PhET Tips for Teachers

Quantum Measurement

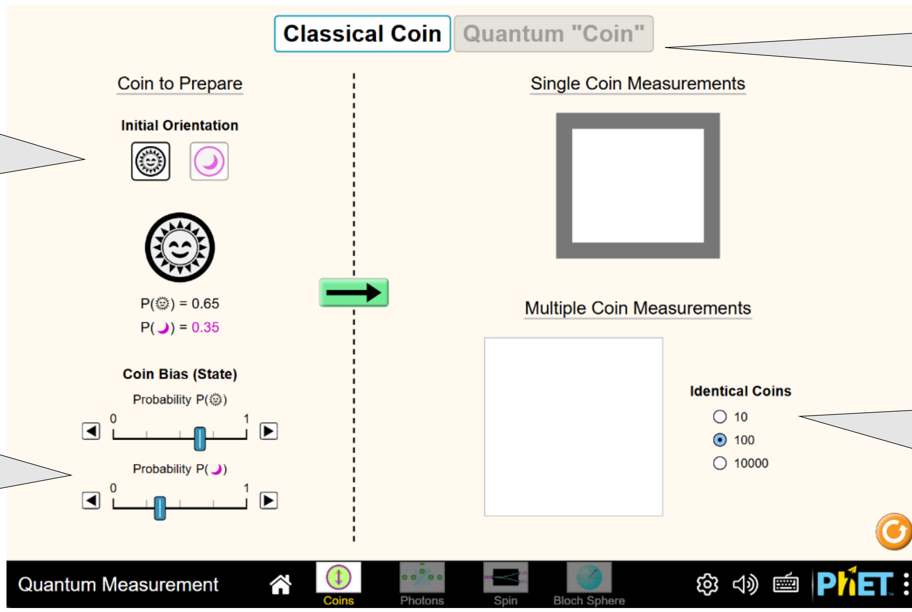
The ***Quantum Measurement*** simulation allows students to explore multiple contexts involving 2-level quantum systems and see the results of preparing and measuring a superposition of quantum states.

Coins Screen (Preparation mode)

In the coins screen, 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 and observed.

CHOOSE the initial orientation of prepared coins

SET the bias or state of the prepared coins



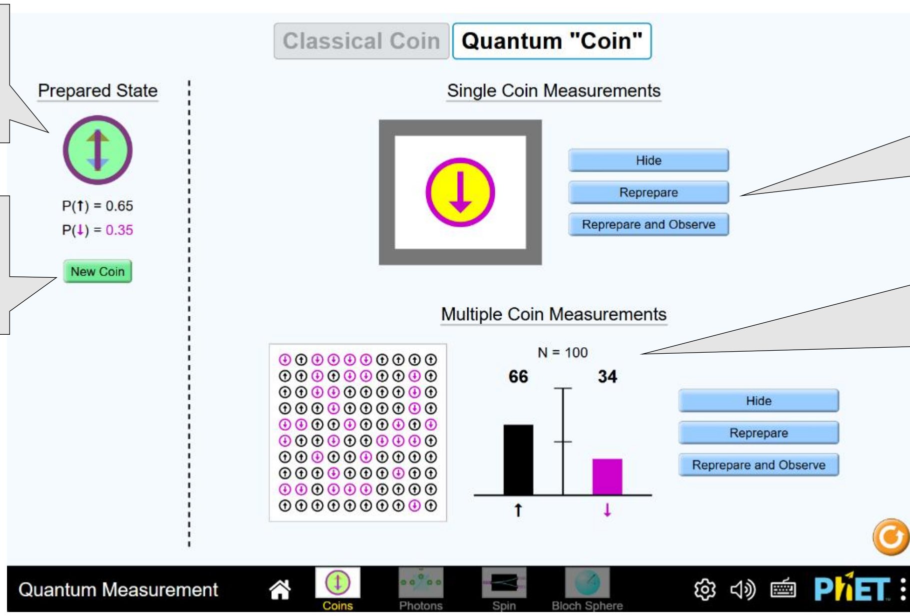
SELECT classical or quantum

CHOOSE the number of identical coins to prepare

Coins Screen (Measurement mode)

