60 minutes

Grades 6-8

Scratch Thaumatropes

Exploring Superposition, Measurement & Probability Distributions

Learning Goals

Students will:

- Identify examples of *superposition* & *measurement* and connect these concepts to thaumatropes
- Be introduced to key differences between classical computers & quantum computers
- Explore how doing the same thing can result in different outcomes
- Explore probability distributions and how the probability of an outcome can be changed to be more or less likely

Materials

- ❏ Slide deck
- ❏ TIPP&SEE+Modify worksheet
    - ❏ TIPP&SEE+Modify Answer Key
- ❏ Scratch project link

Importance in Quantum Computing

Quantum computers use quantum bits (or qubits) to store information. Qubits can be in a state of ***superposition***, such that they are both 0 and 1.

Measurement collapses the superposition and forces the qubit to a value of either 0 or 1 - it can no longer be both.

Preparation

- ❏ Print student worksheets (OR create a copy of Google Form)
- ❏ Make sure you can project slides
- ❏ Students will need to have Scratch accounts to save their work.

Background Knowledge

Objects exist in a state of *superposition* when they can be more than one thing at once. In quantum computing, quantum bits (qubits) can exist in multiple states at the same time. The different states can add together and interfere with each other to define the overall state of the qubit. Classical computers use bits that can have a value of 0 or 1. A qubit, however, can be 0 or 1 - or anywhere in between. The computational power of superposition arises when more than one qubit is involved, because the number of possible combinations grows exponentially, rather than linearly. This is often referred to as the quantum advantage.

We expect that when we do the same task (such as measuring the length of a table) multiple times, we will always get the same result. But sometimes doing the same thing over and over again yields different results each time. For example, when you flip a coin you flip it the same way each time but you don't always get the same result. It's important to understand how many times we expect the coin to land each way. This is called the *probability* or the chances of getting each result. If we flip a coin 100 times we would expect that the coin would land heads-up approximately 50 times, however we cannot predict the exact outcome of each individual flip. Qubits store two values, with a probability of reading each one (just like the heads/tails of the flipping coin). And, like the coin, it is only when the qubit is measured that we get one or other value (like when the coin lands). Like qubits, the Scratch thaumatropes in this activity have a probabilistic nature (like flipping a coin). Also like qubits, it is possible to change the probability of each outcome, making one more likely than the other.

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Facilitating the Activity

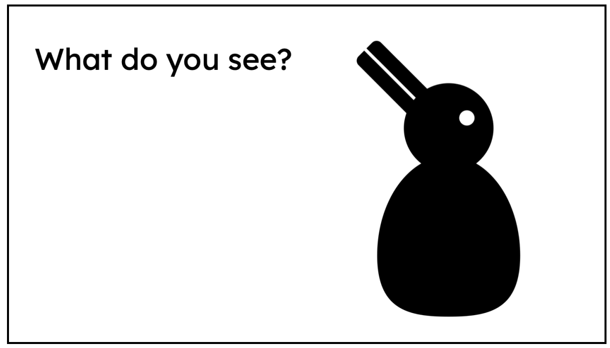
ENGAGE (15 minutes)

[SLIDE 1]

[SLIDE 2]
ASK: What do you see?
Students*: Duck / Rabbit / Both*

Note: Students may see only one interpretation. The next slide clarifies each interpretation.

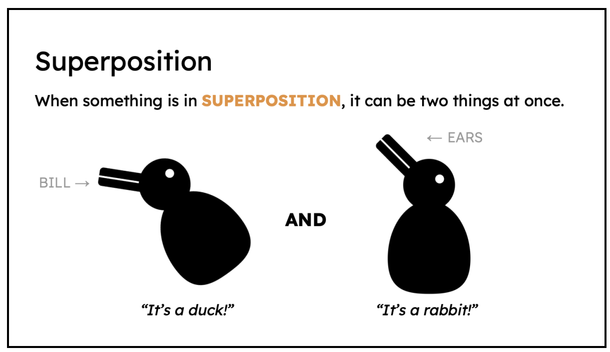
ASK: Raise your hand if you see: a duck? / a rabbit? / or a duck AND a rabbit?



