the center of the screen, at y=200.)

- **Boundary-detection**: Keep the player on screen by changing the condition for moving up so that the player only moves up if the up ke was pressed AND player-y is below the top border. Likewise, change the condition for down to also check that player-y is above the bottom.
- **Wrapping**: Add a condition (before any of the keys) that checks to see if the player's y-coordinate is above the screen. If it is, have the player warp to the bottom. Add another condition so that the player warps back up to the top of the screen if it moves below the bottom.
- **Dissapear/Reappear**: Have the player hide when the "h" key is pressed, only to re-appear when it is pressed again!

Standards Alignment

Common Core Math Standards

- ▸ **EE** - Expressions And Equations
- ▸ **F** - Functions
- ▸ **MP** - Math Practices
- ▸ **NS** - The Number System
- ▸ **OA** - Operations And Algebraic Thinking
- ▸ **Q** - Quantities

Lesson 10: Collision Detection and the Pythagorean Theorem

Overview

Determining when objects on the screen touch is an important aspect of most games. In this lesson we'll look at how the Pythagorean Theorem and the Distance Formula can be used to measure the distance between two points on the plane, and then decide whether those two points (or game characters) are touching.

Agenda

Getting Started

Are they Touching?

Activity

Proving Pythagoras
Collision Detection

Anchor Standard

Common Core Math Standards

- **8.G.7** - Apply the Pythagorean Theorem to determine unknown side lengths in right triangles in real-world and mathematical problems in two and three dimensions.

Objectives

Students will be able to:

- Demonstrate that circles will overlap if the distance between their centers is less than the sum of their radii.
- Show that the distance of two points graphed in 2 dimensions can be represented as the hypotenuse of a right triangle.
- Understand that the Pythagorean Theorem allows you to calculate the hypotenuse of a right triangle using the length of the two legs.
- Apply the Pythagorean Theorem to calculate the distance between the centers of two objects.

Links

For the Students

- **Detecting Collisions** - Worksheet
- **Safe-right? Design Recipe** - Worksheet
- **Onscreen? Design Recipe** - Worksheet

Teaching Guide

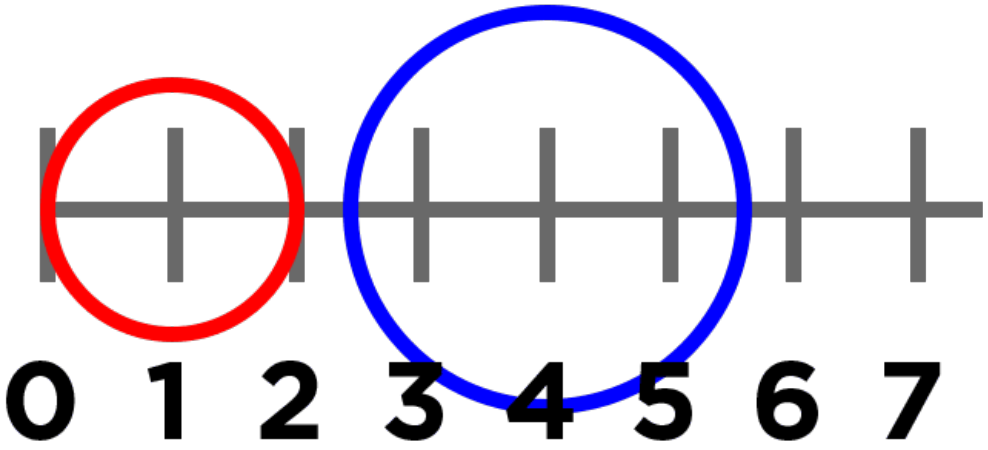
Getting Started

Are they Touching?

Suppose two objects are moving through space, each one having its own (x,y) coordinates. When do their edges start to overlap? They certainly overlap if their coordinates are identical ($x_1 = x_2$, $y_1 = y_2$), but what if their coordinates are separated by a small distance? Just how small does that distance need to be before their edges touch?

Visual aids are key here: be sure to diagram this on the board!

In one dimension, it's easy to calculate when two objects overlap. In this example, the red circle has a radius of 1, and the blue circle has a radius of 1.5 The circles will overlap if the distance **between their centers** is **less than the sum of their radii** (1 + 1.5 = 2.5). How is the distance between their centers calculated? In this example, their centers are 3 units apart, because 4 – 1 = 3.



Prompt the class: Would the distance between them change if the circles swapped places? Why or why not?

Work through a number of examples, using a number line on the board and asking students how they calculate the distance between the points. Having students act this out can also work well: draw a number line, have two students stand at different points on the line, using their arms or cutouts to give objects of different sizes. Move students along the number line until they touch, then compute the distance on the number line.