COMPARE the prepared state to observations

CREATE a new coin to run with a different state



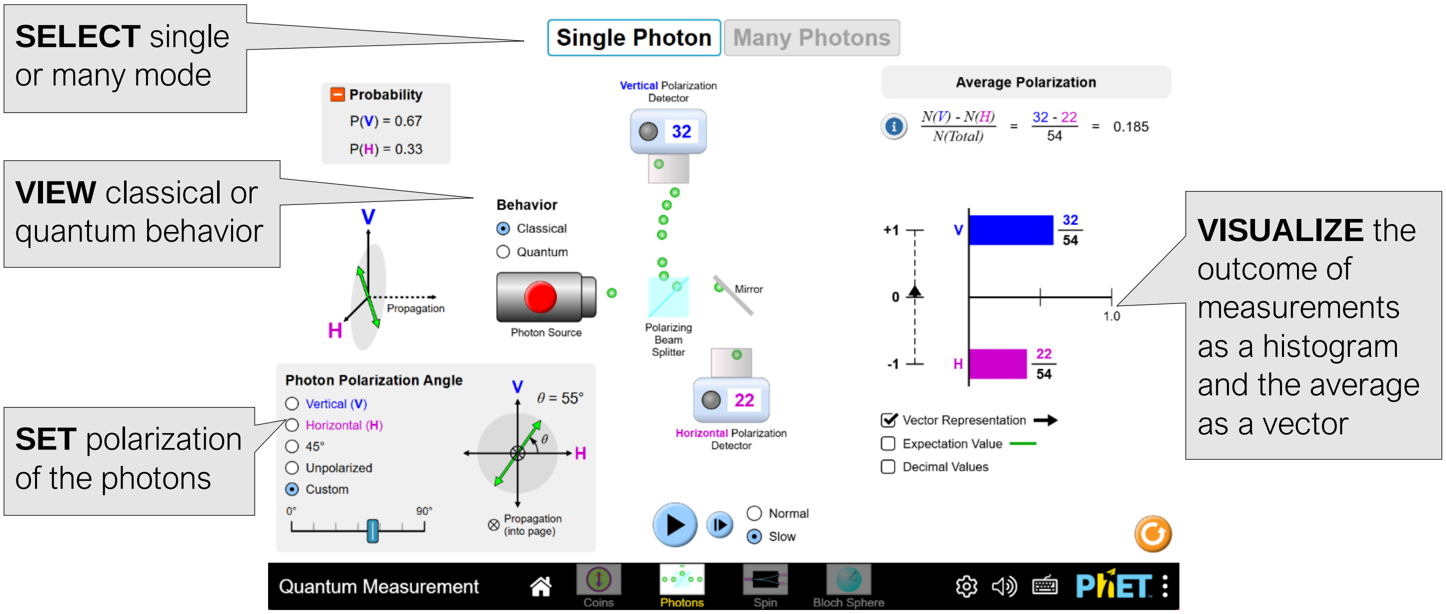
REPEAT observations with the same prepared state