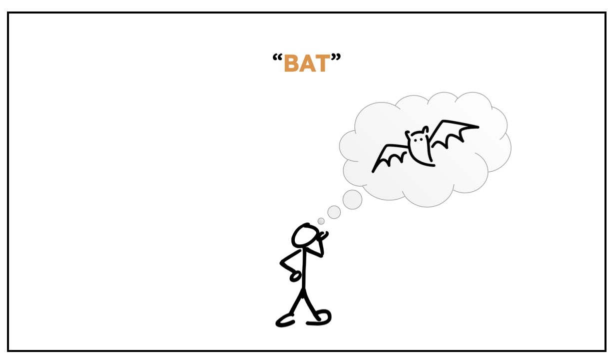
[SLIDE 3]
SAY: When's something is two things at once, it is called a **SUPERPOSITION**

SAY: This optical illusion is an example of a superposition. The image contains two possible interpretations - a duck and a rabbit. The same image is both of these things - ***at the same time***.

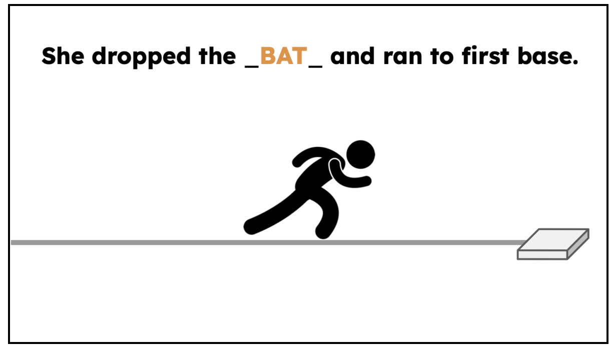
Use this slide to clarify both interpretations (duck and rabbit) for students.



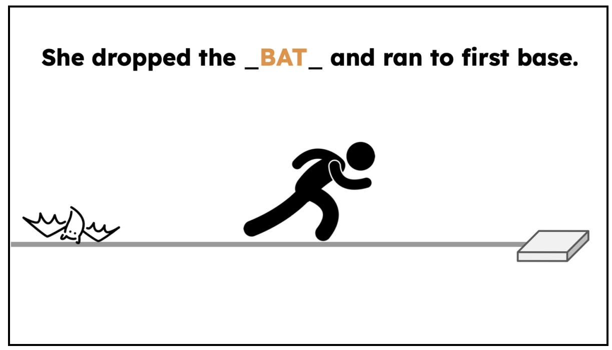
[SLIDE 4]
Describe the picture, or ask a student to do so. If needed, **ASK**: What is the person thinking of?



[SLIDE 5]
SAY or **Have a student read** : She dropped the BAT and ran to first base.



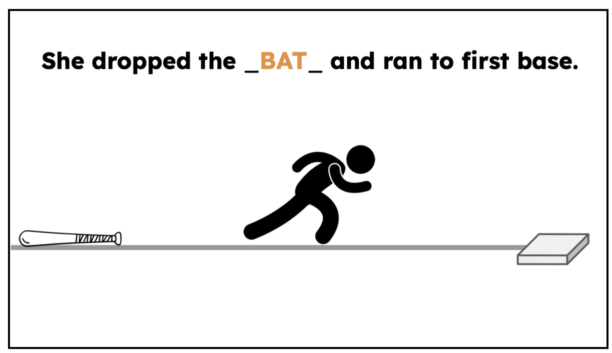
[SLIDE 6]
ASK: Hmm…Does that seem right?
Students*: No.*



[SLIDE 7]
ASK: Ok. Does this make more sense?
Students*: Yes!*

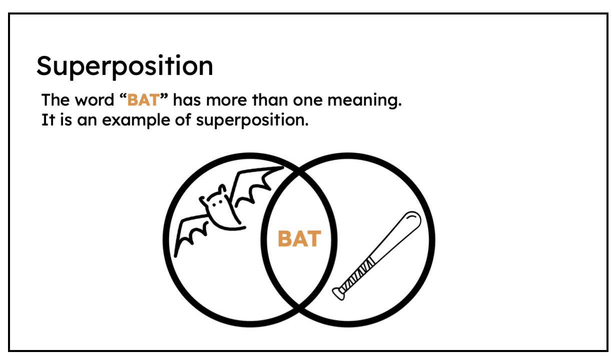
ASK: How did you know that one meaning of BAT was correct and the other was incorrect?

