PhET Tips for Teachers — Quantum Coin Toss

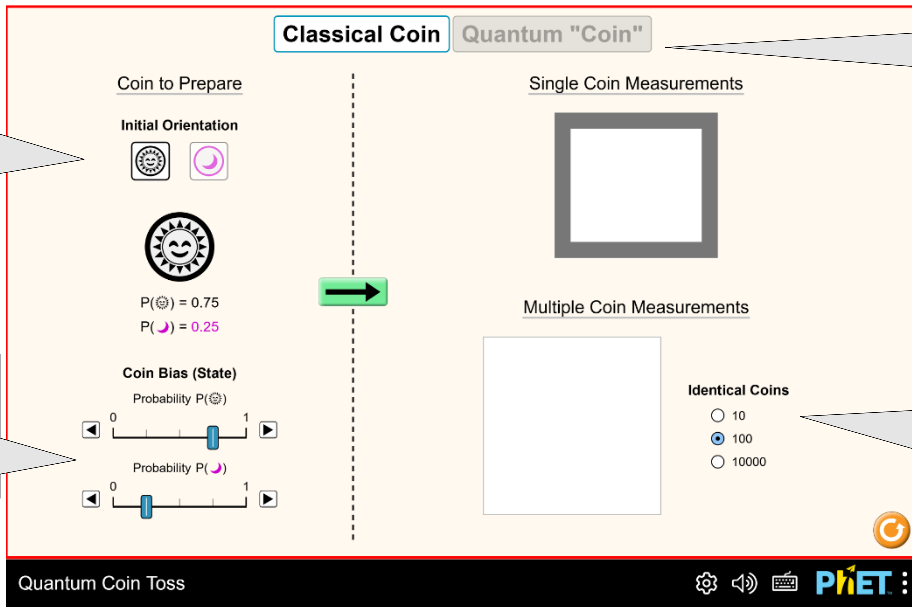
The ***Quantum Coin Toss*** simulation allows students to compare and contrast classical and quantum 2-level systems and see the results of preparing and measuring a superposition of quantum states.

Preparation mode

In the preparation mode, students can choose to measure classical coins that can be set to a particular bias and flipped, or quantum "coins" that can be prepared in a chosen quantum superposition.

CHOOSE the initial orientation of prepared coins

SET the bias or state of the prepared coins



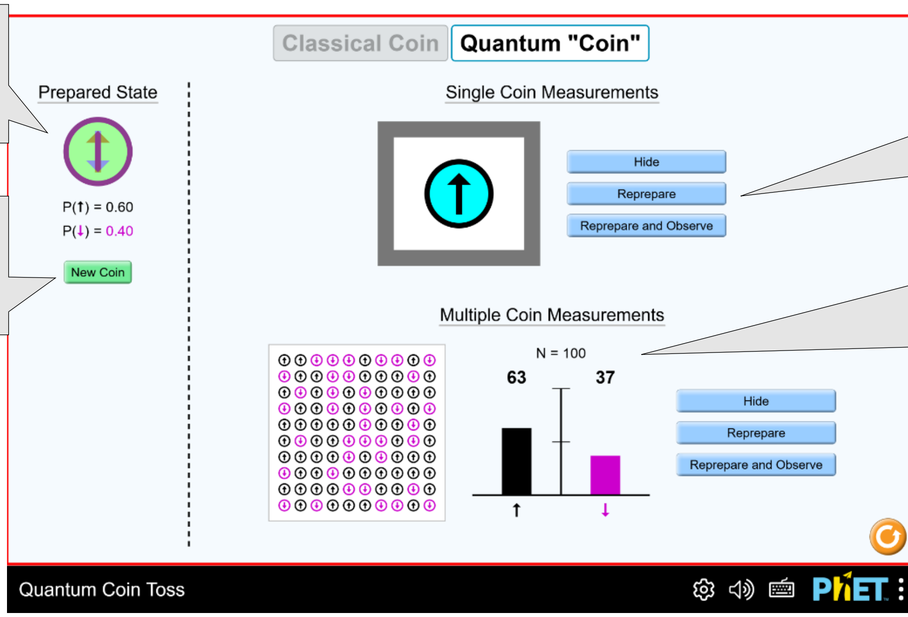
SELECT classical or quantum

CHOOSE the number of identical coins to prepare

Measurement mode

COMPARE the prepared state to observations

CREATE a new coin to run with a different state



REPEAT observations with the same prepared state

VISUALIZE the results of multiple measurements on identically prepared coins

Paul, May 2025

Insights into Student Use

- Students may need support to recognize that although the amplitudes of the State to Prepare for the quantum coin do not sum to 1, the squares of the amplitudes do (and represent the probability of each outcome)
- Students may be surprised that a classical coin can start in a particular orientation but be completely biased to the opposite orientation. For instance, when moved to the measurement area, all coins are initially heads, but when flipped they all land tails if the coin is set to be perfectly biased to tails.

Customization Options

Query parameters allow for customization of the simulation and can be added by appending a '`?`' to the sim URL, and separating each query parameter with a '`&`'. The general URL pattern is:
`…html?queryParameter1&queryParameter2&queryParameter3`

For example, to run this in Spanish (`locale=es`) with audio muted by default (`audio=muted)`, the URL would become:
`https://phet.colorado.edu/sims/html/quantum-coin-toss/latest/quantum-coin-toss_all.html?locale=es&audio=muted`

Query Parameter and Description	Examples
⚙ `locale` - specify the language of the simulation using ISO 639-1 codes. Available locales can be found on the simulation page on the Translations tab. Note: this only works if the simulation URL ends in "_all.html".	`locale=es` (Spanish) `locale=fr` (French)
⚙ `classicalCoinsStartHidden` - when `true`, classical coins are hidden when moved into the measurement area after being prepared	`classicalCoinsStartHidden=true`
`audio` - if `muted`, audio is muted by default. If `disabled`, all audio is permanently turned off.	`audio=muted` `audio=disabled`
`supportsPanAndZoom` - when `true`, enables panning and zooming of the simulation using pinch-to-zoom or browser zoom controls.	`supportsPanAndZoom=false`

⚙ Indicates this customization can be accessed from the Preferences menu within the simulation.

Suggestions for Use

- Use as an introduction to compare the differences between measuring a classical biased coin and the novel representation of a quantum “coin”
- Explore how the number of measurements affects that discrepancy between the prepared probabilities and the outcomes.
- Use the Quantum “Coin” representation to build an understanding of the superposition of the states, and what happens when a superposition is observed.

Important Model Simplifications and Notes

- Because of the nature of rounding errors, and since the sim only displays a limited number of decimal points, the sum of the squares of the amplitudes of quantum states will sometimes not sum perfectly to 1.00.

Sample Challenge Prompts

- When the Quantum “coin” is in a superposition of states, can you ever directly observe the superposition in the measurements?
- How does the number of coins measured affect the resemblance of the outcome to the prepared state’s probability amplitudes?
- Can you determine the bias of a classical coin from a single measurement? How is the bias of a classical coin similar and different from the state of the quantum “coin”?

See all published activities for Quantum Coin Toss here.
For more tips on using PhET sims with your students, see Tips for Using PhET.