VISUALIZE the results of multiple measurements on identically prepared coins

Paul, April 2025

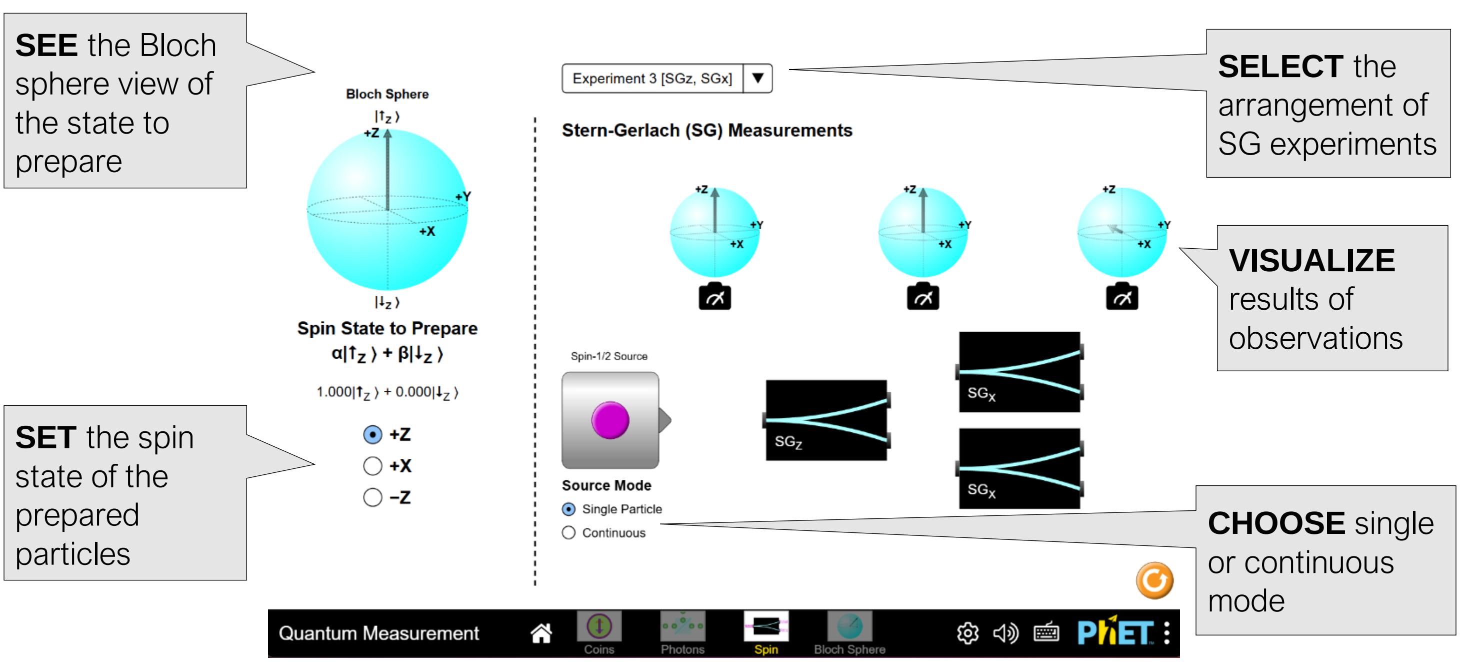
Photons Screen

In the photons screen, students can measure the polarization of single photons sent through a polarizing beam splitter. Photons can be sent into the experiment one at a time, or in a continuous stream.