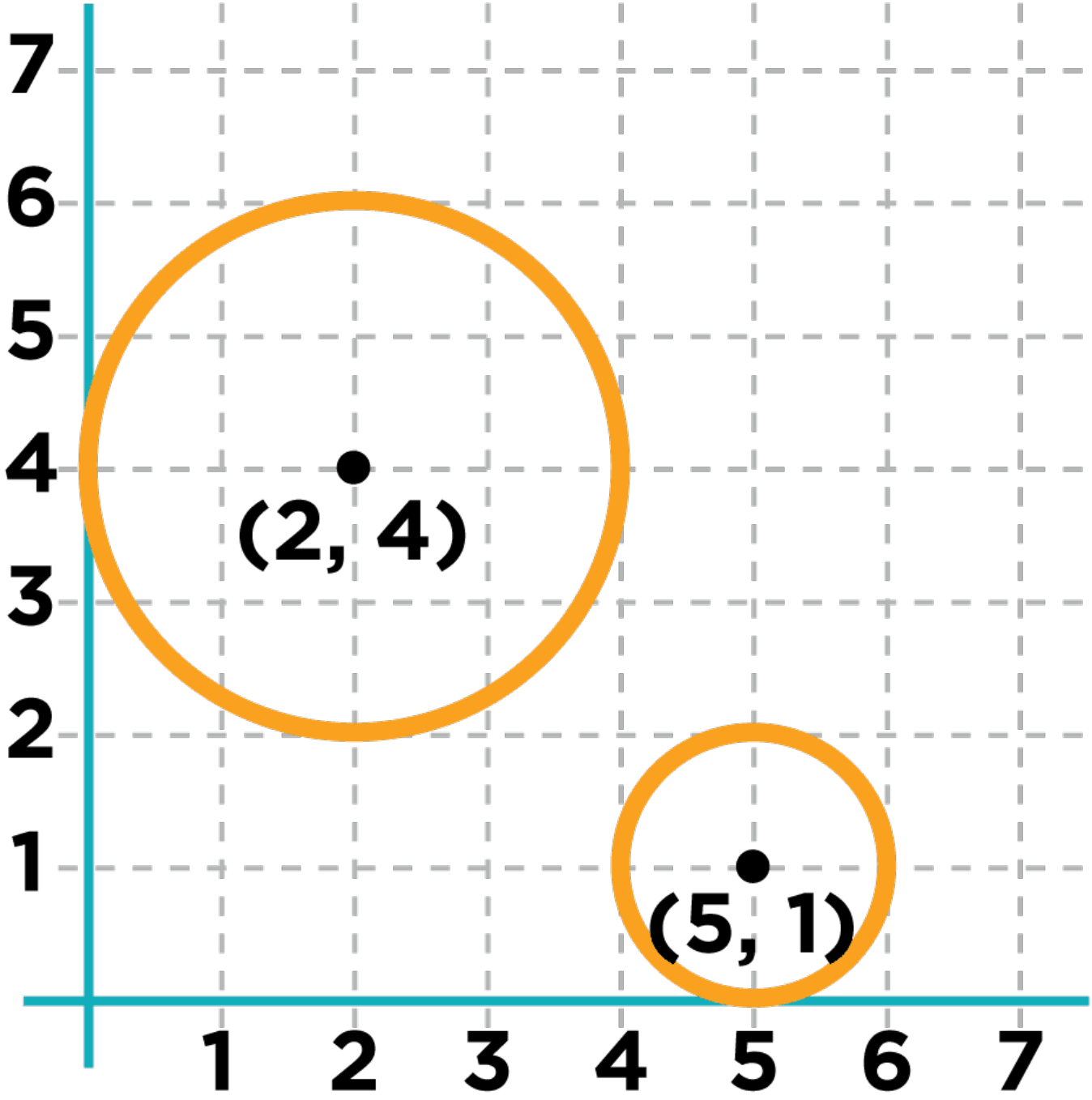
Your game file provides a function called line-length that computes the difference between two points on a number line. Specifically, line-length takes two numbers as input and determines the distance between them

Prompt the students:

