EPiQC

45 minutes

Grades 3-5

Art in Superposition

Superposition & Measurement with Thaumatropes

Learning Goals

Students will:

- Be able to identify examples of *superposition* & *measurement* and connect these concepts to thaumatropes
- Be introduced key differences between classical computers and quantum computers

Materials

- ❏ ***Art in Superposition*** slide deck

Thaumatrope materials:

- ❏ Paper, preferably cardstock (~3"x6")
- ❏ pencil (alternatives: chopstick, pen, straw)
- ❏ Tape

Importance in Quantum Computing

Quantum computers store information using quantum bits (or qubits). Qubits can exist 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

- ❏ Make sure you can project the slides

Background Knowledge

Objects exist in a state of ***superposition*** when they can be more than one thing at once. For units of light (photons), this means that they behave both as a wave and as a particle. 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.

When something is measured, it is usually the same before and after we measure it. For example, if you measure the length of a book using a ruler, the book is the same before and after measurement. However, some forms of ***measurement*** can change the thing we are measuring. For example, we might want to know how many licks it takes to get to the center of a Tootsie Pop; licking the Tootsie Pop until you get to the center means the Tootsie Pop changes as we measure it. In science, it is often important that the method of measurement does not "intrude" on what you are measuring. Classical computers store simple values (i.e., 0 or 1) in memory, and the storage devices are able to both measure and retain the value when you read out of memory. Quantum computers, however, have a very complex, fragile state at the molecular level. No measurement device exists that can measure without fundamentally changing what is being stored.

Facilitating the Activity

ENGAGE (15 minutes)

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<tr>
<td><u>[SLIDE 1]</u></td>
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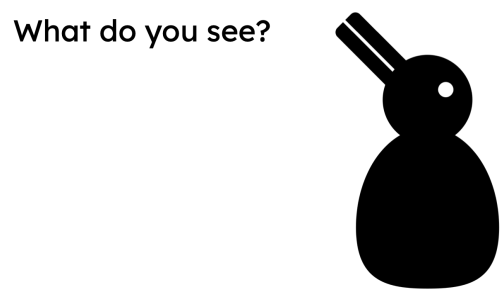
<td><u>[SLIDE 2]</u>
ASK: What do you see?
Students: *Duck / Rabbit / Both*

(<u>Note</u>: 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?</td>
<td>
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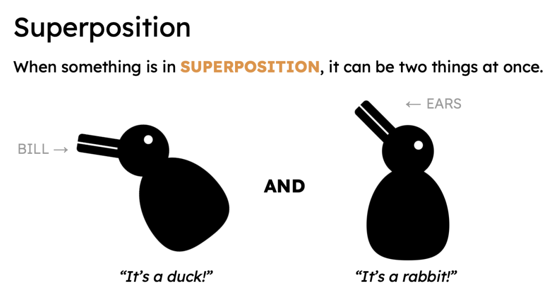
<td><u>[SLIDE 3]</u>
SAY: When's something is two things at once, it is called a **SUPERPOSITION**

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.</td>
<td>
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<td><u>[SLIDE 4]</u>
Describe the picture, or ask a student to do so. If needed, **ASK**: What is the person thinking of?</td>
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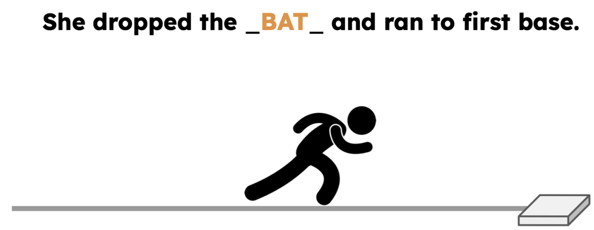
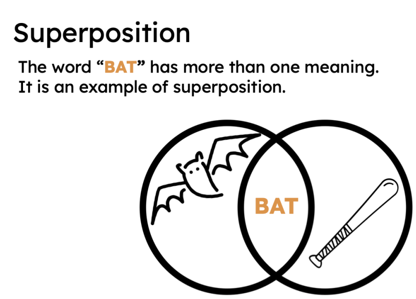
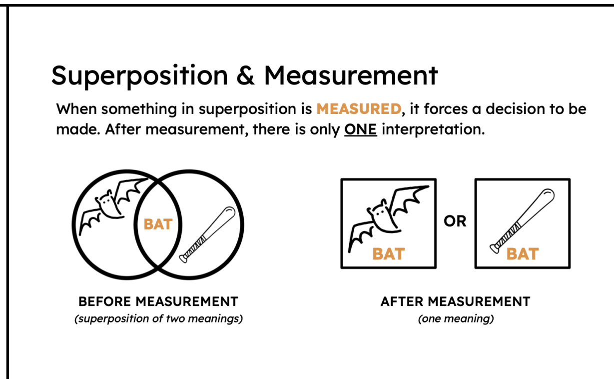
[SLIDE 5] SAY / Have a student read : She dropped the BAT and ran to first base.	
[SLIDE 6] **ASK**: Hmm...Does that seem right? *Students: No.*	
[SLIDE 7] **ASK**: Ok. Does this make more sense? *Students: Yes!* ASK: How did you know that one meaning of BAT was correct and the other was incorrect? The word "BAT" has more than one meaning (animal, baseball bat); "dropped the bat" and "ran to first base" help us to know that the sentence is about baseball. We use context clues to decide which meaning is correct.	
[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