Students*: The word "BAT" has more than one meaning (animal, baseball bat). We use context clues like "dropped the bat" and "ran to first base" to pick the correct meaning (baseball bat).*



[SLIDE 8]
SAY: Just like the duck/rabbit optical illusion, the word "BAT" is an example of "superposition".

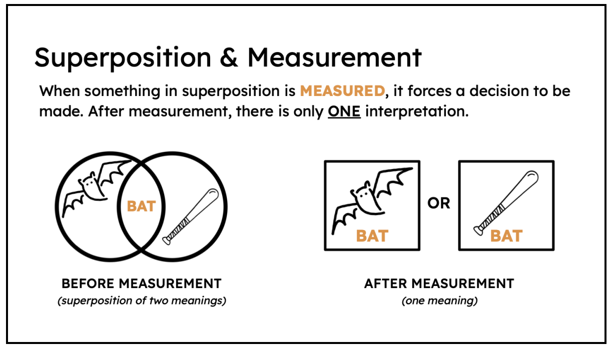
You do not know which meaning is correct, unless you have enough information (context) to decide.



[SLIDE 9]

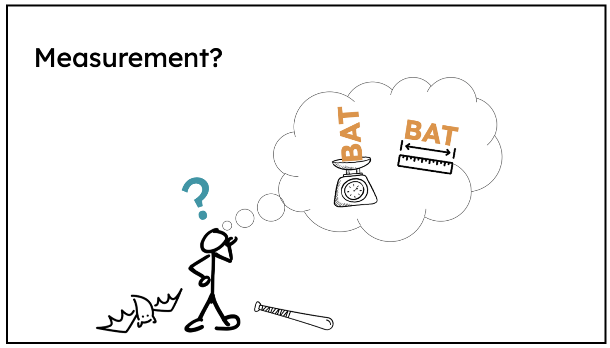
SAY: When something in superposition is **measured**, it forces a decision to be made.

In the case of the word "BAT," a decision about which meaning is correct. After measurement, there is only one interpretation.



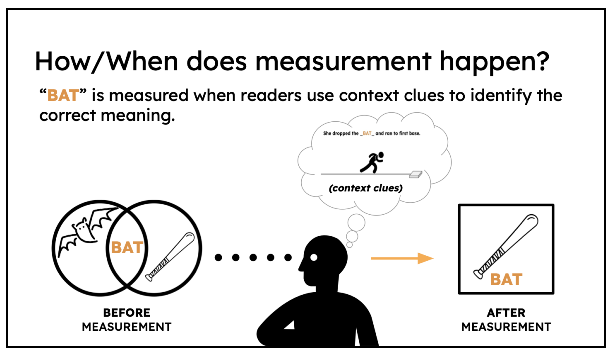
[SLIDE 10]

ASK: How is this different from the way that you have used the word "measurement" in school?



[SLIDE 11]

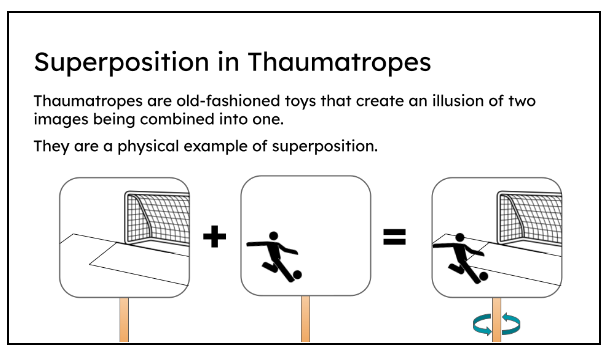
SAY: Measurement happens when readers use context clues to figure out the correct meaning.