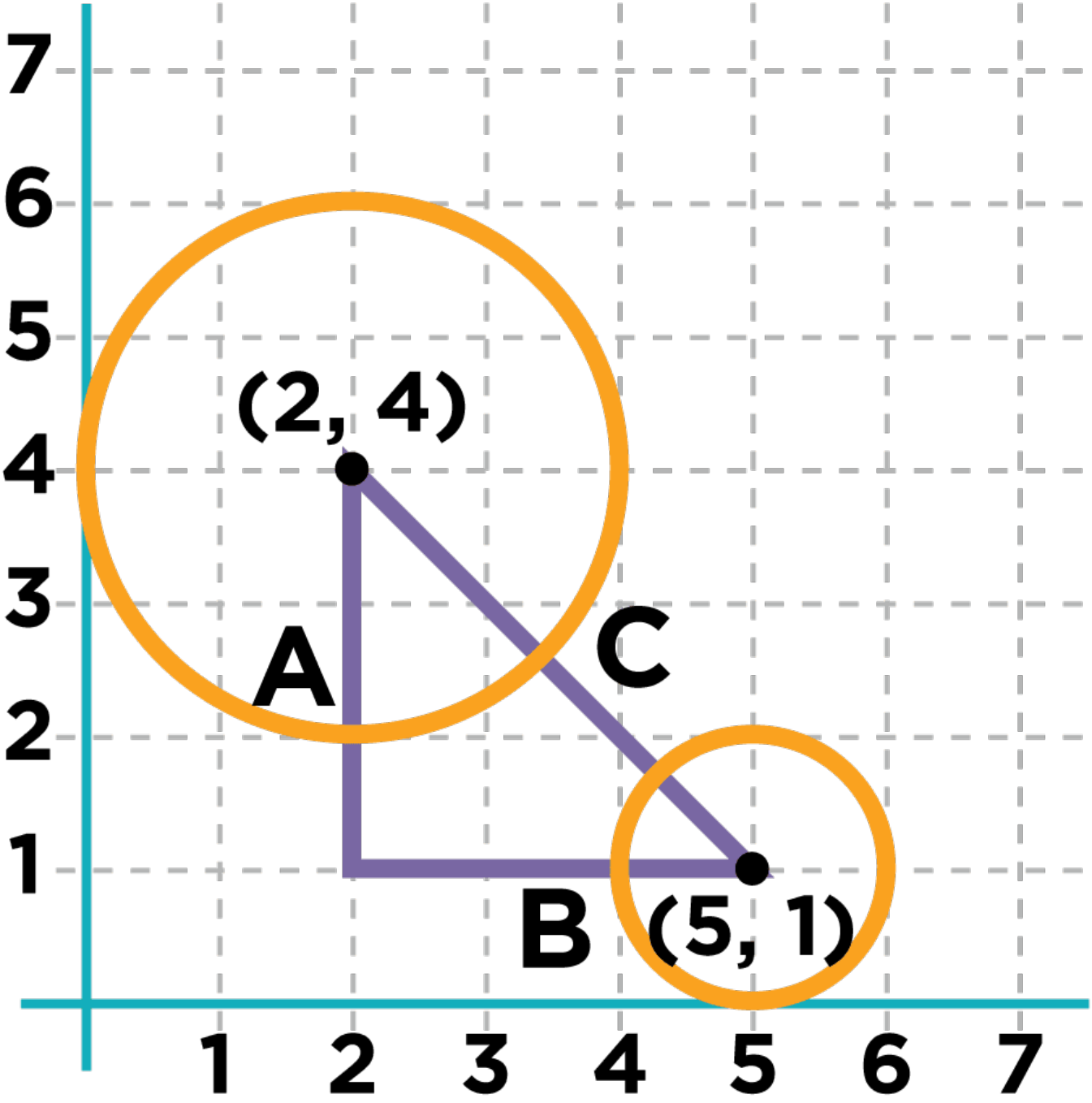
What answers would you expect from each of the following two uses of line-length:

- line-length(2, 5)
- line-length(5, 2)

Do you expect the same answer regardless of whether the larger or smaller input goes first?



Unfortunately, line-length can only calculate the distance between points in a single dimension (x or y). How would the distance be calculated between objects moving in 2-dimensions (like your game elements)? **line-length** can calculate the vertical and horizontal lines in the graphic shown here, using the distance between the x-coordinates and the distance between the y-coordinates. Unfortunately, it doesn't tell us how far apart the two centers are.



Drawing a line from the center of one object to the other creates a right-triangle, with sides A, B and C. A and B are the vertical and horizontal distances, with C being the distance between the two coordinates. **line-length** can be used to calculate A and B, but how can we calculate C?

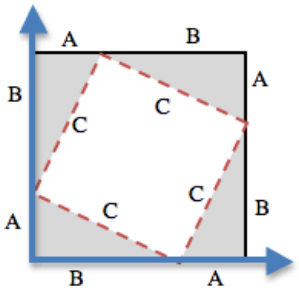
In a right triangle, the side opposite the 90-degree angle is called the hypotenuse. Thinking back to our collision detection, we know that the objects will collide if the hypotenuse is less than the sum of their radii. Knowing the length of the hypotenuse will be essential to determine when a collision occurs.