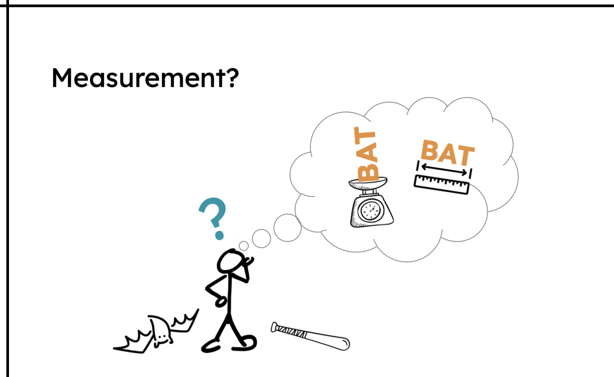
(In the case of the word "BAT," a decision about which meaning is correct).

After measurement, there is only one interpretation.



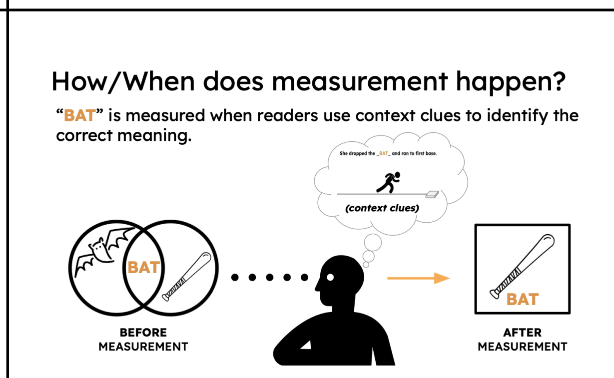
[SLIDE 10]

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



[SLIDE 11]

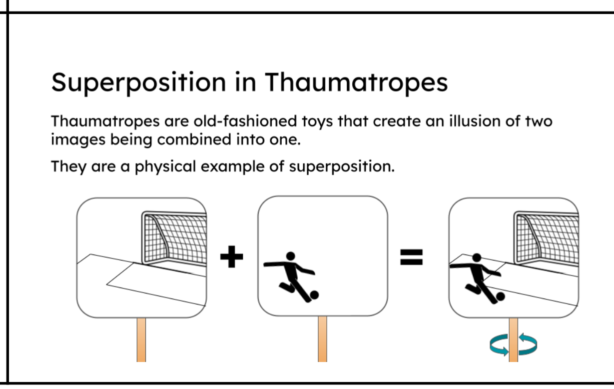
SAY: Measurement happens when readers use context clues to figure out the correct meaning.



[SLIDE 12]

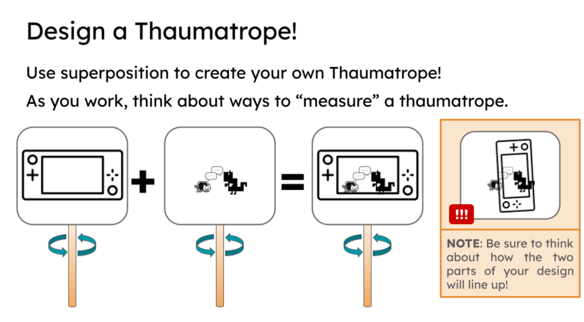
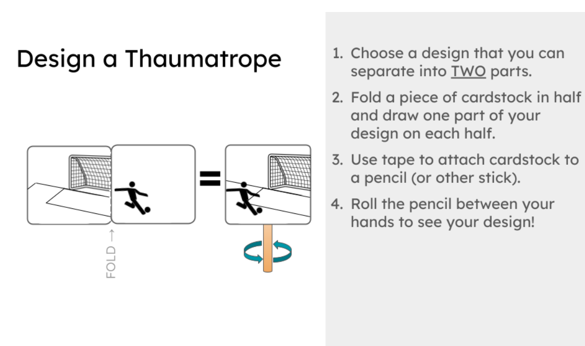
SAY: Thaumatropes are old-fashioned toys that create an illusion of two images being combined into one.

They are a physical example of superposition.



ACTIVITY (15 minutes)

Distribute thaumatrope materials.
Allow approximately 10 for students to design and make their thaumatropes.