[SLIDE 12]

SAY: Thaumatropes are old-fashioned toys that create an illusion of two images being combined into one.

They are a physical example of superposition.



ACTIVITY (30 minutes)

Distribute Scratch Thaumatropes: TIPP&SEE+Modify worksheet.

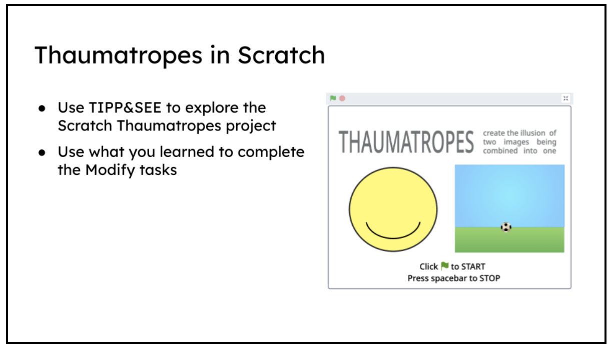
[SLIDE 13]

SAY: Now, you are going to explore and modify a Thaumatrope Scratch project.

Consider projecting the [Scratch Project](#) to demonstrate its functionality.

- *Stay on Project Page - do not show code*
- *Click the GREEN FLAG to start thaumatrope*
- *Click the SPACEBAR to stop thaumatrope*

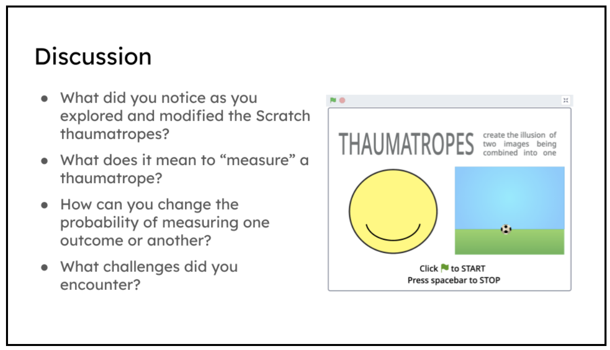
Give students ~30 minutes to complete the TIPP&SEE + Modify activities.



[SLIDE 14]

Facilitate a discussion about the activity:

- What did you notice?
- What does it mean to measure a thaumatrope?
- How is the probability of stopping on one costume type or another controlled in the project?
- What challenges, if any, did you encounter?

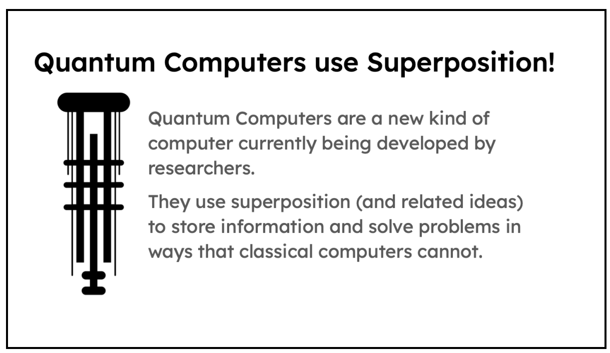


Read and/or have students read through the text on the following slides:

[SLIDE 15]

Quantum Computers are a new kind of computer currently being developed by researchers.

They use superposition (and related ideas) to store information and solve problems in ways that classical computers cannot.



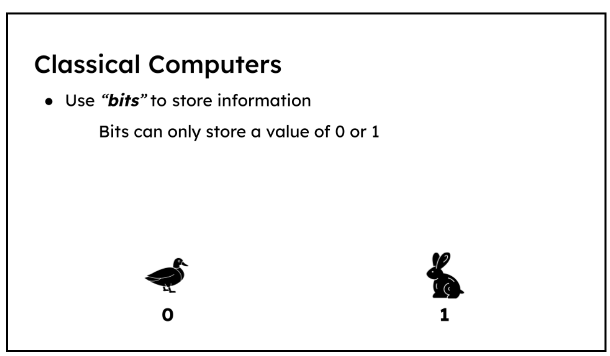
[SLIDE 16]

Classical Computers

Use "**bits**" to store information.