Activity

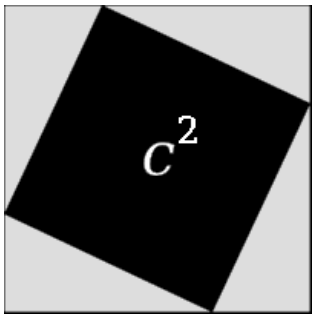
Proving Pythagoras

If your students are new to the Pythagorean Theorem, or are in need of a refresher, this activity is an opportunity to strengthen their understanding in a hands-on fashion.

Organize students into small groups of 2 or 3.

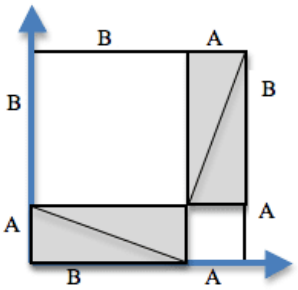


- Pass out Pythagorean Proof materials (**1**, **2**) to each group.
- Have students cut out the four triangles and one square on first sheet.
- Explain that, for any right triangle, it is possible to draw a picture where the hypotenuse is used for all four sides of a square.
- Have students lay out their gray triangles onto the white square, as show in this diagram.
- Point out that the square itself has four identical sides of length C, which are the hypotenuses for the triangles. If the area of a square is expressed by **side ∗ side**, then the area of the white space is C^2.
- Have students measure the inner square formed by the four hypotenuses (C)



By moving the gray triangles, it is possible to create two rectangles that fit inside the original square. While the space taken up by the triangles has shifted, it hasn't gotten any bigger or smaller. Likewise, the white space has been broken into two smaller squares, but in total it remains the same size. By using the side-lengths A and B, one can calculate the area of the two squares.

- You may need to explicitly point out that the side-lengths of the triangles can be used as the side-lengths of the squares.
- Have students measure the area of the smaller square (A)
- Have students measure the area of the larger square (B)
- Ask students to compare the are of square A + square B to the area of square C



The smaller square has an area of A^2, and the larger square has an area of B^2. Since these squares are just the original square broken up into two pieces, we know that the sum of these areas must be equal to the area of the original square:

$A^2 + B^2 = C^2$

Collision Detection

In this activity students will:

- Create right triangles on a graph.
- Calculate the hypotenuse by direct measurement and by the Pythagorean Theorem.
- Determine if circles have collided by examining visually.
- Determine if circles have collided by comparing distance and radii.

Detailed instructions are provided on the **Detecting Collisions - Worksheet** .

Standards Alignment

Common Core Math Standards

- **EE** - Expressions And Equations
- **F** - Functions
- **G** - Geometry
- **MP** - Math Practices
- **NS** - The Number System
- **Q** - Quantities

Lesson 11: The Big Game - Collision Detection

Overview

To finish up their video games, students will apply what they have learned in the last few stages to write the final missing functions. We'll start by using booleans to check whether keys were pressed in order to move the player sprite, then move on to applying the Pythagorean Theorem to determine when sprites are touching.

Agenda

Getting Started

Introduction

Activity

Online Puzzles

Anchor Standard

Common Core Math Standards

- **8.G.7** - Apply the Pythagorean Theorem to determine unknown side lengths in right triangles in real-world and mathematical problems in two and three dimensions.

Objectives

Students will be able to:

- Apply the Distance Formula to detect when two points on a coordinate plane are near each other.

Links

For the Students

- **Line-length Design Recipe** - Worksheet
- **Distance Design Recipe** - Worksheet
- **Collide Design Recipe** - Worksheet

Teaching Guide

Getting Started

Introduction

Let's get back into that Big Game from stages 7, 12, and 16.

Previous work with the game has created movement for the danger and target characters, using Booleans to check if they have left the screen. The last time students worked on their game they used a conditional to check which key was pressed and make the player move accordingly. At this point the only thing left to do is to decide when the player is touching either the target or danger. Once students have successfully completed the **distance** and **collide?** functions, their score will increase when the player touches the target, and decrease when it touches the danger.

The Pythagorean Theorem studied in the last lesson will be used to determine when the characters have made contact. Students are not required to write their own `line-length` function, but you may ask them to complete the Design Recipe for it anyway.

Students will first complete the `distance` function so that it measures the distance between two points, (px, py) and (cx, cy). After the students implement the distance formula, they will need to implement the tests in the `collide?` function.

Once these last functions are put into place, scoring will automatically update based on collisions between target and danger.

Activity

Online Puzzles

Return to your Big Game to use collision detection logic so that you know when your player is touching the target or the danger. Head to **Course B Stage 11** in Code Studio to get started programming.

Standards Alignment

Common Core Math Standards

- **EE** - Expressions And Equations
- **F** - Functions
- **G** - Geometry
- **MP** - Math Practices
- **NS** - The Number System
- **Q** - Quantities