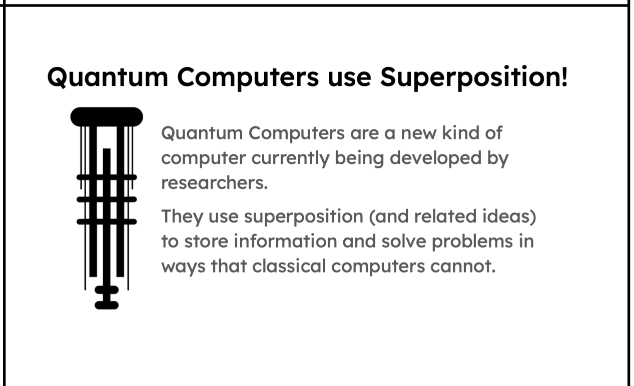
[SLIDE 13] **SAY**: Now, you are going to design your own Thaumatrope using superposition. When you draw the two parts of your image, be careful to think about how they will line up! As you work, think about what it means to measure a thaumatrope and how you might do it.	
[SLIDE 14] Review and/or have students read through the steps for making a thaumatrope: 1. Choose a design that you can separate into TWO parts. 2. Fold a piece of cardstock in half and draw one part of your design on each half. 3. Use tape to attach the cardstock to a pencil (or other stick). 4. Roll the pencil between your hands to see your design!	

DISCUSSION (15 minutes)

[SLIDE 15]
Give students time to share their thaumatropes.
ASK:
- What design did you choose?
- How did you separate your design into two parts?
- Did it work out the way you had planned?
- What challenges, if any, did you encounter?

[SLIDE 16] *Read and/or have students read through the text on the slide:*

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.

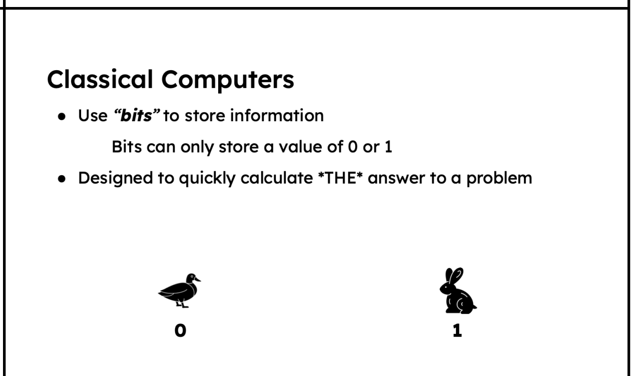


[SLIDE 17] *Read and/or have students read through the text on the slide:*

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

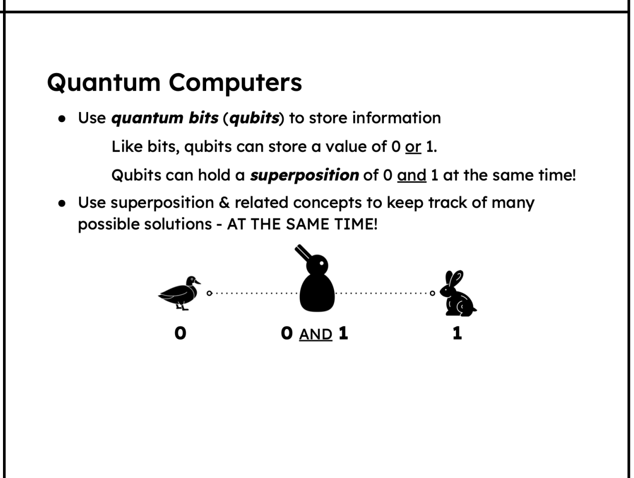


[SLIDE 18] *Read and/or have students read through the text on the slide:*

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!

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



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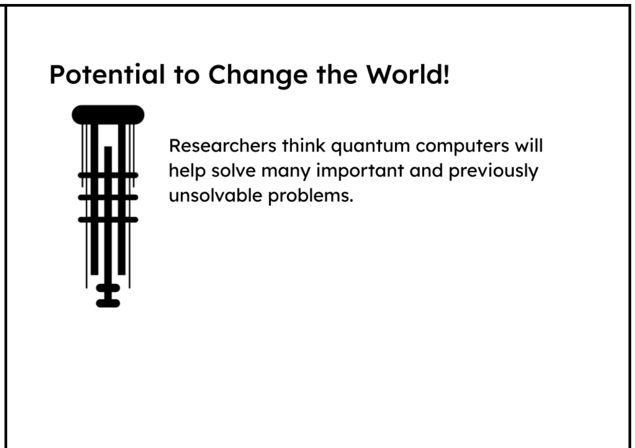
<td>[SLIDE 19] Read and/or have students read through the text on the slide:

Potential to Change the World!

Researchers think quantum computers will help solve many important and previously unsolvable problems.</td>
<td>
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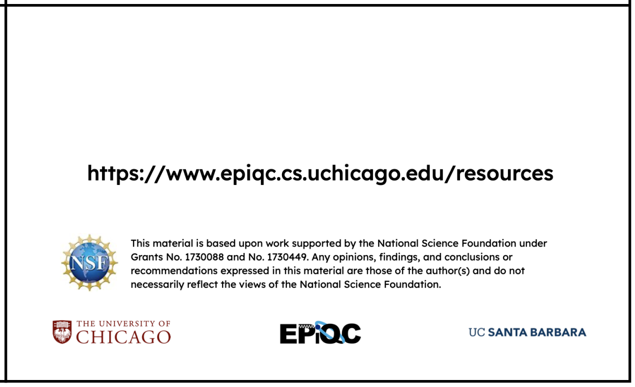
<td>[SLIDE 20]

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

https://www.epiqc.cs.uchicago.edu/resources</td>
<td>
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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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