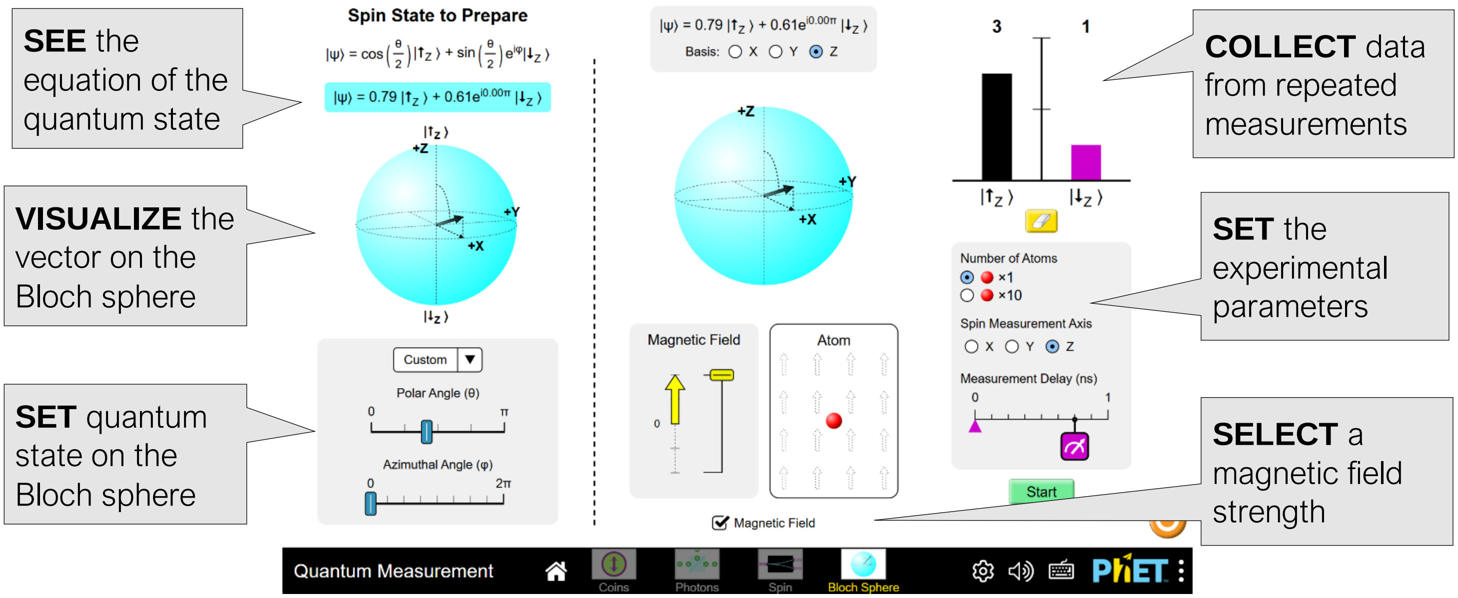
Spin Screen

In the Spin screen, students can prepare various states of a spin-1/2 particle and send particles through various arrangements of Stern-Gerlach experiments



Bloch Sphere Screen

In the Bloch Sphere screen, students can more deeply explore the Bloch Sphere geometry, its connection to the representation of state, and the evolution of a spin state in a magnetic field.

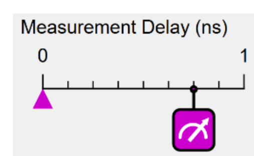


Insights into Student Use

- Unless used in slow motion or with the step function, students may not notice that when Behavior is set to the Quantum mode photons split and take both paths after the beam splitter and then “collapse” into a single photon once in the detection zone of the detector.
- Students may need support recognizing that the average polarization on the Photons Screen can be represented as a vector that sits between +1 and -1
- Students will likely be surprised on the Spin Screen with experiments like Experiment 5 that a begins spin up in the Z direction (+Z), may not still be +Z after being measured in the X direction.

Complex Controls

- On the Bloch Sphere screen, students may not discover that the measurement delay can be altered. On each succesive measurement, this slider sets the time the quantum state evolves in the magnetic field before a measurement occurs.



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, in Quantum Measurement, if you only want to include the 1st and 2nd screens (`screens=1,2`), with
the 2nd screen open by default (`initialScreen=2`) use:
https://phet.colorado.edu/sims/html/quantum-measurement/latest/quantum-measurement_all.html?screens=1,2&initialScreen=2

To run this in Spanish (`locale=es`), the URL would become:
https://phet.colorado.edu/sims/html/quantum-measurement/latest/quantum-measurement_all.html?locale=es&screens=1,2&initialScreen=2

Query Parameter and Description	Examples

`screens` - specifies which screens are included in the sim and their order. Each screen should be separated by a comma. For more information, visit the Help Center.	`screens=1`
	
	`screens=2,1`

`initialScreen` - opens the sim directly to the specified screen, bypassing the home screen.	`initialScreen=1` `initialScreen=2`
⚙ `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)
⚙ `showGlobalPhase` - when `true`, displays the global phase of quantum of state on the Bloch Sphere screen	`showGlobalPhase=true`
⚙ `classicalCoinsStartHidden` - when `true`, classical coins on the Coins Screen 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 the Coins Screen as an introduction to compare the differences between measuring a classical biased coin and the novel representation of a quantum “coin”
- Explore how the rate of measurements affects that discrepancy between a measured value and the expectation value
- Explore various arrangements of Stern-Gerlach experiments on the spin screen to discover how measurement in one axis can affect the state of a particle when it is subsequently measured in another access.
- Explore the Bloch Sphere representation and how this visualization of the quantum state can show the time evolution of spin-1/2 state in the presence of a magnetic field.

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.
- On the Spin Screen, the histogram is displayed in the same visual order as the equation, so “spin up” is on the left side of the histogram.
- On the Spin Screen, the “Y” direction is not available as a state to prepare since Stern-Gerlach apparatus do not function when the spin state is in the propagation direction
- In general, for instances where time averaging of data occurs, like on the Photons Screen in continuous mode, the measurement data displayed updates every 0.5 seconds, and is averaged over the previous 1.0 seconds.

Sample Challenge Prompts

- When the Quantum “coin” is in a superposition of states, can you ever observe the superposition in the measurements?
- How does the number of coins measured affect the resemblance of the outcome to the prepared states probability amplitudes?
- Can you predict which polarization detector a photon will be detected at?
- What arrangements of Stern-Gerlach experiments and prepared states give perfectly predictable outcomes?
- How does changing the magnetic field strength change the experiment on the Bloch Sphere screen?

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