- Bits can only store a value of 0 or 1

Designed to quickly calculate *THE* answer to a problem



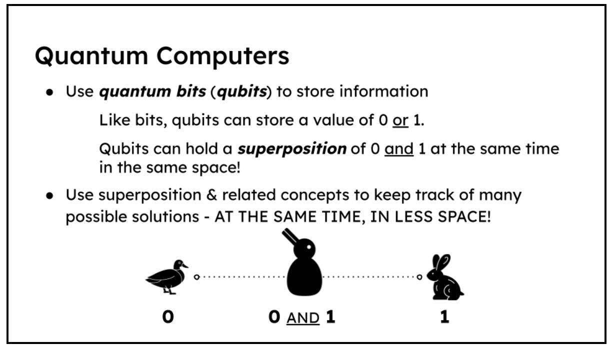
[SLIDE 17]

Quantum Computers

Use **quantum bits** (**qubits**) to store information.

- Like bits, qubits can store a value of 0 or 1.
- Qubits can also hold a superposition of 0 and 1 at the same time in the same space!

Use superposition & related concepts to keep track of many possible solutions - AT THE SAME TIME, IN LESS SPACE!



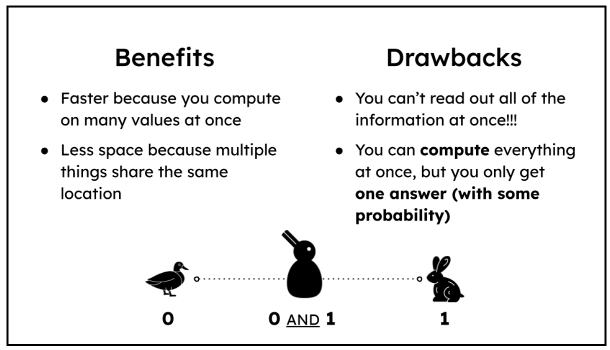
[SLIDE 18]

Benefits

- Faster because you compute on many values at once
- Less space because multiple things share the same location

Drawbacks

- You can't read out all of the information at once!!!
- You can compute everything at once, but you only get one answer (with some probability)

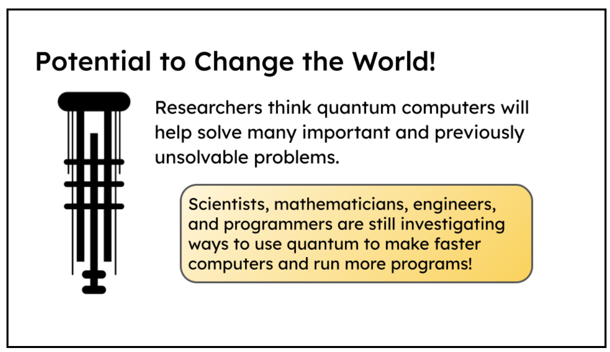


[SLIDE 19]

Potential to Change the World!

Researchers think quantum computers will help solve many important and previously unsolvable problems.

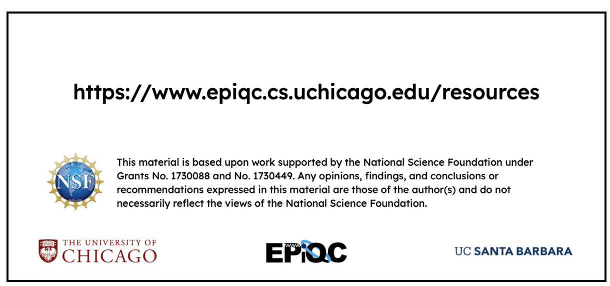
Scientists, mathematicians, engineers, and programmers are still investigating ways to use quantum to make faster computers and run more programs!



[SLIDE 20]

Visit our website for more activities and resources about quantum computing!

https://www.epiqc.cs.uchicago.edu/resources



Connections to Standards

Next Generation Science Standards*

Crosscutting Concepts: Cause and Effect, Stability and Change
Science and Engineering Practices: Planning and Carrying Out Investigations, Using Mathematics and Computational Thinking

Acknowledgements

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